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DENTURES

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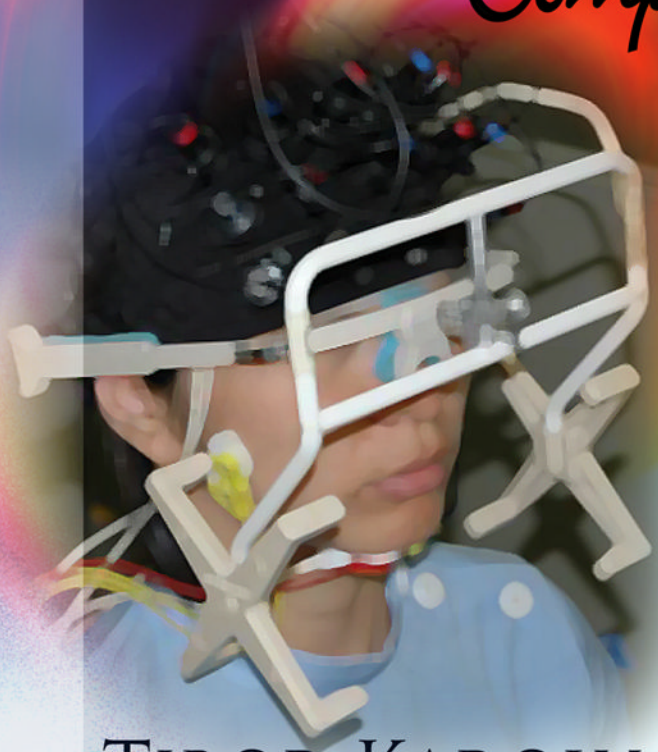

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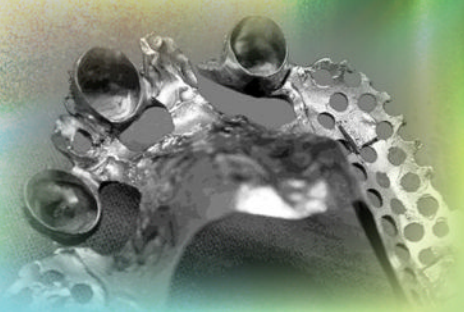

DENTURES

TYPES, BENEFITS AND POTENTIAL COMPLICATIONS

DENTAL SCIENCE, MATERIALS AND TECHNOLOGY

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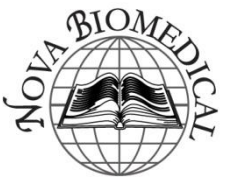

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Contents

Preface

This work is an edited collection of miscellaneous chapters from the huge field of prosthetic dentistry, about dentures, and their types, benefits and potential complications. Besides most frequently discussed related topics of the field, this edited collection also includes some chapters dedicated to rarely reviewed research areas like preprosthetic orthodontics, brain correlates of wearing denture, psychosomatic aspects of prosthetic dentistry, denture related microbiology and the use of mind-body therapies, physicotherapies as well as complementary and alternative approaches for prosthetic dentistry, which may supply a great want. This book gathers and presents data on the leading edge of prosthetic dentistry.

Chapter I – Major goal of the "prosthetic classification" is to enhance treatment planning and denture designing procedures. With regard to this aspect partially edentulous arches can be rendered to classes as follows: *Class 1A*: one or more primary fulcrum lines (straight line drawn between two teeth adjacent to the edentulous space) may exist; but none of the primary fulcrum lines is going to become a factual rotation axis when a denture is inserted. No force of rotation will be generated and the denture may not settle. In this class of arches fixed dentures are recommended. *Class 1B*: one or more fulcrum line(s) may exist, which may become a factual rotation axis when a denture is inserted. The rotational forces, however, will not be very powerful, so that the settling of the denture can be equalized (i.e. compensated due to multiple abutments). In this class of arches fixed dentures may be recommended. *Class 2A*: only one primary fulcrum line exists, which may become a factual rotation axis when a denture is inserted. Rotating around this factual rotation axis the denture may settle in one direction. In this class of arches RPD is recommended and the baseplate of RPD can be moderately reduced. *Class 2A/1*: only one fulcrum line exists, which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the denture may settle in one direction. This class is a special case (subclass) of class 2A characterized by very few (maximum one or two) remaining teeth. In this class of arches RPD is recommended and the baseplate of RPD can *not* be reduced. *Class 2B*: Several primary fulcrum lines may exist, one of which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the denture may settle in one direction. In this class of arches RPD (combined with or without fixed dentures) are recommended and the baseplate of RPD can be moderately reduced. *Class 3*: one or more primary fulcrum line(s) may exist; from which one or more may become a factual rotation axis when a denture is inserted. Rotating around

this/these rotation axis the denture will tip upward on one side and downward on the other side (i.e. two-directional rotary movements occur). In this class of arches RPD is recommended, the baseplate of RPD can not be reduced and, *resilient* type telescopes (i.e. delayed type dental support) should be used.

Chapter II – Various dental specialties have made such enormous advances that it has become impossible to absorb all that is new in all dental areas. Therefore a collaborative effort between orthodontist and prosthodontist is often necessary to achieve an optimal treatment result. Prosthodontists and restorative dentists rely on orthodontics as a means of providing more comprehensive care to their patients. Such collaboration is not only desirable, but mandatory if dentists are to provide highest level care for their patients. Preprosthetic orthodontics gains significance in both esthetics and functionality of the denture being under preparation. Therefore, an interdisciplinary approach may also be cost-effective for both patient and dentist from the standpoint of producing more stable and durable restorations of high esthetics. Orthodontics may contribute to the success of cases undergoing restorative dental procedures where preliminary minor tooth movement is necessary, to correct local malpositions and/or to move abutment teeth with simple appliances. Success of implant placement may also be improved via orthodontic forced extrusion of periodontally compromised teeth. Collaboration of orthodontist and prosthodontist may be even more demanding when correction of primary orthodontic anomalies would be needed. No wonder that, the integration of orthodontics and prosthetic dentistry into a multidisciplinary rehabilitation is often indispensable for a proper dental care of the patients. A proper plaque control is also essential for a successful treatment in all cases. Along with mechanical and biological principles, unique psychological and social aspects of the combined orthodontic and prosthetic treatment should also be considered for a successful therapy. In this chapter the important role of orthodontics and its contribution to the success of prosthetic dentistry for adult patients is discussed.

Chapter III – *Purpose:* Denture wearing is considered to improve chewing ability, chewing comfort, and quality of life in elderly individuals. In an attempt to clarify the effects of prosthodontic treatment on activation of the prefrontal cortex involved in higher cognitive functions, the authors investigated the efficacy of wearing partial denture from the aspects of jaw functions such as muscle and movement activities and associated prefrontal cortex activity. *Methods:* Twelve partially edentulous patients were enlisted as subjects. Functional near-infrared spectroscopy was used to detect changes of hemoglobin concentration in the prefrontal cortex area, while jaw muscle EMG and jaw motion activities were simultaneously examined. Masticatory scores were also determined to evaluate the subjective awareness of chewing ability and occlusal contact features were examined using a Dental Prescale Occluzer System. Statistical comparisons were performed to compare between data obtained while wearing and not wearing a partial denture prosthesis. *Results:* Significant increases were seen in chewing-related jaw functions such as jaw muscle EMG and jaw motion activities, as well as prefrontal cortex activity associated with wearing a partial denture prosthesis as compared with the not wearing condition. Furthermore, occlusal contact and masticatory scores were also significantly increased by wearing a partial denture prosthesis. *Conclusions*: Occlusal reconstruction obtained by wearing a partial denture prosthesis improved prefrontal cortex activity and the awareness of chewing ability, as well as jaw functions, as shown by increased jaw muscle EMG and jaw motion activities. From these findings, the authors concluded that appropriate denture wearing might have an impact on not

only jaw functions, but also cognitive functions closely related to masticatory performance. The relationship between masticatory function and cognitive ability is discussed from the standpoint of prosthodontic treatment in this chapter.

Chapter IV – Patients often refuse these options since the reasons of high cost and/or surgical intervention. The full coverage retainers for tooth supported fixed partial denture is a conventional approach to replace one or several missing teeth. Two types of full coverage retainers FPDs are used in dental clinics: porcelain fused to metal and all ceramic. Porcelain fused to metal provides great fracture strength and relatively good long-term clinical success. One of significant disadvantages of the porcelain fused to metal, as well as modern all ceramic FPDs is that large amount of sound tooth substance of the abutments needs be removed in FPD fabrication. An inlay-retained FPD (IRFPD) is, however, a less-invasive treatment modality and a more conservative option for restoration of damaged teeth, because it requires minimal tooth reduction, preserves healthy tooth structure, and maintains the periodontal tissue's integrity. Inlay-retained FPDs are, therefore, alternatives to both anterior and posterior complete coverage conventional restorations. Inlay retained FPDs can be constructed by using dental alloys, ceramic materials, and fiber-reinforced composite. Several types of preparations for inlay retained FPDs are used: Occluso – proximal inlay, Tub-shaped , Proximal box, Rest seat on the occlusal surface, Lingual tooth reduction, and Retentive-slot preparations. The size of these preparation features depends on the size of the tooth. Several researches were carried out about the effect of various designs, materials, connectors size on the fracture resistance, marginal integrity and retention of inlay retained FPDs.

Chapter V – Correctly indicated and accurately made, partial denture with double crowns is a dental restoration of the highest biological, prophylactic and aesthetic values. However, insufficient knowledge of double crowns systems, as well as errors and omissions in the clinical and laboratory work invalidate this type of restoration and can have negative effects on the supporting tissues. Double crowns may come in form of telescope crowns and conical crowns. Double crowns as connecting elements should provide: retention, stabilization, physiological transmission of occlusal loads through the abutment teeth as well as the prophylactic value, comfort for the patient, durability and aesthetics. In order to achieve these qualities, it is necessary, among other things: to make proper indication, to execute adequate tooth preparation (grinding), to make the choice of materials for the construction, to establish proper connection of the outer crown and the metal framework and to choose a suitable aesthetic material for veneering. It is necessary to understand the mechanism of double crowns retention so that the optimal value of the retention force which should be 5-9 N per each patrix can be established. Insufficient retention force will reduce the comfort for the patient because would make the separation too easy, whereas an excessive force may negatively affect the periodontium of the abutment teeth. Retention force and durability of restorations with telescope and conical crowns depend also on the characteristics of the material they are made of. The most frequently used are gold and palladium-silver alloys. In recent years, titanium and the combination of ceramic and galvanized gold are used. Prophylactic effect of double crowns is also provided by a proper planning that will enable the physiological transfer of the forces on the abutment teeth and the health of free gingiva. A special challenge is to plan the connection of outer crown with the metal framework. The best results showed optimized approximal extensions. Double crown production demands experience of a clinician and dental technician in the performance of clinical and laboratory phases. A removal of sufficient tooth tissue during grinding in order to avoid getting

oversized artificial teeth and a formation of the appropriate demarcation line which will provide sufficient stability of the system in the gingival area represent a particular challenge. Errors in laboratory work can be avoided with a good knowledge of the milling proceedings, a selection of a suitable material for the external crowns modeling and acquisition of precision castings.

Chapter VI – The aging population has profoundly transformed the profile of patients seeking oral rehabilitation. Care delivery to these patients, who present with multiple comorbidities and are usually being treated with various drugs, is becoming increasingly more frequent. Systemic changes prompted by the use of many medications may impose limitations to clinical practice with regard to indication, planning, materials, preparation techniques, and maintenance of prosthetic rehabilitation. Unfortunately, the dental literature is lacking in scientific papers reporting oral manifestations of systemic diseases, as well as in works describing the type of assistance that is necessary to treat such patients. The reported findings are limited to the description of techniques, which are sometimes adapted, for complete denture treatment in patients with neurological diseases, such as Alzheimer's and Parkinson's syndrome, and burning mouth in cases of allergy to dental materials. Several systemic conditions and different treatments should be taken into account when it comes to the correct time for prosthetic rehabilitation completion, the materials and technique to be used, and the maintenance procedures to be employed. It is known that in the case of patients with severe immunosuppression, whose origin can be constitutional (senile), pathological (hematological, immune, or endocrine), or prompted by medication (use of immunosuppressants, corticosteroids, chemotherapy, among others), there is higher incidence of oral infections by fungi, especially opportunistic infections such as aspergillosis and mucormycosis, whose incidence may increase due to badly fitted and poorly cleaned dentures. Another group of autoimmune diseases, the so-called pemphigus vulgaris, may have repercussions in the oral mucosa. This disease predisposes the oral cavity to serious injury by lack of adherence of epithelial tissue and by infection due to the constant utilization of immunosuppressants, making the use of dentures very difficult. In addition, patients with renal failure and severe liver disease may present changes in both oral mucosa and salivary glands, which demands manufacture and use of dentures. Treatments such as radiotherapy and the chronic use of bisphosphonates imply in severe changes in both the bone and soft tissues. The common denominator of all these diseases or therapeutic protocols is that they have temporary or permanent contraindications for rehabilitation with conventional dentures or implant overdentures. Thus, on the basis of literature and a 10-year clinical group experience in a dental hospital service, this book chapter aims to describe major diseases and drug therapies that directly or indirectly reflect on the oral cavity, including the necessary adjustments in materials, manufacturing techniques, and maintenance of complete dentures.

Chapter VII – Laboratory processing techniques have been refined in an attempt to achieve complete dentures with better clinical performance. Regardless of the type of denture base material (microwave-, light-, or heat-polymerized polymethyl methacrylate, for example), materials as well as handling and polymerization methods have been continuously modified with a view to obtaining more resistant dentures. In an attempt to improve the mechanical properties of base materials and to try to overcome the low impact and flexural strength of currently available dentures, which often results in clinical failure, various laboratory treatments have been proposed. The incorporation of reinforcing structures such as glass fiber, carbon fiber, Kevlar, aramid, and fiber-reinforced composite, which can be found

in different sizes and shapes and are sometimes impregnated with substances such as silanes, has been successfully tested in some cases. However, incorporation of such compounds can culminate in undesirable effects such as larger amount of residual monomer, difficult polishing, and unsatisfactory aesthetics. Metal wires have also been used over time for this purpose, as well as substances such as methyl acetate and methyl formate. The increased bond strength between artificial teeth and the denture base material has also been relentlessly pursued. New positive results are being obtained by means of techniques that promote interpenetration of the polymer networks of the two materials and make use of substances such as dichloromethane. To improve the biological properties of dentures, simple procedures such as immersion in water for defined time periods has been evaluated, in order to reduce their totoxicity. Studies have shown that dibenzoyl peroxide, used as initiator in polymethyl methacrylate resin and associated with allergic processes, is released from conventional dentures after polymerization, but this event can be substantially reduced with completion of an additional polymerization cycle. Still, in order to reduce dentures contamination, several antimicrobial agents such as silver have been incorporated into the base material, which has led to positive effects with regard to their antimicrobial action. However, decrease in flexural and impact strength has sometimes been observed. In this context, this book chapter intends to update the reader on materials and laboratory techniques that can optimize the physical, mechanical, and biological properties of dentures that are considered to be the most relevant to the clinical performance of complete dentures.

Chapter VIII – The global population is ageing at an unprecedented rate. The result of this process has produced an important change in the healthcare system, with the cure of acute diseases giving way to the treatment of chronic illnesses. The impact of this demographic change is of considerable concern due to the increase in the cost of healthcare systems, although the current correlation between health costs and the elderly population is weak. In the last ten years, Brazil has made considerable progress in the prevention and control of caries among children. However, the situation among adults and the elderly is among the poorest in the world. However, the rehabilitation of these individuals is hindered by a number of factors. The difficulty of retaining and adapting lower dentures is common and constitutes an obstacle to the complete success of prosthesis use, as reported in a number of studies. Moreover, the lack of information on the part of patients regarding the limitations of conventional complete dentures contributes toward dissatisfaction and the abandonment of complete lower denture use. The aim of this chapter is to carry out a systematic review of methods for the rehabilitation of individuals with an edentulous lower jaw in the search for an alternative solution that is biological, functional and financially viable. This review will consist of the treatment and options for edentulismo including the bone loss risk, the patient satisfaction, the masticatory efficiency, the number of implants and the economic cost/analysis. At the final presents a discussion on clinical decisions in the edentulous rehabilitation.

Chapter IX – Denture Adhesives have always been surrounded by an infinite number of controversies. Prosthodontists and dentists in general have never really accepted the role of denture adhesives in improving denture retention, stability and function. Despite substantial and significant records encouraging the use of adhesives, the dental fraternity by large still considers adhesive use as a poor echo of their treatments and prosthetic proficiencies. However, in view of a longer-living population with an increasing rate of chronic residual ridge resorption and a consequent increase in dentures that are unsteady because of

parameters beyond the control of the patient or dentist, denture adhesives deserve a place in removable prosthodontics as an effective and active aide in denture treatment and denture aftercare. Complete dentures constitute one of the most important treatment options in prosthodontics, more so with an increase in average life expectancy of the individual. However, retention of complete dentures has always posed to be a problem for the dentist and the dental industry. Solutions to the problem, over the years have included overdentures, implants, and denture adhesives. From time immemorial adhesives have been used by denture wearers and advertised commercially, however these dental materials have not been given their due place in prosthetic dentistry. These materials are specially promoted in certain special conditions such as complicated prostheses–obturators, dry mouth, difficult and exacting patients (e.g. Parkinson's disease, Alzheimer's disease), compromised ridges, single complete denture or in public figures. Besides, adhesives are also normally used by denture wearers to psychologically support the patient so as to make the complete dentures more acceptable. Conflicting views still persist. The ancient views regard these materials as a poor replacement for a proper fit and adjustment of dentures. However, existing literature supports the use of denture adhesives i.e. if properly used. Adhesives can be a valuable aid in management of challenging denture patients. Therefore, the following article aims to solve this dilemma regarding the use denture adhesives, oust some of the myths related to adhesives in order to allow good use and avoid misuse of the same.

Chapter X – A wide range of medical devices used in elderly patients shown to support colonization and biofilm formation by *Candida spp*. Among them, more attention must be paid to denture plaque because similar to dental plaque it also serves as a reservoir of potentially infectious microorganisms. Continuous swallowing or aspiration of microorganisms from denture plaque exposes elderly patients to the risk of unexpected infections. The level of oral hygiene in elderly people, especially those living in long-term care institutions, has been reported to be poor, both for dentures and remaining teeth. The upper denture has been suggested to be the major source of infection in long term hospital care patients. It has also been reported that larger quantities of *Candida spp.* reside in the denture base and not in the palate. The most frequent isolated yeast species in dentures is *C. albicans*. Although, recent reports show high proportions of *non-albicans Candida* spp., thus showing a shift from *C. albicans* towards *non-albicans* spp. This shift has already been reported over the last years with *C. glabrata* emerging as the second most prevalent species found in dentures. Infections related to *C. glabrata* can lead to systemic infections with high mortality rates. The increased inadequate use of topical and systemic antifungals has been proposed to contribute to this fungal profile change. Several studies show a correlation between poor denture hygiene and prevalence of *Candida* species and also a statistically significant relationship between denture related stomatitis (DRS), presence of *Candida* and denture cleanliness. High frequency and quantity of *Candida spp.* detection is sometimes associated with few clinically detectable cases of DRS. Hyphae detection by microscopy is now the gold standard (with the exception of *C. glabrata*) for the diagnosis of oropharyngeal fungal infections (OFI). Presence of oral lesions associated with OFI has been reported only in one third of microscopically affected patients. Frequent use of toothpaste to clean dentures has an influence on dentures surface roughness due to the presence of abrasives. Surface roughness being positively correlated with the rate of fungal colonization of biomaterials, a rougher surface may be a risk factor for microorganism adhesion and biofilm formation. Conclusion: High levels of *Candida spp.* are reported on dentures of elderly patients. A high

frequency of *non-albicans Candida spp.* (particularly *C. glabrata*) has been detected in recent studies. This seems to confirm a change in the mycological ecology involved in yeast denture colonization and DRS. Keywords: *Candida* spp., dentures, elderly.

Chapter XI – Psychogenic denture intolerance (PDI) patients suffering from several denture induced psychogenic symptoms refuse to accept psychological background of their symptoms frequently. Instead of psychiatrists or psychotherapists, first they visit dentist and insist on the somatic origin of their symptoms. Since most of these patients refuse a referral to psychiatrist and/or psychotherapist, an initial psychosomatic therapy is needed, which is a scope of dental profession's duty. Initiation of a palliative dental care and gradual escalation of any kind of mind-body therapy (as "basic therapeutics" for psychosomatic disorders) are "cornerstones" of such dental psychosomatic interventions. Introduction of any method of complementary/alternative medicine may also be useful especially for the prevention of relapse. To carry out efficient palliative dental care useless repetition of previous dental treatment (or any further invasive dental treatment) should be avoided, certain psychotherapeutic approaches should be introduced and several other treatment modalities like physiotherapy, medication, medicinal herb therapy or acupuncture should also be administered. For mind-body therapies, relaxation, hypnosis, self-hypnosis, meditation, photo-acoustic stimulation or biofeedback may be used. For complementary and alternative medicine prayer, breathing exercises, Tai-Chi and Qigong, Yoga or several other therapies (i.e. sleep deprivation, vigil, fasting therapy etc.) may be considered.

Chapter XII – Psychogenic complications of making dentures as well as consequently appearing psychogenic denture intolerance is a complex and rising problem of dentistry and presents many intricate problems, which are being tackled by various disciplines of both basic and clinical research. Estimations based on the available data and clinical experience indicate that, at least 3-4% of denture wearers suffer from psychogenic symptoms caused by the treatment procedure, insertion or wearing of fixed or removable dentures. No wonder that, there is a high amount of scientific information gathered so far, however data are rather divergent, sometimes even contradictory and there are numerous questions without any available data to answer. Present chapter is primarily dedicated to the clinical aspects of these phenomena, including clinical manifestations, diagnosis, prevention and treatment possibilities. Other relevant subject areas of this chapter include theoretical background and peculiarities of denture-related psychological and psycho-physiological phenomena, background and pathomechanisms of denture induced psychosomatic manifestations, basic principles of communication and patient-nurse-dentist interrelationships. This collection of information helps the reader to be at home in scientific field of denture related psychogenic manifestations.

Chapter XIII – Data in the literature revealed that bone formation around dental implants can be promoted due to PEMF treatment significantly. Since PEMF decreases the rate of residual ridge resorption following tooth extraction, PEMF is likely to improve healing of implants inserted into extraction sites as well. PEMF may also be used advantageously for accelerating bone healing following advanced implant surgery. Although PEMF stimulation during the first two weeks after surgery seems to be the most efficient; late phase bone healing (even four weeks after surgery) may also be accelerated with PEMF administration. Moreover, PEMF stimulation speeds up bone remodeling processes which effect is likely to be a crucial factor of the phenomenon that PEMF accelerates tooth movement (and coupled periodontal processes). PEMF also influence the function of periodontal ligament fibroblasts,

which also may play a significant role in the acceleration of bone remodeling around orthodontically moved teeth as well as around teeth subjected to high mechanical load during mastication (i.e. abutment teeth) or because of parafunction. Although PEMF was found to be beneficial to a wide variety of therapeutic processes also in dentistry; the exact mechanisms by which PEMF affects alveolar bone and other periodontal tissues is far not fully understood yet. However, certain mechanisms are already recognized and the increased amount of knowledge may be utilized also for the clinical practice. In this chapter scientific data of clinical relevance are collected and discussed.

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Chapter I

The Prosthetic Classification of Partially Edentulous Dental Arches and Its Use for Treatment Planning

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Abstract

Major goal of the "prosthetic classification" (Fábián and Fejérdy 1979) is to enhance treatment planning and denture designing procedures. With regard to this aspect partially edentulous arches can be rendered to classes as follows:

Class 1A: one or more primary fulcrum lines (straight line drawn between two teeth adjacent to the edentulous space) may exist; but none of the primary fulcrum lines is going to become a factual rotation axis when a denture is inserted. No force of rotation will be generated and the denture may not settle. In this class of arches fixed dentures are recommended.

Class 1B: one or more fulcrum line(s) may exist, which may become a factual rotation axis when a denture is inserted. The rotational forces, however, will not be very powerful, so that the settling of the denture can be equalized (i.e. compensated due to multiple abutments). In this class of arches fixed dentures may be recommended.

Class 2A: only one primary fulcrum line exists, which may become a factual rotation axis when a denture is inserted. Rotating around this factual rotation axis the denture may settle in one direction. In this class of arches RPD is recommended and the baseplate of RPD can be moderately reduced.

Class 2A/1: only one fulcrum line exists, which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the denture may settle in one direction. This class is a special case (subclass) of class 2A characterized by very few

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(maximum one or two) remaining teeth. In this class of arches RPD is recommended and the baseplate of RPD can *not* be reduced.

Class 2B: Several primary fulcrum lines may exist, one of which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the denture may settle in one direction. In this class of arches RPD (combined with or without fixed dentures) are recommended and the baseplate of RPD can be moderately reduced.

Class 3: one or more primary fulcrum line(s) may exist; from which one or more may become a factual rotation axis when a denture is inserted. Rotating around this/these rotation axis the denture will tip upward on one side and downward on the other side (i.e. two-directional rotary movements occur). In this class of arches RPD is recommended, the baseplate of RPD can not be reduced and, *resilient* type telescopes (i.e. delayed type dental support) should be used.

Introduction

A survey and an account of the diverse factors influencing treatment planning are only possible if they are systemized. This is the primary aim of the prosthetic classification of partially edentulous arches (Fábián and Fejérdy 1979) described in this chapter. This classification is referred to as "prosthetic classification"; because its major goal is to enhance treatment planning and denture designing procedures for those partially edentulous patients being suitable for complete arch reconstruction ("full-arch" reconstruction) but not suitable for implant dentistry (Fábián and Fejérdy 1979, 1981). (Please consider that a patient may be not suitable for implant dentistry because of dental, medical but also because of social, psychological or numerous other reasons). However, all systemization may lead to simplification which is a huge mistake of treatment planning in dentistry, and lack of attention to all facets of treatment planning may invite treatment failure (Laney 1983, Bensing 2000, Green and Laskin 2000, Fábián and Fejérdy 2010). Therefore, besides giving an introduction to prosthodontic classification (see second and third part of this chapter) several other aspects recommended for consideration during treatment planning will be mentioned first as an introduction as follows.

It should be emphasized that patient's subjective need as well as the normatively determined need for replacement of missing teeth should be evaluated carefully before any prosthodontic treatment aiming at complete arch ("full-arch") reconstruction (Elias and Sheiham 1998, Heft et al. 2003, Mazurat and Mazurat 2003, Graham et al. 2006, Fábián and Fejérdy 2010). Accordingly, the success of a prosthetic treatment strongly depends on the patients' perception of the value of such replacement (Mazurat and Mazurat 2003). It should be considered that, patients are rather focused on psychosocial meaning of the mouth than to physiological function of the teeth when defining subjective need for replacement of missing teeth (Graham et al. 2006). Although occlusion of a complete dental arch is preferable normatively in most cases, many people are really satisfied with less than 28 natural (± wisdom) teeth (Rosenoer and Sheiham 1995, Elias and Sheiham 1998, Jones et al. 2003, Ekanayake and Perera 2005, Cunha-Cruz et al. 2007). In fact, there is a discrepancy between the normative need and perceived need. Therefore, prompt replacement of absent teeth without a subjective need of patients may lead to an overtreatment and discomfort (Witter et al. 1994, 1999, Mazurat and Mazurat 2003, Fejérdy 2007) especially when removable partial

dentures (RPDs) are used because of financial (or other) reasons (Witter et al. 1994, 1999, Mazurat and Mazurat 2003, Bae et al. 2006).

It should be also considered that aesthetics seems to be more important than other functions for a great majority of individuals (Elias and Sheiham 1998, Shor et al. 2005, Zlatarić and Celebić 2008); therefore there can be a lack of subjective need for replacement of missing posterior (particularly molar) teeth (Witter et al. 1994, Elias and Sheiham 1998, Mazurat and Mazurat 2003) especially if only a few teeth are absent (Zitzmann et al. 2007). Although aesthetics seems to be more important than other functions for a great majority of individuals (Elias and Sheiham 1998, Shor et al. 2005, Zlatarić and Celebić 2008), expectations and wishes of patient related to chewing (Mazurat and Mazurat 2003, Szentpétery et al. 2005, Zlatarić and Celebić 2008, Roumanas 2009) must also not be underestimated (Mazurat and Mazurat 2003, Fábián et al. 2007, Zlatarić and Celebić 2008, Fábián and Fejérdy 2010). Although chewing ability can be acceptable for patients functioning from second premolar to second premolar (i.e. when all molars missing) (Mazurat and Mazurat 2003); more advanced loss of teeth may induce strong difficulties of chewing. In such cases improvement of mastication may be a highly important wish of patients certainly (Mazurat and Mazurat 2003).

Patients' expectations related to speech may also influence satisfaction with dentures strongly (Zlatarić and Celebić 2008, Roumanas 2009, Fábián and Fejérdy 2010). Similarly, numerous other expectations and wishes of patients related to the denture and/or dental treatment may also appear (Levin and Landesman 1976, Fábián and Fábián 2000, Fábián et al. 2007, Roumanas 2009). Importantly, executable and acceptable wishes and expectations of patient should be fulfilled (Fábián and Fábián 2000, Mazurat and Mazurat 2003, Fábián et al. 2007). If inexecutable and/or unacceptable wishes and expectations also appear, the clinician should carefully weigh the option of nontreatment (Levin and Landesman 1976, Stein 1983, Fábián and Fábián 2000, Fábián et al. 2007).

Besides premised subjective need and conscious wishes (Fábián and Fábián 2000, Smith and McCord 2004, Fábián et al. 2007) related to denture function, unconscious wishes of patients related to both dental treatment and denture (as well as to dentist) should also be considered (Fábián and Fábián 2000, Fábián et al. 2007, Fejérdy and Orosz 2007). In contrast to conscious wishes, understanding unconscious wishes (e.g. to look younger, to stop the appearance of aging, to be loved by the dentist etc.) may be more challenging but highly important for preventing psychogenic manifestation (Fábián and Fábián 2000, Fábián et al. 2007, Fejérdy and Orosz 2007, Fábián and Fejérdy 2010). It may occur that, the patient's conscious and/or unconscious wishes related to the dental treatment and/or dentures and/or dentist may not harmonize with the reality and possibilities of a prosthetic treatment. It is a matter of considerable significance that the clinician carefully weighs the option of nontreatment in such cases (Stein 1983, Fábián and Fábián 2000, Fábián et al. 2007, Fejérdy and Orosz 2007).

It should be also considered that, fixed dentures are usually preferable to a removable one for most patient (Szentpétery et al. 2005). Therefore properly planned fixed dentures supported either by natural abutment teeth or by properly inserted (Bartling et al. 1999) dental implants may be preferable for most patients. However, financial means (Ringland et al. 2004, Roumanas 2009) and compliance of the patient as well as the amount of stress and possible complications induced by preparation of teeth (Cronström et al. 1998, Goodacre et al. 2003/a) and/or implant-surgical interventions (Kaptein et al. 1998, Bartling et al. 1999,

Walton 2000, Goodacre et al. 2003/b) should also be considered very carefully. Because of the high success rate of endosseus dental implants (Nedir et al. 2004, Comfort et al. 2005, Goené et al. 2005, Schwartz-Arad et al. 2007), strategic extraction of compromised tooth/teeth and their replacement with implant supported fixed dentures should also be considered (Barone et al. 2006, Schwartz-Arad et al. 2007, Kao 2008), especially because compromised teeth may significantly worsen the perceived oral health (Cunha-Cruz et al. 2007).

Fixed dentures are especially preferable in instances in which a space created by the loss of a single tooth or perhaps two adjacent teeth is bounded by clinically adequate abutments (Laney 1983, Fábián and Fejérdy 2010). Besides bridges, use of implant supported single crown(s) may also be a proper solution in such cases (Nedir et al. 2004, Schwartz-Arad et al. 2007, Kao 2008). If the edentulous areas are longer, multiple abutments are usually necessary to support fixed restorations (Fábián and Fejérdy 1979, 1981, Fábián et al. 1983, Laney 1983, Fejérdy et al. 2007); however, the increased length of the span may invite symptoms in sensitive patients. Implant supported fixed prostheses may also be a proper solution also in such cases (Goené et al. 2005, Schwartz-Arad et al. 2007, Kao 2008).

It should be also considered that, the farther the pontics deviate from the straight line through the abutments, the longer is the operative lever arm that may also invite problems due to tipping forces (Fábián and Fejérdy 1979, 1981, Fábián et al. 1983, Laney 1983). In cases of increased estimated tipping forces, either insertion of implants or orthodontic movement of the abutment tooth/teeth or use of an RPD may be preferable. In the absence of sufficient number (and/or quality) of abutment teeth (and/or implants) RPDs should be used (Fábián and Fejérdy 1979, 1981). Combinations of RPDs and fixed dentures may also be used advantageously in such cases (Fábián and Fejérdy 1979, 1981). In cases with only a few remaining teeth (and/or implants), RPDs may be used. In such cases, especially rotary movements (especially two-directional rotary movements around intermediary abutment tooth interrupting long edentulous areas) may be difficult to control (Fábián and Fejérdy 1979, 1981, Fábián 1980, Laney 1983).

Besides above, there are some other aspects of prosthodontic treatment that should also be considered for proper treatment planning. Possibilities to correct patients' existing malocclusion (if any) should be considered before prosthodontic treatment. Occlusal early contacts (Biondi and Picardi 1993, Learreta et al. 2007), alterations of horizontal maxillomandibular relationship (Biondi and Picardi 1993) and improper vertical dimension (Piquero et al. 1999) should be corrected with the new denture(s) (Fábián and Fejérdy 2010). Possibilities to decrease the risk of an inflammatory response in the pulp following tooth preparation should also be considered (Fábián and Fejérdy 2010); and time need of careful preparation technique, making well fitting provisional crowns/bridges, applying chemical defense of the stump, and proper methodology for the cementation of both provisorical and permanent restorations (Kern et al. 1996, Brännström 1996) should also be taken into account. Time need of proper shaping of occlusal contacts for both provisional and permanent dentures (avoiding the "prophylactic" removal of occlusal contacts as a "pain preventive measure" (Creech et al. 1984)) as well as time need of accurate precise shaping of marginal closure and gingival site for both provisorical and permanent dentures should also be considered for planning (Hermann et al. 2009, Fábián and Fejérdy 2010).

Importantly, planning of a time-schedule ensuring enough time to carry out a high quality, precise, "lege artis" dental treatment is one of the most important points to achieve a

successful prosthodontic treatment (Hermann et al. 2009, Fábián and Fejérdy 2010). Timing of the start of prosthetic treatment and the insertion of dentures may also be of particular importance (Müller-Fahlbusch and Sone 1982, Fábián and Fejérdy 2010), because heavy psychosocial and/or psychoemotional stress condition as well as the active phases of psychiatric disorders significantly increase the risk of the appearance of psychogenic manifestations in relation with the prosthodontic treatment (Müller-Fahlbusch and Sohne 1982, Fábián and Fejérdy 2010). Therefore, starting of prosthetic treatment or insertion of dentures under any heavy psychological stress conditions and/or active phases of psychiatric disorders should be avoided (Müller-Fahlbusch and Sone 1982, Fábián and Fejérdy 2010); and the prosthetic treatment or insertion of denture should be delayed (Müller-Fahlbusch and Sone 1982, Fábián and Fejérdy 2010).

Basic Principles of the Prosthetic Classification

As indicated above, this classification is referred to as "prosthetic classification" (Fábián and Fejérdy 1979, 1981); because its major goal is to enhance treatment planning and denture designing procedures for those partially edentulous patients being suitable for complete arch reconstruction (“full-arch” reconstruction) but not suitable for implant dentistry. With regard to these aspects partially edentulous arches can be rendered to five main classes such as 1A, 1B, 2A, 2B and 3, and to one subclass (2A/1) as described below (see also Figure 1).

Class 1A: one or more primary fulcrum lines (straight line drawn between two teeth adjacent to the edentulous space) may exist; but none of the primary fulcrum lines is going to become a factual rotation axis when a denture is inserted. No force of rotation will be generated and the denture may not settle. In case of partially edentulous arches of class 1A fixed dentures are recommended (Fábián and Fejérdy 1979, 1981, Fábián et al. 1981). If still a removable partial denture (RPD) were made, baseplate of RPD can be extremely reduced to a framework. Class 1B: one or more fulcrum line(s) may exist, which may become a factual rotation axis when a denture is inserted. The rotational forces, however, will not be very powerful, so that the settling of the denture can be equalized (i.e. compensated due to multiple abutments). In case of partially edentulous arches of class 1B fixed dentures may be recommended (Fábián and Fejérdy 1979, 1981, Fábián et al. 1983). If still a removable partial denture (RPD) were made, baseplate of RPD can be strongly reduced.

Class 2A: only one primary fulcrum line exists, which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the denture may settle in one direction. In case of a partially edentulous arch of class 2A removable partial denture (RPD) is recommended and the baseplate of RPD can be moderately reduced only (Fábián and Fejérdy 1979, 1981, Fábián 1980/b). Class 2A/1: only one fulcrum line exists, which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the denture may settle in one direction. This class is a special case (subclass) of class 2A characterized by very few (maximum one or two) remaining teeth. In case of partially edentulous arches of class 2A/1 removable partial denture (RPD) is recommended and the baseplate of RPD can not be reduced (Fábián and Fejérdy 1979, 1981, 1991, Fábián 1980/a,b). Class 2B: Several primary fulcrum lines may exist, and one of which may become a factual rotation axis when a denture is inserted. Rotating around this rotation axis the

denture may settle in one direction. In case of partially edentulous arches of class 2B removable partial denture (combined with or without fixed dentures) are recommended and the baseplate of RPD can be moderately reduced only (Fábián and Fejérdy 1979, 1981, 1991, Fábián 1980/b).

Class 3: one or more primary fulcrum line(s) may exist; from which one or more may become a factual rotation axis when a denture is inserted. Rotating around this/these rotation axis the denture will tip upward on one side and downward on the other side (i.e. two-directional rotary movements occur). In case of partially edentulous arches of class 3 removable partial denture (RPD) is recommended, the baseplate of RPD can not be reduced and, importantly, resilient type telescopes (i.e. delayed type dental support) should be used (Fábián and Fejérdy 1979, 1981, Fábián 1980/a,b).

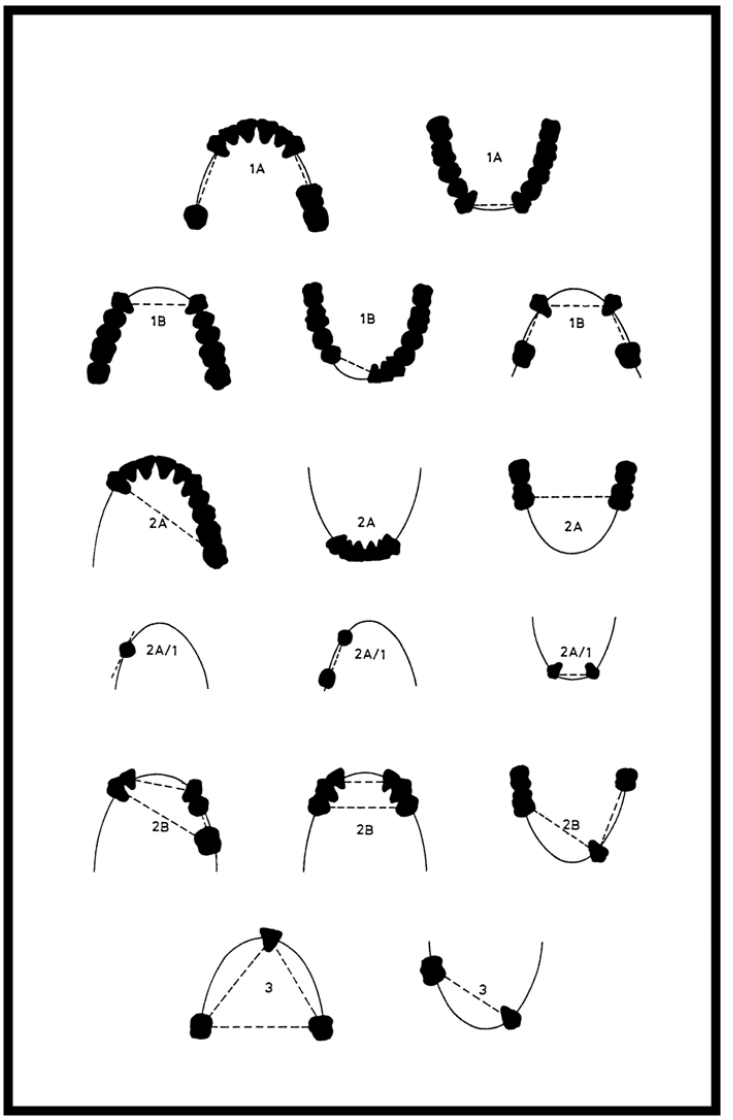

Figure 1. Typical examples for the prosthodontic classification of edentulous dental arches (*Fábián and Fejérdy 1979*).

Planning Partial Dentures for Various Types of Edentulous Arches

Treatment Planning for Cases of Class 1A and Class 1B

According to the basic principles of prosthodontic classification introduced above, in classes 1A and 1B the conditions for making a bridge are given. The type of denture to be made should be chosen after waging the advantages and disadvantages of a bridge as opposed to a removable partial denture. (Please remember that, prosthodontic classification is for patients not suitable for implant dentistry, therefore the advantages/disadvantages of implant based restorations will not be discussed.)

For the restoration of partially edentulous arches of class 1A bridge(s) should be made in the first place, because the full dental support the foremost condition of making a bridge is given. In case of dentures made to restore arches of class 1A, pontics do not deviate from the straight line through the abutments. Consequently there is no primary operative lever arm and there are no significant tipping forces. Therefore involvement of auxiliary abutment teeth for dental support of a bridge is not necessary if the periodontal tissues of abutment teeth are healthy. (Fábián and Fejérdy 1979, 1981, Fábián et al. 1981, Fábián 1983, 2001, Fejérdy 2007, Fejérdy et al. 2007).

If still a removable partial denture (RPD) were made, an RPD with metal framework should be used, the baseplate of RPD can be extremely reduced to framework, and dental support (support on remaining teeth only) should be given primarily to equalize masticatory forces. However, RPDs are expedient only if one of their major advantages (i.e. they can be made without preparing a tooth; they are usually cheaper than fixed dentures etc.) predominates because of medical, social, psychological or other reasons (Fábián and Fejérdy 1979, 1981, Fábián et al. 1981, Fábián 1983, 2001, Fejérdy 2007).

In the case of dentures made to restore edentulous arches of class 1B one or more pontic(s) deviate(s) from the straight line through the abutments. Consequently, primary operative lever arm(s) and significant tipping force(s) appear(s). Therefore, involvement of one or more auxiliary tooth/teeth is needed, to prevent the overload of the abutment teeth. If still a removable partial denture (RPD) were made, an RPD with metal framework should be used, the baseplate of RPD can be reduced significantly but saddle(s) should be used. A dento-musocal support (support primarily on remaining teeth but also on mucosal tissues) should be given to equalize the masticatory forces (Fábián and Fejérdy 1979, 1981, Fábián et al. 1981, Fábián 1983, 2001, Fejérdy 2007, Fejérdy et al. 2008).

Treatment Planning for Cases of Class 2A

In class 2A a large edentulous area is located either on distal end(s) of the arch (in one or both side) or interdentally in the premolar or frontal region, whereas the remaining teeth are located in one group (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007). As a result of such a location of a rather large edentulous area, a relatively long operative lever arm and significant tipping force appears which can not be equalized by the remaining teeth. Therefore, in class 2A an RPD with metal framework should be used, the

baseplate of RPD can be reduced significantly but saddle(s) should be used and a dento-musocal support should be given to equalize masticatory forces (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007, Fejérdy et al. 2008).

The conditions for a dento-mucosal support are relatively advantageous in this class, because there is only one primary fulcrum line (straight line drawn between two teeth adjacent to the edentulous space) which is going to become a factual rotation axis when a denture is inserted; and the artificial teeth of RPD lie only on one side of the primary fulcrum line functioning as the axis of rotation (rotating around this rotation axis the denture may settle or tip in one direction only). Therefore, the masticatory force will cause a small-scale settling of the saddle(s) which will stay stable in this position (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007).

In view of retention class 2A is inadvantageous, because tensile forces will tip the saddle(s) of denture (either mesially or distally), therefore RPDs should be completed with an indirect retainer in class 2A. In case of clasp retention, we may put the occlusal support far from the saddle, because it removes the rotation axis of the RPD away from the point of greatest settlement of the saddle(s).

Consequently, an advantageous decrease of the angle of rotation occurs, while the occlusal rest positioned far from the saddle advantageously acts as an effective indirect retainer as well. If precision attachment is used, involvement of auxiliary abutment tooth may be needed for proper support and anchorage of the attachment (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007).

Treatment Planning for Cases of Class 2A/1

This class is a special case (subclass) of class 2A characterized by very few (maximum one or two) remaining teeth. In case of partially edentulous arches of class 2A/1 removable partial denture (RPD) is recommended (Fábián and Fejérdy 1979, 1981, 1991, Fábián 1980/a,b). Because of the very few remaining teeth muco-dental support (support primarily on mucosal tissues but also on remaining teeth) should be used to equalize masticatory forces. Therefore the baseplate of RPD can not be reduced, but even may be extended to an optimal dimension using functional impression to improve anchorage (Fábián and Fejérdy 1979, 1981, 1991, Fábián 1980/a,b).

There are three basic forms may be considered for the prosthetic restoration of cases of class 2A/1 as follows: (1).: An RPD retained by telescope may be advocated in the first place. In case of two remaining teeth (located near by each other) the primary telescopes should preferably be splinted together. Since the baseplate of RPD can not be reduced, a baseplate of acrylic resin without any metal framework will met the demands in this case usually. (2).: RPD may be retained by clasps also in cases of class 2A/1. In such cases however RPD with metal framework should be used, even if the baseplate is not reduced. Abutment crowns may also be used according to indication, and the remaining teeth may be splinted in this case. (3).: If the remaining teeth are two lower cuspids the denture can be advantageously retained using a bar (preferably of precision attachment) (Fábián and Fejérdy 1979, 1981, 1991, Fábián 1980/a,b, Fábián 1983, 2001, Fejérdy 2007).

Treatment Planning for Cases of Class 2B

Cases of class 2B differ from those of class 2A in so far as the remaining teeth are not situated in one group, but there are edentulous areas between them (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007). The basic similarity between cases of class 2B and those of class 2A is seen in the considerable, not compensable extension of the edentulous ridge on one side of the primary fulcrum line functioning as the axis of rotation (rotating around this rotation axis the denture may settle in one direction only). (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007). Because of the relatively long operative lever arm and significant tipping force (which can not be equalized by the remaining teeth) a dento-musocal support should be given to equalize masticatory forces also in class 2B. Therefore, an RPD with metal framework should be used also in class 2B. Similarly to cases of class 2A, the baseplate of RPD can be reduced significantly but saddle(s) should be used. Because of the edentulous areas between the remaining teeth, the possibilities for retention are in this class always quite favorable, therefore no indirect retainers are necessary (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007, Fejérdy et al. 2008).

There are four basic forms may be considered for the prosthetic restoration of cases of class 2B as follows: (1).: Edentulous areas between remaining teeth will be restored by a bridge with a subsequently fabricated RPD. In this case we in fact transform the case of class 2B into a case of class 2A. (2).: A bar (preferably of precision attachment) will be applied along the edentulous areas between the remaining teeth, which serves as both dental support and anchorage for an RPD. (3).: In case of multiple edentulous areas between the remaining teeth, these areas may be restored using a combination of both bridge(s) and bar(s) as well. Patients usually find it more convenient to have their missing front teeth restored by a bridge while bars (preferably of precision attachment) can be used for proper retention and anchorage in the lateral edentulous areas between remaining teeth (4).: Cases of class 2B may be restored with RPD without the use of any fixed prosthesis (but abutment crowns at best according to indication) (Fábián and Fejérdy 1979, 1981, Fábián 1980/b, Fábián 1983, 2001, Fejérdy 2007).

Treatment Planning for Cases of Class 3

In the case of class 3 few remaining teeth interrupt long edentulous areas, therefore two-directional rotary movements around these remaining teeth (interrupting long edentulous areas) occur which is difficult to control. Rotating around factual rotation axis the denture will tip upward on one side and downward on the other side. Therefore, mucosal support and a delayed type dental support achieved by resilient type telescopes should be used to control two-directional rotary movements. This will ensure primary settlement of the RPD thereby creating evenly distributed load on the underlying teeth and mucosa (Fábián and Fejérdy 1979, 1981, Fábián 1980/a,b, Fábián 1983, 2001, Fejérdy 2007). Accordingly, in case of class 3, removable partial denture is recommended, the baseplate of RPD can not be reduced and resilient type telescopes (i.e. delayed type dental support) should be used to achieve (delayed) dental support and to improve anchorage. The anchorage may also be improved via extension of the baseplate to an optimal dimension using functional impression. A baseplate of acrylic

resin without any metal framework will met the demands in cases of class 3 usually (Fábián and Fejérdy 1979, 1981, Fábián 1980/a,b, Fábián 1983, 2001, Fejérdy 2007).

Conclusion

The prosthetic classification of partially edentulous dental arches (Fábián and Fejérdy 1979, 1981) may enhance treatment planning and denture designing procedures for those partially edentulous patients being suitable for complete arch reconstruction ("full-arch" reconstruction) but not suitable for implant dentistry. However, simplification of treatment planning because of systemization should be avoided and all facets of a case should be considered to prevent treatment failure.

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Chapter II

Orthodontics for Patient of Prosthetic Dentistry. Possibilities and Complications of Psychosomatic Origin

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Abstract

Various dental specialties have made such enormous advances that it has become impossible to absorb all that is new in all dental areas. Therefore a collaborative effort between orthodontist and prosthodontist is often necessary to achieve an optimal treatment result. Prosthodontists and restorative dentists rely on orthodontics as a means of providing more comprehensive care to their patients. Such collaboration is not only desirable, but mandatory if dentists are to provide highest level care for their patients. Preprosthetic orthodontics gains significance in both esthetics and functionality of the denture being under preparation. Therefore, an interdisciplinary approach may also be cost-effective for both patient and dentist from the standpoint of producing more stable and durable restorations of high esthetics. Orthodontics may contribute to the success of cases undergoing restorative dental procedures where preliminary minor tooth movement is necessary, to correct local malpositions and/or to move abutment teeth with simple appliances. Success of implant placement may also be improved via orthodontic forced extrusion of periodontally compromised teeth. Collaboration of orthodontist and prosthodontist may be even more demanding when correction of primary orthodontic anomalies would be needed. No wonder that, the integration of orthodontics and

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prosthetic dentistry into a multidisciplinary rehabilitation is often indispensable for a proper dental care of the patients. A proper plaque control is also essential for a successful treatment in all cases. Along with mechanical and biological principles, unique psychological and social aspects of the combined orthodontic and prosthetic treatment should also be considered for a successful therapy. In this chapter the important role of orthodontics and its contribution to the success of prosthetic dentistry for adult patients is discussed.

Introduction

Various dental specialties have made such enormous advances that it has become impossible to absorb all that is new in all dental areas [LaSota 1988]. Therefore a collaborative effort between orthodontist and prosthodontist is often necessary to achieve an optimal treatment result [LaSota 1988]. Prosthodontists and restorative dentists rely on orthodontics as a means of providing more comprehensive care to their patients [LaSota 1988]. Such collaboration is not only desirable, but mandatory if dentists are to provide highest level care for their patients [LaSota 1988]. Orthodontics may contribute to the success of cases undergoing restorative dental procedures where preliminary minor tooth movement is necessary, to correct local malpositions and/or to move abutment teeth with simple appliances [Shapira 1978, Keesee et al. 2002]. Success of implant placement may also be improved via orthodontic forced extrusion of periodontally compromised teeth [Atherton 1970, Heithersay 1973, Ingber 1974]. Collaboration of orthodontist and prosthodontist may be even more demanding when correction of primary orthodontic anomalies would be needed [LaSota 1988]. No wonder that, the integration of orthodontics and prosthetic dentistry into a multidisciplinary rehabilitation is often indispensable for a proper dental care of the patients [Diedrich 1996]. A proper plaque control [Diedrich 1996, Fábián et al 2000] as well as careful evaluation of relevant psychosocial and psychoemotional aspects [Fábián et al 2000] are also essential for a successful treatment in all cases. In this chapter the important role of orthodontics and its contribution to the success of prosthetic dentistry for adult patients is discussed.

Correction of Drifting or Tilting towards the Adjacent Tooth

Caries or other approximal lesion may result in the drifting or tilting of teeth towards their neighboring teeth, which makes restoration difficult. The close root approximation and poor long-axis alignment, may lead to inability to restore proper contours and to establish esthetics [Keesee et al. 2002]. Protection of the adjacent tooth during preparation procedure and avoidance of the exposure of the pulp of a tipped tooth under preparation may also be difficult. In other cases lack of adequate mesiodistal space may not provide adequate space for fabrication insertion and maintenance of implant crowns, because of a drifting/tilting of the adjacent tooth [Rotella et al. 2011]. To solve all these problems, orthodontic separators have been used to create space for crown placement on misaligned premolars and molars

[Reagan 1988, VanderWeele et al. 1998, Keesee et al. 2002, Rotella et al. 2011]. Placement of an elastic orthodontic separator accomplished with 2 standards of dental floss used to stretch the separator and snap it in between the two teeth may be used as a simple technique to achieve minor tooth movement [VanderWeele et al. 1998, Keesee et al. 2002]. Similarly, orthodontic separator can be placed between the adjacent tooth and a provisional screw-retained temporary crown of an implant [Rotella et al. 2011].

Roughly 1-1.5 mm of separation can be reached in 1-2 weeks with this method [Keesee et al. 2002, Rotella et al. 2011]. If further separation is needed, the tooth contact can be restored with an interim restoration and the process can be repeated [Keesee et al. 2002, Rotella et al. 2011]. However, it should be considered that, bodily movement (translation) cannot be expected because the application of force is a tipping one. Further, the tipping force may be extrusive therefore the occlusion must be monitored during the treatment [Keesee et al. 2002]. It should be also considered that the procedure may lead to transient hypermobility of the involved teeth [Keesee et al. 2002], and that the procedure is just as likely to move both adjacent tooth if the anchorage of both of them is insufficient [Keesee et al. 2002]. Since osseointegrated implants do not move in response to orthodontic loads [Odman et al. 1994, Kato and Kato 2006] premised problems do not occur when the separator was placed between an adjacent tooth and an implant (i.e. implant with provisional crown certainly) [Rotella et al. 2011]

Correction of Drifting or Tilting into the Pontic Space

To set a tooth (tipped into the pontic space) upright and/or to decrease the span (diastema) between an abutment tooth (drifted into the pontic space) and the adjacent tooth may also be needed frequently [LaSota 1988, Claman et al. 2003, Lewinstein et al. 2003]. In such cases the position of the abutment tooth may be optimized using brackets, arch wire, and elastic chain [Claman et al. 2003] or activated coil-spring [Lewinstein et al. 2003]. Removable orthodontic appliance may also be used to close a diastema between teeth [Schmitz et al. 2001]. In certain cases orthodontic rubber band fixed with two composite buildups on the labial surface of two adjacent teeth may also be used to close a diastema between them [Schmitz et al. 2001]. In certain cases adjacent osseointegrated implants serving as abutments for permanent prosthetic constructions (i.e. after the completion of the orthodontic treatment) may also be used to set a tooth upright and/or to achieve bodily movement to decrease the span between the tooth and the implant [Odman et al. 1994]. If brackets are used, they should be placed onto all the abutment teeth of the planned bridge and also on the adjacent teeth (at least on the adjacent tooth of the drifted/tipped tooth). If activated coil-spring is used, it should be positioned in that way that the force hits the drifted/tipped abutment tooth from the pontic side certainly. The orthodontic movement may take few months.

Forced Eruption of Periodontally Compromised Teeth

The use of forced eruption followed by extraction of periodontally compromised teeth provide the opportunity to permanently increase the vertical height of hard and soft tissues at the site of the tooth undergoing this procedure (i.e. forced eruption followed by extraction) [Atherton 1970, Heithersay 1973, Ingber 1974,1989, Mantzikos and Shamus 1997, Capri et al. 2003]. However the bone that moves coronally is attached to the apical third of the root (because of the advanced periodontal disease of the tooth at issue), where the root diameter is relatively narrow [Capri et al. 2003]. Therefore, the coronal movement of the bone may produce the necessary height to the edentulous ridge for making esthetic pontic or insertion of an implant [Capri et al. 2003, Chambrone and Chambrone 2005, Holst et al. 2007, Kim et al. 2011]; but the width may remain deficient in many cases because of the narrow root diameter [Capri et al. 2003]. To increase the buccolingual bulk of the alveolar bone, a buccal root torque component may be applied concomitantly [Korayem et al. 2008], but a mucogingival surgery to widen the ridge may also be needed in certain cases to develop a desired ridge width [Capri et al. 2003].

For forced eruption of periodontally compromised teeth brackets should be bounded to the treated tooth and two-three adjacent neighboring teeth at both sides [Capri et al. 2003]. The orthodontic movement can be achieved by a 0.016 inch nickel titanium wire [Capri et al. 2003, Chambrone and Chambrone 2005] with the insertion of the bracket in a more apical position onto the erupted tooth [Capri et al. 2003, Erkut et al. 2007]. To avoid intrusion of the anchorage teeth, use of a 0.019 x 0.025 inch stainless steel overlay wire (auxiliary anchorage wire) is also recommended [Chambrone and Chambrone 2005, Korayem et al. 2008]. For tooth eruption, light constant extrusive forces are recommended (i.e. 15 g for anterior and 50 g for posterior teeth) [Korayem et al. 2008]. The extrusion rate is roughly 2.0 mm per month. A retention/stabilization phase of the same length as of the active extrusion phase is recommended prior to extraction [Korayem et al. 2008]. The desired movement can be usually achieved in roughly three months with another three month retention phase before extraction [Capri et al. 2003, Chambrone and Chambrone 2005].

Forced Eruption of Teeth with Advanced Hard Tissue Damage

Forced eruption generates alteration of the periodontal tissues resulted in a coronal shift of periodontal fibers, marginal gingiva and bone (coupled with a somewhat more pronounced coronal shift of the erupted tooth certainly). Forced eruption may be used for clinical crown lengthening of buried roots, teeth with non-restorable advanced coronal damage and teeth with subgingivally located hard tissue damage (i.e. deep approximal carious lesion) [Ingber 1976, Heithersay 1973, Shiloah 1981, Stein and Sidley 1997, Ziskind et al. 2000]. In such cases the coronal movement of the bone produces both the necessary height and width to the alveolar crest for making esthetic restoration (i.e. crown or post and core with crown).

Forced eruption of a buried root can be carried out with a simplified eruption procedure using a horizontal bar fixed between the neighboring teeth, a hook cemented into the root canal, and an elastic band responsible for the tooth movement [Stein and Sidley 1997, Ziskind et al. 2000]. Brackets bounded to two-three adjacent neighboring teeth at both side together with a 0.016 inch nickel titanium wire [Ziskind et al. 2000, Chambrone and Chambrone 2005] fixed to the hook cemented into the root canal may also be used certainly. Forced eruption of teeth with non-restorable coronal damage may be carried out either in the same way as described for buried roots (i.e. after initial preparation of the tooth for post and core) or after a temporary restoration of the crown with proper buildup for fixation of a bracket [Stein and Sidley 1997, Chambrone and Chambrone 2005]. In the case of teeth with subgingivally located hard tissue damage but with more or less intact coronal region (i.e. a tooth with deep approximal carious lesion), a bracket should be fixed onto an intact coronal surface area of the teeth at issue.

Since in the above cases an extrusion of few mm is usually enough, the orthodontic procedure may take roughly a month only. Care should be taken that placement of the horizontal bar (or orthodontic wire) the hook and the elastic band influence the direction of eruption [Ziskind et al. 2000]. Therefore a root may be unintentionally moved in buccolingual or mesiodistal direction as an accompanying side effect of the forced eruption procedure [Ziskind et al. 2000].

Intrusion of Supraerupted Teeth

Supra-erupted teeth may cause problems such as functional disturbances and occlusal interference and may also cause great difficulty during prosthetic reconstruction. However, prosthetic crown reduction often leads to root canal therapy. To prevent this complications an orthodontic intrusion of supraerupted teeth may be need [Rabie et al. 1998]. However it should be emphasized that, intrusion of teeth without a proper plaque control may lead to pocket formation [Diedrich 1997], therefore great care should be taken about patients' oral hygiene activities and proper professional plaque control should also be carried out regularly [Diedrich 1997]. In this way an increase of bone coverage of the root surfaces can be reached [Heravi et al. 2011], however it is not yet clear that whether an increase of periodontal attachment (i.e. increase of the surface of attachment with periodontal fibers) also occurs or not [Diedrich 1997]. It is very likely that a significant increase of periodontal attachment (i.e. significant increase of attachment with periodontal fibers) can only be achieved if the intrusion procedure is coupled with guided tissue regeneration.

Major problem from an orthodontic point of view of intrusion of elongated teeth is that the procedure may accompanied by the extrusion of the teeth used for anchorage [Kravitz et al. 2007, Heravi et al. 2011]. Orthodontic intrusion of molars requires anchorage reinforcement by incorporating multiple teeth and/or using extraoral devices [Kravitz et al. 2007, Heravi et al. 2011]. However, despite these efforts, efficient intrusion of molars is still difficult to accomplish, and the procedure needs high level compliance of the patient too [Kravitz et al. 2007, Heravi et al. 2011]. Since osseointegrated implants do not move in response to orthodontic loads [Odman et al. 1994, Kato and Kato 2006], orthodontic temporary anchorage devices (i.e. osseointegrated miniscrews) and/or implants inserted for

prosthodontic restorations provide a proper treatment alternative [Greekmore 1983, Costa et al. 1998, Kato and Kato 2006 Kravitz et al. 2007, Landes et al. 2008, Heravi et al. 2011].

Miniscrews should be inserted into a region with high bone density covered by thin keratinized soft tissue [Kravitz et al. 2007, Landes et al et al. 2008]. (Placement of screws into a region covered by nonceratinized soft tissue may lead to greater failure rate than insertion into attached soft tissue [Kravitz et al. 2007]). Placement of screws into the tuberal region of maxilla is not recommended because of the fine trabecular bone (i.e. low bone density) of this region [Kravitz et al. 2007]. The size of the screw should be selected according to the bulk of the available bone. Diameter of the screws is ranging from 1 mm to 2,3 mm, whereas length of the screws is ranging from 6 mm to 17 mm in the related literature [Chen et al. 2009]. Use of a pilot drill (of 0.2-0.5 mm less diameter than the miniscrew itself) is recommended, although self drilling methods (without pilot drilling and incision) may also be used [Chen et al. 2009]. The screws can be loaded immediately, and most miniscrews can withstand 100-200 g of horizontal immediate load [Chen et al. 2009]. One or two screws are usually inserted into the interradicular bone adjacent to the tooth for intrusion [Kravitz et al. 2007, Landes et al. 2008]. If inadequate interradicular bone is available, screws can be placed palatally [Kravitz et al. 2007]. In certain cases osseointegrated dental implants inserted as abutments for prosthetic restorations (i.e. for implant crowns or bridges) may also be used for anchorage (before making definitive prosthetic restoration) using provisional crowns with proper buildups for orthodontic anchorage [Kato and Kato 2006].

For tooth movement titanium-molybdenum springs [Heravi et al. 2011] as well as elastic chain or nickel titanium coil [Kato and Kato 2006, Kravitz et al. 2007, Landes et al. 2008] may be used. The duration of such an orthodontic procedure usually ranges from 4 to 8 months using 100-200 g force per tooth [Kravitz et al. 2007, Heravi et al. 2011, Landes et al. 2008], and an amount of intrusion between 1.5 – 4.5 mm can be achieved under such circumstances. In certain cases (i.e. for molars) 300 g force per tooth may also be needed for such efficient movement [Kato and Kato 2006]. Importantly, pressure from intrusive forces concentrates at the root apex, which may lead to compression and necrosis of the periodontal ligament and root resorption [Kravitz et al. 2007, Heravi et al. 2011]. However, the amount of the resorption was found to be roughly 0.3 – 0.4 mm which is clinically not significant [Heravi et al. 2011]. A small amount of crest resorption may also occur during active intrusion. However, it is not comparable to the amount of intrusion, therefore there is improved final root coverage at the end of the treatment [Heravi et al. 2011].

Abutment Positioning

Increase of the pontic space (enlargement of the interabutment span) towards an edentulous area located on distal end of the arch is frequently needed and may be advantageous in many cases for prosthetic treatment [LaSota 1988, Lewinstein et al. 2003, Arslan et al. 2006]. However, orthodontic intervention is often overlooked as a viable modality to solve such problems [Cohen 1995]. For such purposes brackets should be placed onto all the abutment teeth of the planned bridge as well as on some adjacent teeth of the mesial abutment tooth/teeth of the planned bridge [Lewinstein et al. 2003]. In some cases brackets are placed on all remaining teeth of the arch [Arslan et al. 2006]. An activated coil-

spring should be positioned in that way that the force hit the drifted/tipped abutment tooth from the pontic side certainly [Lewinstein et al. 2003, Arslan et al. 2006]. Coil-springs may be applied to both the lingual and vestibular surfaces of the distalized tooth to attain a more parallel distalization [Arslan et al. 2006]. Similarly to above, enlargement of the interabutment span (increase of the pontic space) towards an edentulous area located between remaining teeth may also be needed [LaSota 1988, Savadi et al. 2010]. In such cases insertion of brackets onto all remaining teeth of the arch is usually needed, and elastic chain can be used to achieve tooth movement [Savadi et al. 2010]. Similarly, osseointegrated implants serving as abutments for permanent prosthetic constructions (after completion of the orthodontic treatment) may also be used for bodily movement and positioning of abutment tooth utilizing provisional implant crown with proper buildup for orthodontic anchorage [Odman et al. 1994, Drago 1999]. The orthodontic movement for abutment positioning may take 4-5 months [Lewinstein et al. 2003, Arslan et al. 2006], followed by a restabilization of the teeth within roughly 6-10 weeks [Lewinstein et al. 2003, Arslan et al. 2006].

Correction of Primary Orthodontic Anomalies before Prosthetic Treatment

Correction of primary orthodontic anomalies may be even more demanding cases for the collaboration of orthodontist and prosthodontist [LaSota 1988, Fábián et al. 2000]. Anterior crowding [LaSota 1988], open bite [Fábián et al. 2000, Furuse et al. 2008] and crossbite [Sakar et al. 2004] as well as rehabilitation of patients with congenital abnormalities including hypodontia [Chaushu et al. 2001, Carter et al. 2003, Thilander 2008], ectopic eruption [Savage and Kokich 2002, Jahangiri et al. 2006], ectodermal dysplasia [Suri et al. 2004] and amelogenesis imperfecta [Siadat et al. 2007] may be mentioned at first. Cases treated with orthognatic surgical procedures including cleft lip and palate [Strong 2002, Moore and McCord 2004] as well as mandibular or maxillary prognatism [Sakar et al. 2004] should also not be forgotten. Recently, many patients with premised primary orthodontic anomalies are benefited from orthodontic and/or orthognatic surgical treatment and require little or no prosthodontic treatment. However, still many treatments of such patients are planned with a final prosthetic restoration. These cases are usually rather challenging presenting with their own multidisciplinary diagnostic and treatment problems. However, treatment planning (and execution) for these patients need rather wide spreading multidisciplinary considerations, which will not be detailed in this chapter being dedicated to “preprosthetic” orthodontics.

Psychosomatic Complications

A combined orthodontic-prosthetic treatment approach may invite unique and complex psychosomatic problems. Diagnostic and treatment decisions for these patients are based largely on objective morphological considerations with the goal of proper aesthetics and biomechanics of the denture. Although patients’ decision-making also centers primarily on esthetics, they may vary greatly in their expectations and perceptions of the esthetic effects

and of the desirability and success of a treatment [Fox et al. 1982]. Moreover, little is known about the factors determining these various expectations and perceptions. Further, other subjective factors including self-image [Giddon 1995], self-esteem [Badran 2010], body-image [Polo 2011], treatment related unconscious expectations [Fábián and Fábián 2000, Fábián et al. 2007] and other psychoemotional/psychosocial factors [Fábián and Fejérdy 2010] also strongly influence patients' perceptions, decisions and satisfaction. Because of this complex mixture of treatment related psychological, psychoemotional and psychosocial factors a risk of treatment failure may be high from psychosomatic point of view [Fábián et al. 2000].

Beside above, combined orthodontic-prosthetic treatments are usually time consuming and may be frustrating for the patients, which may also lead to psychogenic manifestations [Fábián and Fábián 2000, Fábián et al. 2007]. Orthodontic pain should be considered first as the most frequent and discouraging complaint during treatment, and primary reason for wanting to discontinue care [Oliver and Knapman 1985, Patel et al. 2011]. Decrease of the oral health-related quality of life [Liu et al. 2011] may also be a cause of treatment related frustration especially in the early phase after the insertion of (fixed)orthodontic appliance [Liu et al. 2011]. Complaints related to esthetics and occlusion following orthodontic-prosthetic treatment may also occur, which may also lead to the appearance of psychosomatic symptoms, especially if the patient is frustrated due to the previous treatment procedure [Fábián et al. 2005].

It should be also considered that, patient satisfaction with a suddenly improved esthetics may lead to a disadvantageous transitory hypomanic reaction in rare cases [Fábián et al. 2000], which may invite disturbances in partner- and family- or workplace relations of the patient as a consequence [Fábián et al. 2000]. The reason behind premised rarely occurring hypomanic reaction may be the sudden improvement of self confidence and social/psychological impact due to improved orofacial esthetics [Fábián et al. 2000, Gazit-Rappaport et al. 2010]. Such reaction may occur after treatment of cases with primary orthodontic anomalies coupled with strongly compromised orofacial esthetics (before the treatment), or after the treatment of patients with strongly compromised esthetics due to edentulousness of the frontal region of the (upper) arch.

Because of above psychosomatic considerations it should be emphasized that, great psychological care should be taken about patients treated with combined orthodontic and prosthetic methods [Fábián et al. 2000, 2005]. During the treatment, frustration of the patient may be decreased whereas mental health and compliance of the patient may be maintained using several psychotherapeutic approaches [Fábián and Fejérdy 2010] advantageously combined with several mind-body type psychological techniques such as relaxation, hypnosis, self-hypnosis, photo-acoustic stimulation, biofeedback etc. [Fábián et al. 2009/a,b, Fábián and Fejérdy 2010]. Treatment induced pain may be reduced with pain killers like ibuprofen [Patel et al. 2011], with certain physiotherapies like pulsed electromagnetic field (PEMF) therapy [Fábián et al. 2006, Fábián and Sőti 2007, Fábián and Fejérdy 2010] and with premised mind-body techniques [Fábián et al. 2009/a,b, Fábián and Fejérdy 2010] or with their combination. Great care should also be taken about the after-care of these patients to prevent late appearance of manifestations [Fábián et al. 2000]. In case of the appearance of psychogenic manifestation(s) an initial psychosomatic dental therapy should be introduced immediately [Fábián and Fejérdy 2010].

Conclusion

Various dental specialties have made such enormous advances that it has become impossible to absorb all that is new in all dental areas [LaSota 1988]. Therefore a collaborative effort between orthodontist and prosthodontist is often necessary to achieve an optimal treatment result. [LaSota 1988]. Such collaboration is not only desirable, but mandatory if dentists are to provide highest level care for their patients [LaSota 1988]. Preprosthetic orthodontics gains significance in both esthetics and functionality of the denture being under preparation [Diedrich 1996]. Therefore, an interdisciplinary approach can be cost-effective for both patient and dentist from the standpoint of producing more stable and durable restorations of high esthetics [Cohen 1995]. A proper plaque control is also essential for a successful treatment in all cases [Diedrich 1997]. Along with mechanical and biological principles, unique psychological and social aspects of the combined orthodontic and prosthetic treatment should also be considered for a successful treatment [January 1951, Fábián et al. 2000, 2005].

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Chapter III

Effects of Wearing Partial Denture Prosthesis on Jaw Functions and Associated Prefrontal Cortex Activity

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Abstract

Purpose: Denture wearing is considered to improve chewing ability, chewing comfort, and quality of life in elderly individuals. In an attempt to clarify the effects of prosthodontic treatment on activation of the prefrontal cortex involved in higher cognitive functions, we investigated the efficacy of wearing partial denture from the aspects of jaw functions such as muscle and movement activities and associated prefrontal cortex activity.

Methods: Twelve partially edentulous patients were enlisted as subjects. Functional near-infrared spectroscopy was used to detect changes of hemoglobin concentration in the prefrontal cortex area, while jaw muscle EMG and jaw motion activities were simultaneously examined. Masticatory scores were also determined to evaluate the subjective awareness of chewing ability and occlusal contact features were examined using a Dental Prescale Occluzer System. Statistical comparisons were performed to compare between data obtained while wearing and not wearing a partial denture prosthesis.

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Results: Significant increases were seen in chewing-related jaw functions such as jaw muscle EMG and jaw motion activities, as well as prefrontal cortex activity associated with wearing a partial denture prosthesis as compared with the not wearing condition. Furthermore, occlusal contact and masticatory scores were also significantly increased by wearing a partial denture prosthesis.

Conclusions: Occlusal reconstruction obtained by wearing a partial denture prosthesis improved prefrontal cortex activity and the awareness of chewing ability, as well as jaw functions, as shown by increased jaw muscle EMG and jaw motion activities. From these findings, we concluded that appropriate denture wearing might have an impact on not only jaw functions, but also cognitive functions closely related to masticatory performance. The relationship between masticatory function and cognitive ability is discussed from the standpoint of prosthodontic treatment in this chapter.

Keywords: Prefrontal cortex; partial denture prosthesis; near-infrared spectroscopy; masticatory score; jaw muscle activity; jaw motion; occlusal contact

Introduction

The relationships between chewing ability, and quality of life and activities of daily life have been reported, and chewing ability has been shown to be closely related to the quality of life of elderly individuals [1]. Findings from a study of an 80-year-old population showed that a greater variety of chewable foods and number of teeth were positively related to indicators of physical fitness, such as hand grip strength and leg extensor strength, which suggested the importance of preventative dental care to preserve chewing ability for enhancing the quality and activities of daily life of very elderly individuals [2]. In addition, edentulous subjects without a denture prosthesis showed significant deterioration in physical ability as compared with that of dentate subjects with 20 or more teeth, while the 6-year mortality rate of edentulous subjects without dentures was significantly higher than that of subjects with 20 or more teeth [3]. From those results, it is assumed that poor dentition status in aged individuals who do not use dentures might lead to deterioration in systemic health condition [4]. Furthermore, few remaining teeth might indicate increased risk of dementia, while edentulous individuals or those with as few as from 1 to 9 teeth may develop dementia later in life. These relationships between masticatory and cognitive functions in aged individuals based on the number of teeth present in cognitively normal subjects were significantly greater than in those who were cognitively impaired.

Maximum bite force, occlusal contact area, and masticatory scores for cognitively normal subjects were also significantly higher than those of cognitively impaired individuals [5]. Considering chewing ability from the standpoint of dental medicine, denture use may improve chewing activity and comfort, denture satisfaction, and dental quality of life in aged individuals, which might also contribute to the prevention of neurological manifestations such as dementia and cognitive impairment. In addition, eating satisfaction and the sense of comfort when chewing with dentures have been suggested to have influences on physiological and psychological wellbeing in elderly individuals in comparison to those who do not wear a denture prosthesis [6].

Based on the above background, we speculated that prosthodontic treatment contributes to higher brain functions and prevents neurological cognitive impairment in aged individuals.

Furthermore, the prefrontal cortex is one of the brain regions strongly susceptible to age-related changes in structure and function, and also has an impact on cognition and behavior [7].

Studies of masticatory function have been conducted using primates to define the detailed cortical neural mechanisms by means of physiological approaches [8-17], and advances over the past decade in brain imaging techniques, such as magnetoencephalography (MEG), functional magnetic resonance imaging (f-MRI), and functional near-infrared spectroscopy (f-NIRS), now allow investigation of neural mechanisms related to human behavior and cognition, such as perception, motor control, memory, and aspects of consciousness.

Recently, we reported the activation of prefrontal cortex by wearing partial denture prostheses with a functional near-infrared spectroscopy system [18]. In this chapter, the effects of wearing a prosthesis on activation of the prefrontal cortex and its functional relationships with reconstructed oral functions are discussed.

Methods

Subjects and Dental Treatments

Twelve partially edentulous patients (6 men, 6 women; average 63.1 years old) were enlisted as subjects, after obtaining informed consent. The Ethical Committee of Nihon University School of Dentistry at Matsudo approved the experimental protocol (EC06-008). During the 3 months prior to the study, the subjects received sufficient prosthodontic treatments in the form of a conventional removable partial denture prosthesis, including artificial teeth, a denture base, clasp retainers, major and minor connectors, and rest under a cross-arch stabilized condition. None of the subjects had complaints about the prosthesis, such as discomfort, pain, or difficulties in masticatory performance. Each had individual patterns of tooth loss, and consequently received examinations in order to determine the effects of wearing a dental prosthesis on higher brain and masticatory functions.

Measurements and Examinations

In this study, prefrontal cortex activity, jaw muscle EMG activity, and jaw movement tracking during masticatory performance, occlusal contact and masticatory scores were examined. Figure 1 presents the feature of simultaneous measuring of prefrontal cortex activity, jaw muscle EMG and jaw motion activities.

Measurement of Activity in Prefrontal Cortex

Functional near-infrared spectroscopy (f-NIRS system, ETG-100 optical topography, Hitachi Medical Co.) was used to measure the activity in the prefrontal cortex during masticatory performance while not wearing and wearing a partial denture prosthesis. This optical topographic system is capable of measuring changes in the concentrations of oxy-hemoglobin ([oxy-Hb]) and deoxy-hemoglobin ([deoxy-Hb]) with a time resolution of 0.1 seconds.

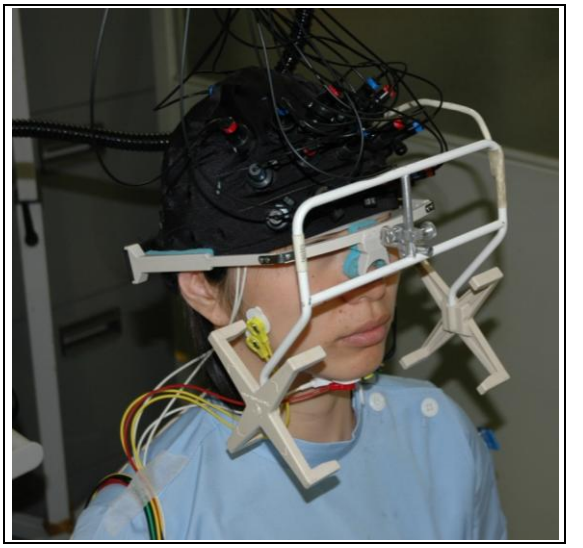


Figure 1. Device used for simultaneous measuring of prefrontal cortex activity, masticatory force, jaw muscle EMG activities, and jaw motion tracking.

Color Fig.1

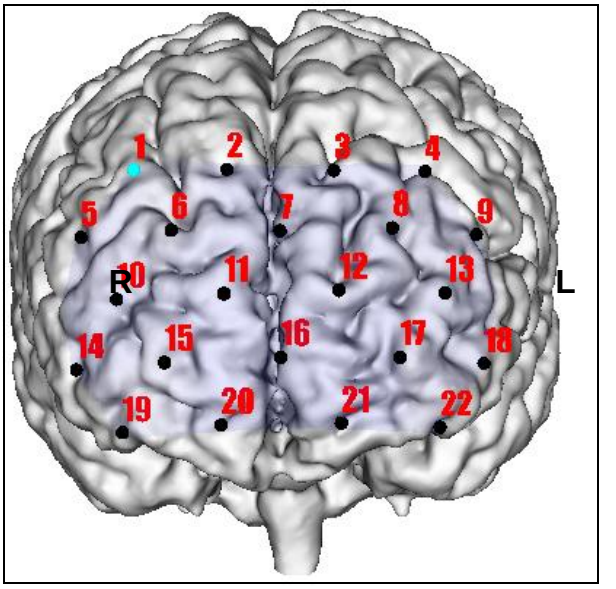


Figure 2. Locations of probe measuring points for near-infrared spectroscopy in dorsal prefrontal cortex area. The positions of the NIRS probes attached to the prefrontal region were standardized. The bottom lines of alignment of the NIRS probes were fit to FP1 and FP2 following EEG electrode placements using the international 10/20 method.

Color Fig.2

The probes of the optical topography system were set in symmetric order over the prefrontal areas in order to detect the changes in cerebral blood volume and near-infrared spectroscopy with 22 channels (3 × 5 arrays) was used. The NIRS probes were attached to the prefrontal region and standardized among the subjects, while the bottom lines of the NIRS probes were set according to the FP1 and FP2 electrode placements, with referral to the international 10/20 method used for electroencephalographic examinations (Figure 2).

Measurements of Jaw Muscle EMG, Jaw Motion Activity, and Features of Occlusal Contacts

EMG recording was simultaneously conducted to detect bilateral jaw muscle activities (masseter muscle: Mm, anterior part of the temporal muscle: Ta, anterior digastrics muscle: AD). EMG signals were monitored with a Bioelectric Amplifier (N5198, NEC Co.) and surface electrodes (SEE105, GE Medical Systems Co.). The subjects were seated in an upright position and fitted bilaterally with EMG electrodes, which were attached to the skin surface corresponding to the Mm, Ta, and AD positions, with a reference electrode attached to the ear lobe. In this study, exact EMG muscles activities for Mm and Ta were used for the data analyses. In addition, a jaw motion tracking device (Mandibular Kinesiograph *K6I*, *Myotronics*) was used to evaluate the differences in jaw motion activities between the not wearing and wearing conditions. Occlusal contact was also examined using a Dental Prescale (50H type R, Fuji Photo Film Co.) and Occluzer System (Fuji Photo Film Co.) to evaluate changes in occlusion with and without wearing a partial denture prosthesis.

Examination of Chewing Ability

Chewing ability was examined by the masticatory score based on a questionnaire reported by Hirai [19]. The masticatory score was calculated using 35 food items divided into 5 groups according to chewing difficulty level. In this study, masticatory scores were examined for both the not wearing and wearing conditions.

Stimulation task

A typical task performance consisted of chewing 5 times with each chewing trial conducted for 10 seconds. Each of the 5 trials was separated from the succeeding trial by a 40-second rest phase (Figure 3).

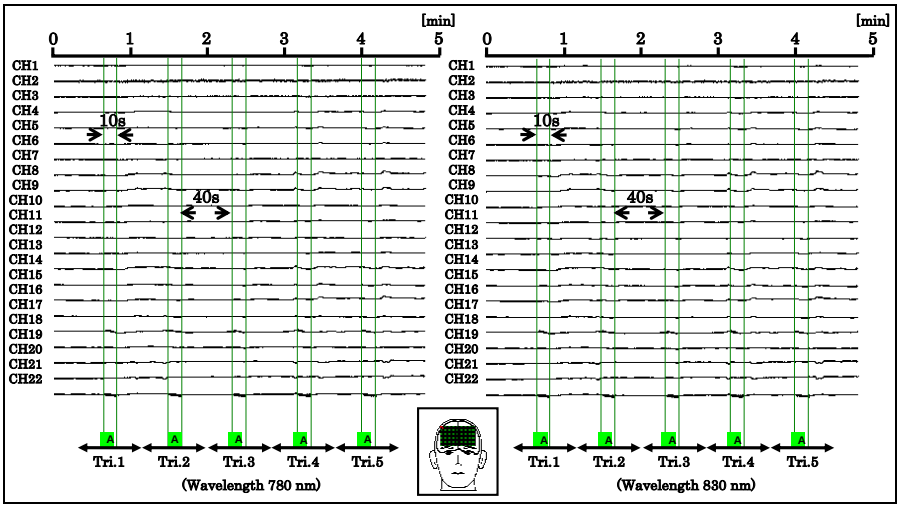


Figure 3. Sequence of task performance. The chewing task consisted of chewing 5 times and each trial lasted for 10 seconds, with a 40-second rest phase between each trial. The NIRS system used (ETG-100 optical topography) utilizes 2 near-infrared wavelengths of 780 and 830 nm.

Color Fig. 3

For the stimulation chewing task, we used 1 piece of chewing gum (Freezone, LOTTE Co.), and the start and end of each chewing trial was indicated to the participant by verbal commands.

The subjects were instructed to chew on either the right or left side during a single session, and avoid intentional head movements while the task performance.

Data Analysis

During each session, data were recorded under 2 different oral conditions; while not wearing and wearing a partial denture prosthesis. Optical data were stored in the f-NIRS system and later transferred to a personal computer (Think Centre, IBM Co.), then quantitatively analyzed using the MATLAB software application (Topo Signal Processing Type G: Hitachi Medical Co.).

By observing changes in wave forms, the average [oxy-Hb] concentrations in all detected channels showed chewing-related changes during task performance under both the not wearing and wearing conditions (Figure 4). In contrast, the average [deoxy-Hb] concentrations in the detected channels did not show clear changes during the task performance under both conditions (Figure 4). Therefore, qualitative and quantitative analyses for the topographical changes in concentrations were conducted using [oxy-Hb] data obtained from all of the subjects (Figures 5, 6).

Jaw muscles EMG and jaw motion activities were quantitatively analyzed using a PC program (Multi-Scope, Medical TrySystem Ltd), as were cycle duration and burst duration. Amplitude activity was also revealed from the peak, area, and average of jaw muscles EMG activities of Mm and Ta, while jaw motion activities shown in the vertical, lateral, and a

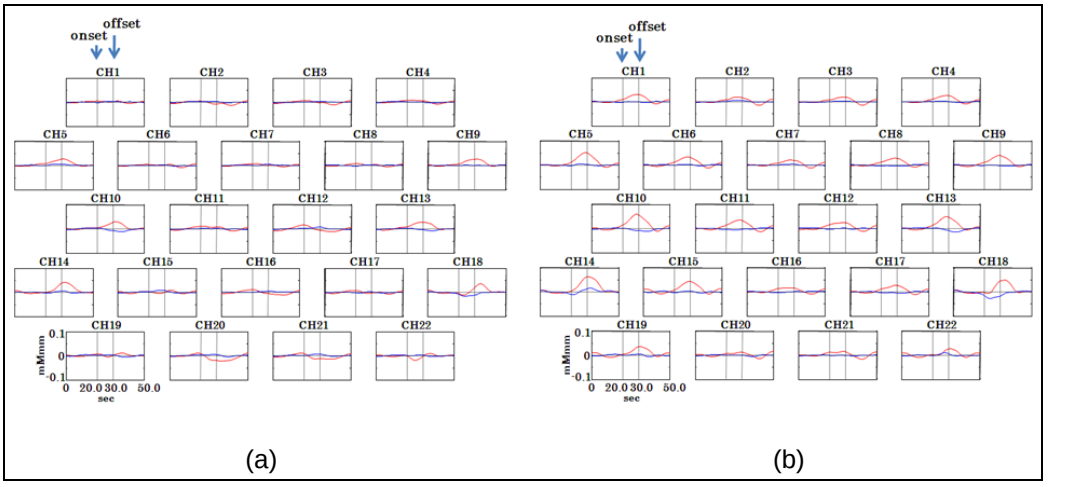


Figure 4. Hb maps of averaged Hb concentrations. Averaged [oxy-Hb] (red line) and [deoxy-Hb] (blue line) concentrations during the not wearing (a) and wearing (b) conditions are presented. Notably, the changes in wave forms and average concentrations of [oxy-Hb] in all detected channels clearly showed chewing-related differences during task performance between the not wearing and wearing conditions. Two blue arrows shown the onset and end of the chewing trial.

Color Fig. 4

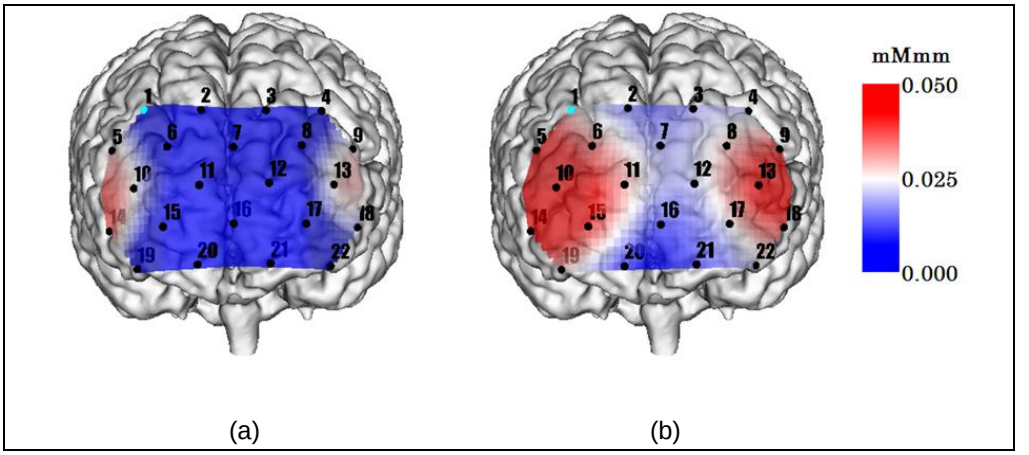


Figure 5. Hb topographies of averaged Hb concentrations. Topographical charts showing prefrontal cortex activation during the not wearing at 30 seconds (a) and wearing at 29.2s (b) conditions. Dorsal prefrontal cortex was markedly activated by wearing a partial denture prosthesis as compared with the not wearing conc

Color Fig. 5

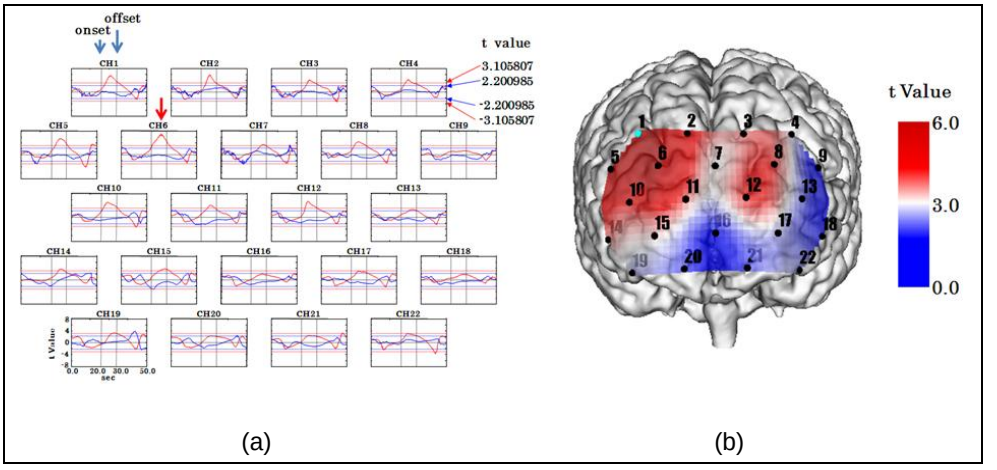


Figure 6. Statistical comparison of prefrontal cortex activities between the not wearing and wearing conditions. (a) Statistical Hb map showing the highest significant t value at 26.7 seconds (red arrow). Red and blue horizontal dotted lines show the significance levels at 0.01 (t value: 3.105807) and 0.05 (t value: 2.200985), respectively. Two blue arrows show the onset and end of the chewing trial. (b) Statistical topography map showing a significant increase of [oxy-Hb] in the dorsal prefrontal cortex area while wearing a partial denture prosthesis as compared with the not wearing condition.

Color Fig. 6

Features of occlusal contact was examined using a Dental Prescale (50H type R, Fuji Photo Film Co.) with 2 seconds of maximal biting, then total bite force and total occlusal contact area were qualitatively evaluated under the not wearing and wearing conditions using an Occluzer System (Fuji Photo Film Co.). Masticatory score determined with the questionnaire was calculated using the following formula: (total score of Group I + total score of Group II × 1.14 + total score of Group III × 1.3 + total score of Group IV × 1.52 + total score of Group V × 3) × 100/111.4 [19].

Statistical Analysis

A paired t-test was used to examine the NIRS data for [oxy-Hb] concentrations obtained under the not wearing and wearing conditions. Data were transferred to a PC (Precision T3400, Dell Co.), then calculated using MATLAB (Topo Signal Processing Type-G: Hitachi Medical Co.) in order to compare the prefrontal cortex activities between the not wearing and wearing conditions. A paired t-test was also used when the data samples were taken from a population in which the changes were normally distributed in order to compare jaw muscle EMG and jaw motion activities, total occlusal contact area and force, and masticatory scores between the not wearing and wearing conditions. On the other hand, if data samples were taken from a population in which the changes were not normally distributed, a Wilcoxon signed rank test was used for non-parametric statistical analysis. The statistical PC program SigmaStat (Jandel Science Inc.) was used for analyses of jaw muscle EMG and jaw motion activities, occlusal contact, and masticatory score. P values less than 0.05 were considered to be statistically significant.

Results

Prefrontal Activity during Chewing Task Performance

Averaged Hemoglobin Map Presentation

The averaged [oxy-Hb] concentrations in all detected channels showed chewing-related changes during task performance under both conditions of not wearing and wearing a denture prosthesis (Figure 4).

The onset of increase in [oxy-Hb] concentration coincided with the start of the chewing period and continued to increase gradually to the end of the period. Thereafter, the concentration returned to the baseline level within several seconds. In addition, wearing a partial denture clearly induced an increase in [oxy-Hb] concentration as compared to the not wearing condition (Figure 4).

Topographical Presentation of Chewing-Related Prefrontal Cortex Activities

Chewing-related topographical charts produced while not wearing and wearing a denture prosthesis are shown in Figure 5. Comparisons of the charts showed that wearing a partial denture markedly expanded the activation area and increased the intensity of the dorsal part of the prefrontal cortex as compared to the not wearing condition (Figure 5).

Statistical Comparison of Chewing-Related Prefrontalactivity between Not Wearing and Wearing Conditions

Prefrontal cortex activity was significantly increased by wearing a partial denture prosthesis as compared with the not wearing condition (Figure 6). According to the results presented as statistical maps and topographies in Figure 6, significant activation by wearing a denture prosthesis was focused on the right lateralized dorsal prefrontal cortex area in accordance with the anatomical structures of the surface cortex (Figure 6-b).

Jaw Muscle EMG and Jaw Motion Activities While Not Wearing and Wearing Partial Dentures

Features of Jaw Muscle EMG and Motion Activities

Representative data showing jaw muscle EMG activity and jaw motion activity during masticatory performance under the not wearing and wearing conditions are shown in Figure 7. Wearing a partial denture prosthesis clearly presented the increased activity in the jaw closing muscles as compared with the features of the not wearing condition.

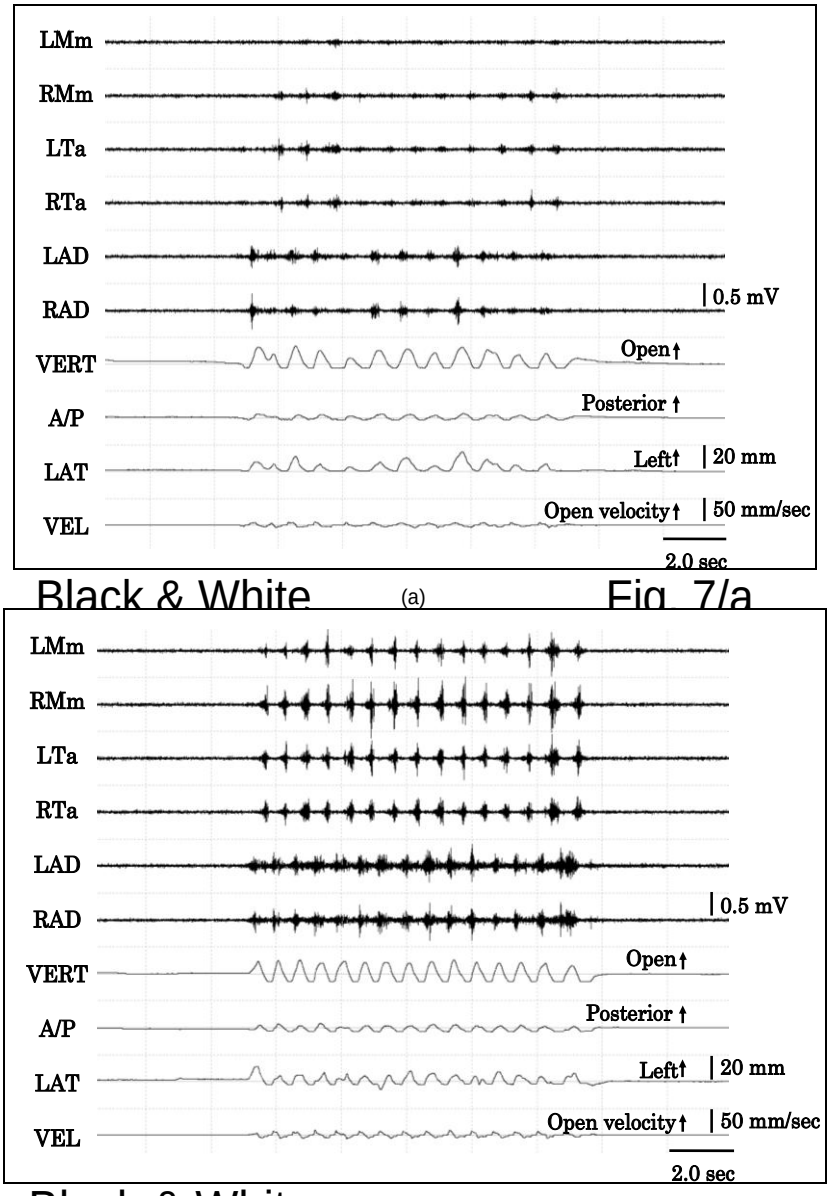
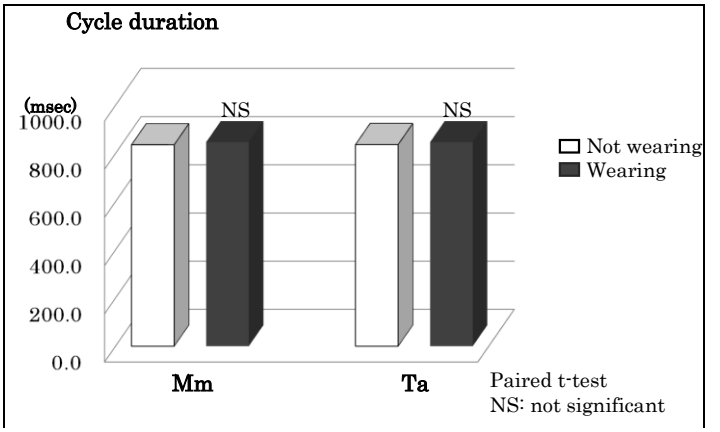
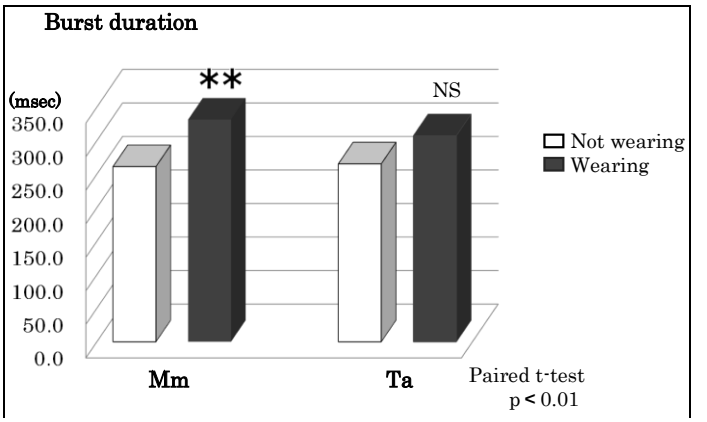


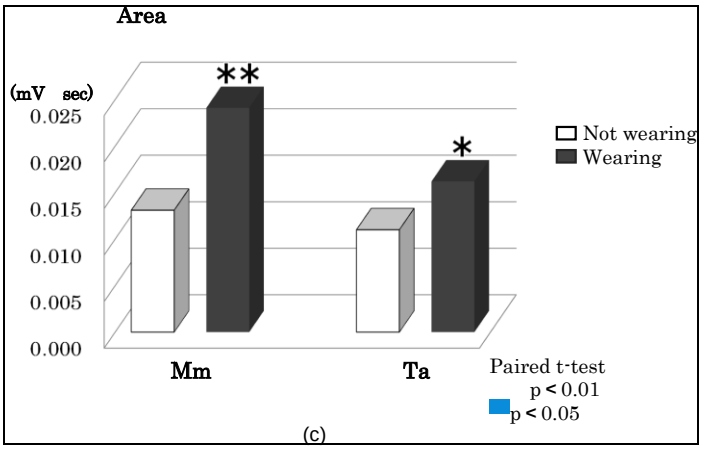
Figure 7. Representative features of jaw muscle EMG and jaw motion activities under the not wearing (a) and wearing (b) conditions. EMG activities of the jaw muscles were clearly increased while wearing a partial denture as compared with the not wearing condition.

Jaw Muscle EMG Activities

Cycle duration was not significantly changed by wearing a partial denture prosthesis as compared

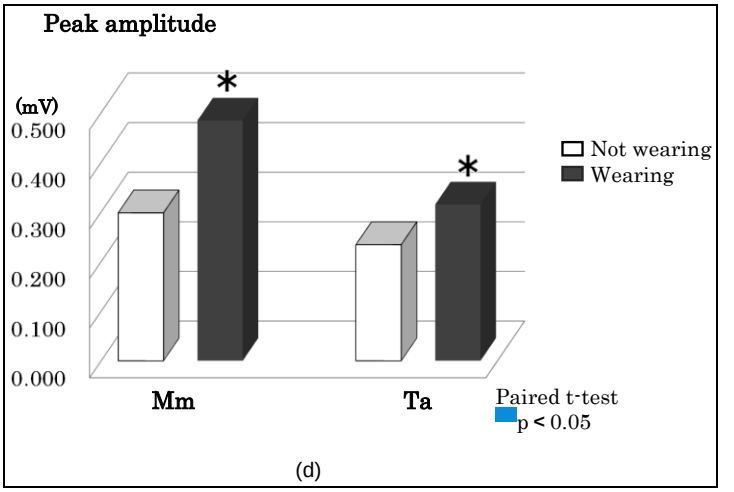






(c)

Black & White Fig. 8/c



Black & White Fig. 8/d

Figure 8. EMG muscle activities. (a) Cycle duration was not significantly changed by wearing a partial denture prosthesis as compared with the not wearing condition. (b) Burst duration, (c) area, and (d) peak amplitude of EMG activity during the chewing task were significantly increased in Mm and/or Ta while wearing a partial denture as compared with the not wearing condition.

In contrast, statistical comparisons of jaw muscle EMG activities between the not wearing and wearing conditions revealed significant increases in the EMG findings for burst duration, area, and peak amplitude in regard to chewing-related jaw muscle EMG activities in the Mm and/or Ta muscles during partial denture wearing (Figure 8-b~d).

Jaw Motion Activities

Vertical and anterior/posterior components of the jaw motion activities, as well as jaw motion velocity were not significantly changed by wearing a partial denture prosthesis as co1

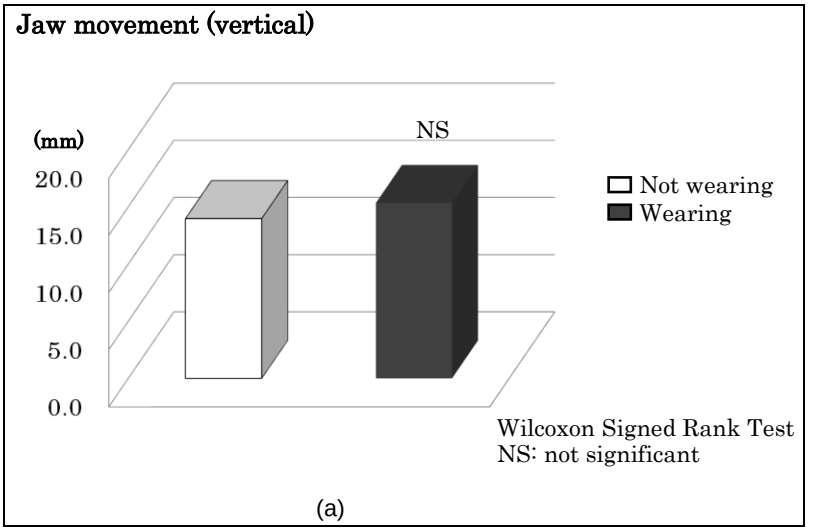
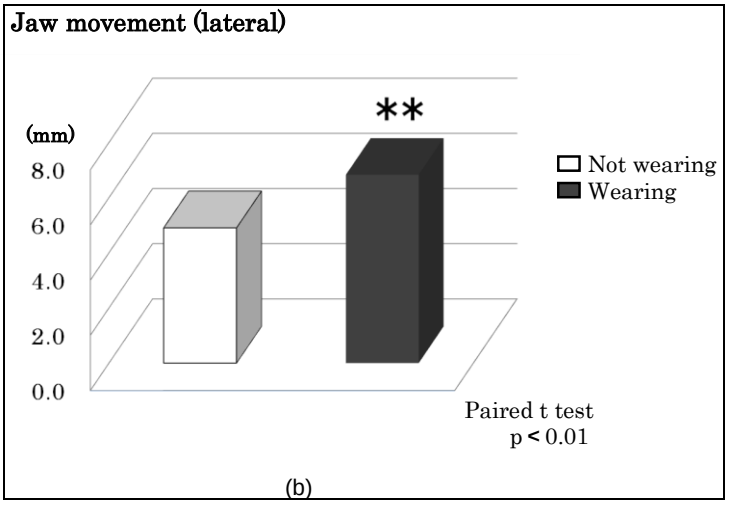


Figure 9. (Continued).

Black & White Fig. 9/a



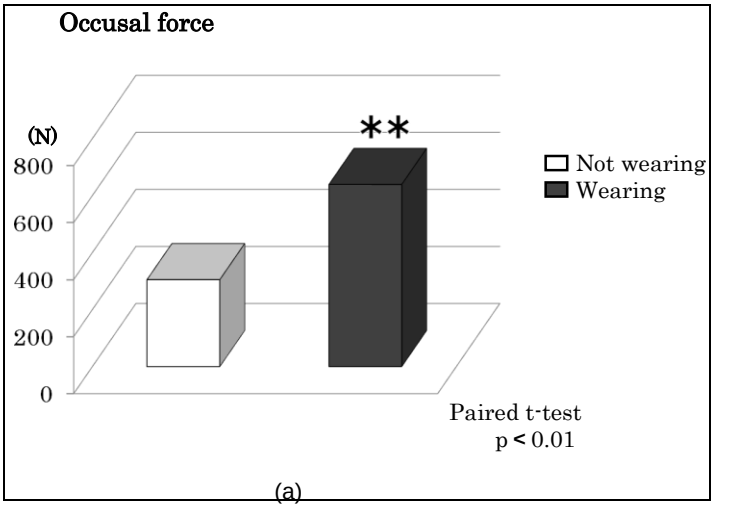
Black & White Fig. 9/b

Figure 9 Jaw motion activities. (a) The vertical component of jaw motion activity was not significantly changed by wearing a partial denture prosthesis as compared with the not wearing condition. (b) The lateral component of jaw motion activity while wearing a partial denture prosthesis was significantly increased as compared with the not wearing condition.

In contrast, a significant increase was seen for the lateral component of jaw motion activity while wearing a partial denture as compared with the not wearing condition (Figure 9-b).

Occlusal Contact

Findings for total occlusal contact while not wearing and wearing a partial denture prosthesis are presented in Figure 10. Significant increases were seen for total occlusal force and total occlusal area when wearing a partial denture prosthesis as compared with the not wea



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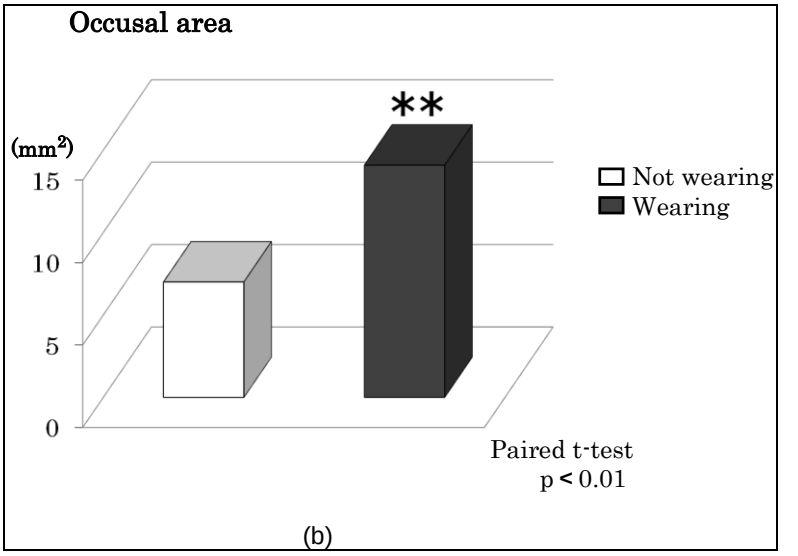

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Figure 10. Occusal control. Significant increases of total (a) occlusal force and (b) occlusal area were seen while wearing a partial denture prosthesis as compared with the not wearing condition.

Masticatory Score

Significantly increased masticatory scores, which may represent subjective awareness of chewing ability, were seen when wearing a partial denture prosthesis as compared with the

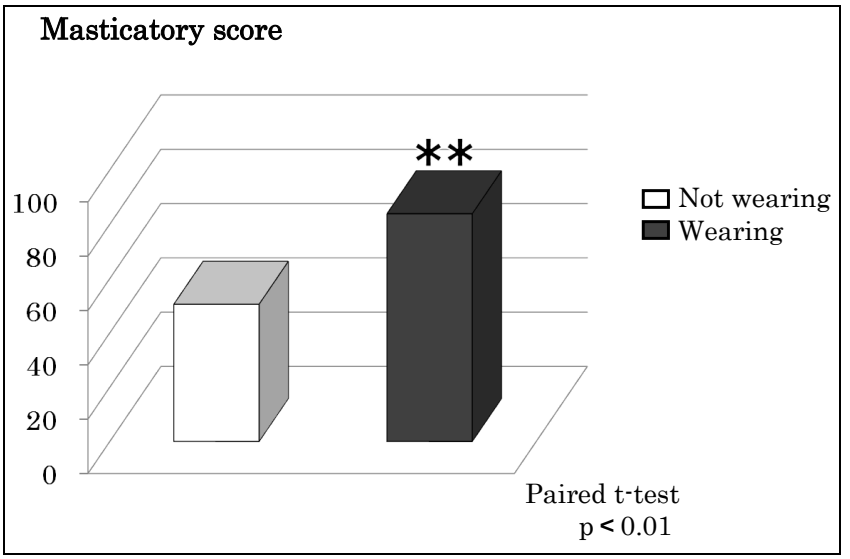

Figure 11. Masticatory score. Significant increases in masticatory scores were seen while wearing a partial denture prosthesis as compared with the not wearing condition.

Black & White Fig. 11

Discussion

Features of Prefrontal Activity when Wearing Partial Dentures and their Functional Significance

In the present study, we found that wearing a partial denture prosthesis significantly activated the dorsal prefrontal cortex as well as jaw functions, such as jaw muscle EMG and jaw motion activities. It has been reported that the dorsal prefrontal cortex is involved in various higher cognitive functions, such as movement planning and execution [20] [21] [22], sensory processing [23] [24] [25] [26] [27], learning and memory [28] [29], reward [30] [31] [32], and attention [33] [34]. According to data obtained in our previous study, which was presented in part at the IADR annual meeting in Toronto in 2008 [35], deafferentation of oral somatosensory input may cause modulated chewing behavior and deactivation of the dorsal prefrontal cortex during masticatory performance, which was especially predominant in the right lateralized prefrontal cortex area. Furthermore, chewing imagery also activated the dorsal prefrontal cortex area, bilaterally (unpublished data).

Taken together, we consider that the dorsal prefrontal cortex may be involved in execution, as well as somatosensory processing and sensorimotor integration during chewing performance.

Possible Relationships among Prefrontal Cortex Activity, Jaw Muscle EMG and Jaw Motion Activities, as well as Occlusal Contact Features, and Masticatory Score

According to our recent data analysis, there are significant correlations between matication-related prefrontal cortex activity, feature in the occlusal contact, and masticatory score considered as the self-evaluation of the masticatory function by wearing partial denture prosthesis. These findings will be presented at the Neuroscience Meeting in 2011 (Abstract submitted) [36]. The prefrontal cortex plays a role in the cognitive process, such as working memory, and enables humans to hold the contents of conscious awareness by maintaining an active representation of information [37]. From these findings, it is considered that occlusal reconstruction obtained by wearing a partial denture prosthesis may contribute to improved conscious awareness of chewing ability and the related prefrontal cortex activity.

Clinical Implications

Stein et al. [5] have examined Oral. Dis.ease as a potential risk factor in the development of dementia and reported that a low number of teeth increased the risk of developing certain forms of dementia. Miura et al. [6] also found that number of teeth, maximum bite force, and masticatory scores in cognitively impaired subjects were significantly lower than those in healthy elderly subjects. Recently, Weijenberg et al. [38] reviewed the causal relationship between mastication and cognition in animal and human experimental studies, and suggested that correlations exist between mastication and activities of daily living and nutritional status.

Furthermore, Hirai et al [39] also reported a relationship between masticatory score and cognitive deterioration, that is, masticatory score was significantly correlated to dementia score (Hasegawa test) in 80 elderly subjects.

Taken together, it is considered that wearing an appropriate denture prosthesis leads to improved conscious awareness of chewing ability, which might be related to prevention of neurological cognitive deterioration in aged individuals.

Conclusion

In the present study, occlusal reconstruction by wearing a partial denture prosthesis improved prefrontal cortex activity and the conscious awareness of chewing ability, as well as jaw functions as shown by increased jaw muscle EMG and jaw motion activities. From these, it is assumed that appropriate denture wearing might have an impact on not only jaw functions, but also higher brain functions closely related to masticatory performance.

Acknowledgments

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Chapter IV

Inlay Retained Fixed Partial Dentures

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Abstract

Patients often refuse these options since the reasons of high cost and/or surgical intervention. The full coverage retainers for tooth supported fixed partial denture is a conventional approach to replace one or several missing teeth. Two types of full coverage retainers FPDs are used in dental clinics: porcelain fused to metal and all ceramic. Porcelain fused to metal provides great fracture strength and relatively good long-term clinical success. One of significant disadvantages of the porcelain fused to metal, as well as modern all ceramic FPDs is that large amount of sound tooth substance of the abutments needs be removed in FPD fabrication.

An inlay-retained FPD (IRFPD) is, however, a less-invasive treatment modality and a more conservative option for restoration of damaged teeth, because it requires minimal tooth reduction, preserves healthy tooth structure, and maintains the periodontal tissue's integrity. Inlay-retained FPDs are, therefore, alternatives to both anterior and posterior complete coverage conventional restorations. Inlay retained FPDs can be constructed by using dental alloys, ceramic materials, and fiber-reinforced composite. Several types of preparations for inlay retained FPDs are used: Occluso – proximal inlay, Tub-shaped , Proximal box, Rest seat on the occlusal surface, Lingual tooth reduction, and Retentive-slot preparations. The size of these preparation features depends on the size of the tooth.

Several researches were carried out about the effect of various designs, materials, connectors size on the fracture resistance, marginal integrity and retention of inlay retained FPDs.

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Introduction

Although implant-supported FPDs are high quality alternatives to the tooth supported FPDs, patients often refuse these options due to the reasons of high cost and/or surgical intervention [1]. The full coverage retainers for tooth supported fixed partial denture is a conventional approach to replace one or several missing teeth [2]. Two types of full coverage retainers FPDs using ceramics are used in dental clinics : porcelain fused to metal and all ceramic. Porcelain fused to metal provides great fracture strength and relatively good long-term clinical success. One of significant disadvantages of the porcelain fused to metal, as well as modern all ceramic FPDs is that large amount of sound tooth substance of the abutments needs to be removed in FPD fabrication [3].

Properties

An inlay-retained FPD (IRFPD) is a less-invasive treatment modality and a more conservative option for restoration of damaged teeth, as it requires minimal tooth reduction so it preserves healthy tooth structure. Inlay-retained FPD finish line is always supra-gingival maintaining the periodontal tissue's integrity [4-7]. Also, inlay-retained FPD is highly esthetic restoration when it is fabricated from ceramic or fiber-reinforced composite [8,9]. Recent, studies showed that inlay-retained FPD showed some drawbacks irrespective to the type of the FPD materials; decreased retention, high marginal discrepancies especially with machinable ceramics [10]. Inlay-retained FPDs are, therefore, alternatives to both anterior and posterior complete coverage conventional restorations, especially with the introduction zirconia ceramics which enables the construction of durable posterior FPDs [11,12]. However inlay-retained FPD is contra-indicated in mutilated, pulpless teeth, in above average functional occlusal forces and when control of moisture contamination is difficult.

Materials

Inlay retained FPDs can be constructed by using dental alloys, fiber-reinforced composite and ceramic materials [3,13]. Clinical results for metal inlay-retained FPDs have been favorable, however the visibility of the metal retainer and the change in natural tooth translucency are aesthetically unfavorable [12].

Inlay retained FPDs may be fabricated from fiber-reinforced composites (FRC). Physical data on reinforced composites suggest that these materials are best suited for conservative inlay FPDs [14]. With a carefully executed bonding technique, good results in marginal adaptation have been achieved with composite inlays. The stress-resistant marginal integrity of composite inlays has been attributed to their dentin-like elasticity modulus [15,16]. FRC inlay-retained FPDs are considered as minimal invasive, metal free, and good aesthetic restorations for replacing missing single or multiple anterior or posterior teeth [17]. Inlay-retained resin-bonded FRC FPDs can be used especially for patients having occlusal or proximal carious lesions or existing fillings in teeth adjacent to the edentulous space. The

abutment teeth are prepared for retaining the FPD without excessive removal of sound tooth substance. Several types of FRC frameworks were used and it was suggested that high-volume fraction frameworks provide better clinical success than low-volume fraction frameworks due to lack of support for the veneering composite of the pontics [18]. Although promising clinical results have been reported for such restorations, these suffer from the disadvantages of unstable aesthetics and problems with wear of the veneering composite. Also the pontic region is considered as a weak point for the fiber-reinforced composite inlay-retained FPD. This may be due to the fact that in occlusal loading conditions where the load is applied to the cusps of posterior teeth instead of central fossa, the delamination of veneering composite can occur at lower load levels [19].

Factors affecting the durability of FRC restorations include the properties of the fibers, matrix, and polymer, impregnation of fibers with the resin, adhesion of fibers to the matrix, the quantity of fibers, and the direction, orientation, location, construction, distribution, and position of the fibers [9,20]. The fiber content not only determines the fiber properties, but so does the matrix composition and the bond between fibers and the matrix [21]. Placement of fibre at or slightly away from the tensile side improved the flexural properties of the composite [1,22]. Fibers used for reinforced composites can be glass-fiber or polyethylene-fiber. Fracture resistance of restorations made of glass-fiber reinforced composite is higher than those of polyethylene fiber-reinforced composite restorations [1,9].

It has been reported that fiber-reinforced FPDs have the necessary fracture strength to withstand the average adult masticatory forces in the molar region, with recorded high fracture strength of approximately 700 N after thermo-cycling and mechanical loading [14]. The basic design of a FRC inlay-retained FPDs preparation is a box-shaped preparation used to achieve optimal extension of the fiber framework and retention [23]. A tub-shaped preparation may be indicated when there is insufficient space to prepare the box or to prevent irritation of the pulp of tipped teeth. Generally, FRC inlay-retained FPDs have been used for 3-unit FPDs replacing a single premolar or molar when the intra-abutment span does not exceed 15 mm [14].

Ceramics inlay-retained FPDs with different strong core are used. They were made either from glass infiltrated alumina ceramic (In-Ceram Alumina), pure alumina ceramic (Procera) or lithium-disilicate based glass-ceramic (IPS Empress 2, IPS e-max) [6]. Recently, another ceramic, yttrium-oxide partially stabilized zirconia (YPSZ) has been made available to dentistry through the CAD/CAM-technique (ice zircon, IPS e-max Zr CAD) or through pressing technique (IPS e-max Zr Press). Using this core material for all-ceramic frameworks, excellent mechanical performance and superior strength and fracture resistance, compared to other ceramics, have been shown [24-26].

Mode of Failure

Stress applied during mastication may range between 441 N and 981 N, 245 N and 491 N, 147 N and 368 N, and 98 N and 270 N in the molar, premolar, canine, and incisor regions, respectively. A restoration should be able to withstand stress to approximately 500 N in the premolar region and 500 N to 900 N in the molar region.

The mode of fracture is a good indicator of the path of crack propagation [27,28]. Mechanical failure of restorations may be due to several factors such as wrong treatment plane and case selection, the properties of the luting agent, the thickness of restoration, the preparation design and the thickness of connectors [8].

The mode of failure of the metal ceramic inlay-retained FPDs is ceramic chipping, which may be due to weak bond between metal and ceramic or due to excessive strength beyond the bearing capacity of the veneering ceramic materials [4,6].

The mode of failure of the fiber-reinforced inlay-retained FPD exhibits a 2-phase pattern, which consists of cracking and chipping of the veneer layer followed by adhesive failure between the veneer and fiber materials. The fracture line, running between the border of the fiber framework and the veneering material, also appeared in the facing material itself, with no evidence of fiber burst [29,30]. In general, stress concentrations within the resin and the interface are relieved by initiation of a crack and propagation of the crack through the resin until it meets the fiber, resulting in debonding of the resin composite. This means that the bond strength between the fiber and facing composite, rather than the strength of the fiber framework itself, appeared to have had the most influence on the fracture resistance. Therefore, it may be necessary to apply a silane-coupling agent to the fiber framework in order to achieve improved chemical bonding [30]. One of the reasons for the adhesive fracture of the restorations was the difference in the elastic modulus between the fiber framework and the veneering composite [31,32]. The flexure strength of fiber-reinforced restorations might be improved with the use of new polymer formulations with high filler particle distribution however, these materials are not suitable for chair-side use. The weakest parts of the restoration were in the cohesive strength of the veneering composite and the bond between the fiber composite framework. The direction of the failures was primarily in the MD direction, indicating that unidirectional fibers change the path of the crack [1,9].

The failure mode observed for all ceramic inlay-retained FPD is delamination and chipping of the veneering material. These observations indicate that the weak points ceramic inlay-retained FPD are the adhesion between the framework and the veneering materials and the strength of the veneering material itself. High fracture strength in case of zirconia ceramic core may be due to the fact that the core is a YPSZ consisting of partially stabilized zirconia particles densely sintered, resulting in a final microstructure in which voids, flaws, and cracks are reduced to a minimum. Also, the transformation toughening mechanisms increase the fracture strength of the material. On the other hand, adhesive failure between veneer and ceramic does not occur in the presence of a good bond between a compatible ceramic core and the veneering material [4-6,8-10].

Fracture of retainers were observed by some researchers, in case of 4x4 mm connector size, whereas in smaller connector size, fracture may happens not also at the retainer but also at the connector. So it is recommended to use a 4x4 mm connector size, in case of inlay-retained FPD [6].

The debonding rate of the long span FPDs was slightly higher than that of the short span FPDs. Debonding in the premolar location appeared to be caused by the smaller bonding area and the narrow connector dimension. When a load was applied to the center of the pontic, traction forces caused a lever effect on the terminal interface of the restorations. It is possible that the bending under load was the cause of debonding failure. It is likely that the box-shaped design is strong enough to resist the bending force due to the additional 2-mm wall

support of the proximal box. The increased debonding of the long span FPDs relative to the short span FPDs could be explained by their flexibility [4,9,10].

Preparations

Several types of preparations for inlay retained FPDs are used : Occluso – proximal inlay (figure 1-3), Tub-shaped (figure 4-6) , Proximal box (figure 7-9), Rest seat on the occlusal surface with or without Lingual tooth reduction and retentive-slot preparations and finally a palatal inlay with or without a proximal grooves. The size of these preparation features depends on the size of the tooth [1,3,4,8,9,12,14,33-35].

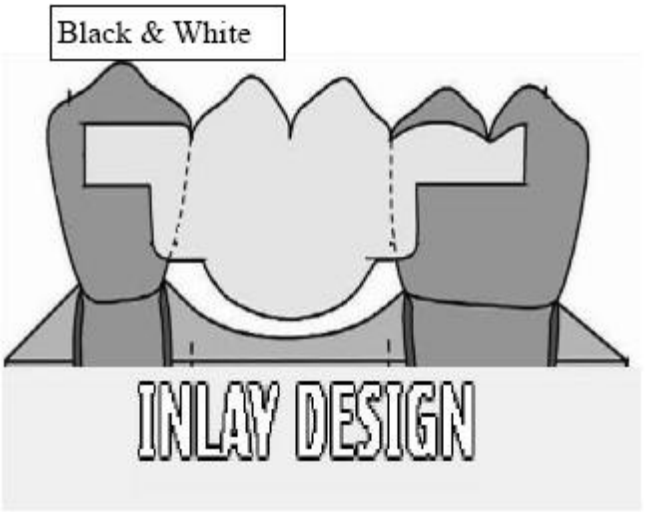

Figure 1. A schematic illustration for an inlay-proximal inlay retained partial denture.

Figure 2. An inlay-proximal inlay retained partial denture preparation.

Figure 3. An inlay-proximal inlay retained partial denture.

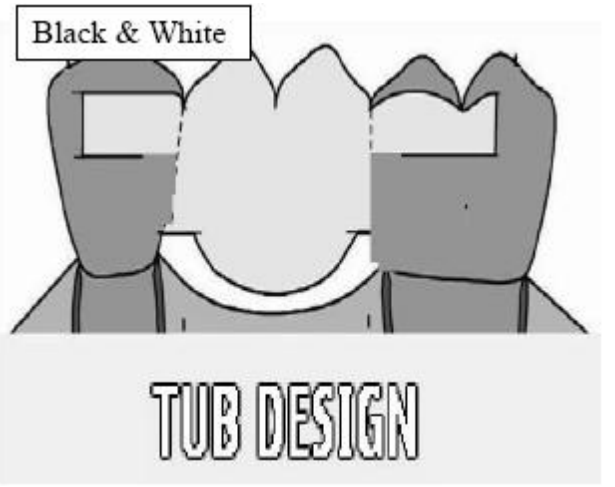

Figure 4. A schematic illustration for an tub design inlay retained partial denture.

The occluso-proximal inlay is composed of an occlusal inlay and a proximal box. The occlusal inlay must remove any carious or undermined enamel. For an intact tooth, the depth of the occlusal preparation must be of 2.0 mm for the ceramic. The occlusal preparation is 4 mm wide and extended 4 or 6 mm mesiodistally for the premolar or molar models, respectively.

The proximal box extends 1mmwide and had approximately 6^0 divergences, extending 2 mm apical to the isthmus floor.

The tub-shaped preparation consisted of an occluso-proximal inlay has the same dimension as the occlusal preparation of an occluso – proximal inlay. While the proximal box inlay retained FPDs has the same dimension of the proximal box in case of occluso-proximal inlay [9].

Figure 5. A tub shaped inlay retained partial denture preparation.

Figure 6. A tub inlay retained partial denture.

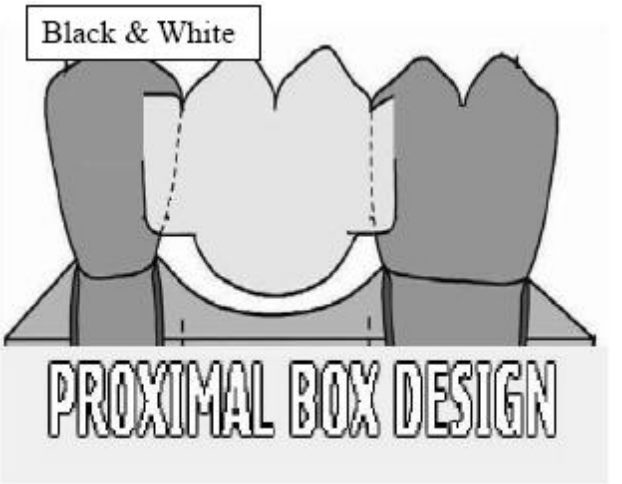

Figure 7. A schematic illustration for an proximal box design inlay retained partial denture.

Figure 8. A proximal box inlay retained partial denture preparation.

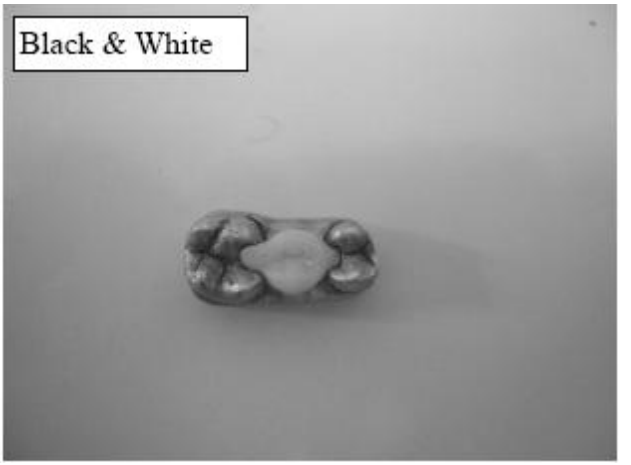

Figure 9. A proximal box inlay retained partial denture.

The rest seat is prepared on the occlusal surface of each abutment with minimal preparation on the proximal wall of the abutments. The drawback of this design is that the pontic may rotate along an axis formed by the 2 rest seats when occlusal force acts on the occlusal incline of the pontic [34].

Rest seat on the occlusal surface and lingual tooth reduction preparation can be performed by proximal and lingual minimal reduction of the abutments, one rest seat prepared on the occlusal surface of each abutment. Proximal boxes are also prepared. The facial and lingual walls of these proximal boxes are slightly convergent toward the occlusal surface to provide "undercut retention." Reduction of the proximal surfaces was accomplished to ensure that the gingival and facial margins of the boxes were completely contained within the proximal reduction area. The grooves on proximal and palatal/lingual surfaces of abutment teeth serve 2 main functions: to define the path of insertion and to provide retention and resistance form to the retainer against the dislodging forces acting on the pontic. When designed with mesial and distal occlusal rests alone, the pontic may rotate along an axis formed by the 2 rest seats when occlusal force acts on the occlusal incline of the pontic [35].

Palatal inlay with or without a proximal grooves preparation is indicated in anterior teeth, the aim of the proximal grooves preparation is to enhance the retentivity of the preparation.

Fracture Resistance

New core materials in combination with new preparation designs have to be tested before they can be recommended for clinical use. It is not known what fracture resistance is needed to achieve a good long-term outcome of IRFPDs in the molar region. Numerous authors investigated the maximum bite forces during mastication. Mean values for the maximum bite force level varied from 98 to 981N. The highest bite force was found in the first molar region.

Reviewing the literature, Körber and Ludwig summarized that posterior FPDs should be strong enough to withstand a load of 500N [26,27]. Additionally, cyclic fatigue loading and stress corrosion fatigue caused by the oral environment has to be considered, because they can considerably weaken the fracture resistance of all-ceramic restorations [36]. Under the conditions of the oral environment, the inherent flaws of ceramic materials act as the origin of crack propagation and can grow to critical sizes [37,38]. The endurance limit for fatigue cycling that can be applied to dental ceramics is approximately 50% of the maximal fracture strength [39]. Therefore it seems reasonable to assume that an initial fracture resistance of 1000N should be required for a favorable clinical prognosis of posterior all ceramic IRFPDs. However, the results of quasi-static fracture tests should be related to dynamic fatigue in a chewing simulator combined with thermo-cycling. According to the literature, fatigue produced by 240,000 cycles in a chewing simulator corresponds to a period of 1 year of clinical service [40]. Therefore 1,200,000 chewing cycles were performed to simulate a service time of 5 years [41].

Material used in the construction of inlay retained FPD, specially the core materials, plays an important factor in the fracture resistance of the restoration as well as the veneering materials and its bonds with the core materials [26,42-45]. Zirconia ceramic core and ceramic veneering inlay retained FPD showed in several studies a significant higher fracture resistance than that of ceramo-metallic inlay retained FPD [4,6].

Connector size is an important factor of fracture resistance of inlay-retained FPD according to the type of core material used. In case of metal core or yttrium-oxide partially stabilized zirconia ceramic, a 3x3 mm or 4x4 mm connector size are clinically successful. As for lithium disilicate glass ceramic or fiber-reinforced composite a 4x4 mm connector size is indicated [6,46].

The occluso – proximal inlay shaped design provides greater surface area to resist the forces and a larger connector dimension of the framework, thereby resisting the bending forces better than the other inlay retained FPD designs. Also, in case of fiber reinforced composite, this design allows for a higher fiber content therefore, it might have provided a greater reinforcement effect near the tensile side and thus a higher fracture strength [5,6,9,19].

Studies in dental literature showed that in case of fiber reinforced composite, increasing span length correlated with the lower fiber-reinforced FPD strength. All FPDs flex slightly when subjected to a load. In other words, the longer the span is, the greater the flexing will be. However, the relationship between deflection and span length is not simply linear but varies with the cube of the span length. Excessive flexing under occlusal loads may cause

failure of a long-span FPD. It can lead to fracture of the veneering material , breakage of a connector, loosening of a retainer, or an unfavorable soft tissue response. Therefore, the application of a fiber-reinforced inlay FPD might be advisable for short pontic spans [9,11,19].

Marginal Adaptation

With a carefully executed bonding technique, good results in marginal adaptation have been achieved. In case of marginal imperfections, the adhesive functions as a second barrier against penetration of bacteria in dentin [11]. In case of fiber reinforced composite, although some authors concluded that with a carefully executed bonding technique, beveling of preparation finishing lines is not necessary, it is accepted that with the shrinking of composite materials, beveling of enamel decreases the risk of marginal gaps, microleakage, and enamel fractures. Beveling of enamel increases the loss of dental hard tissue; however, it may improve marginal adaptation in situations in which difficulties in accessing the margin in the gingival crevice are expected [47-49].

Adequate results in marginal adaptation are achieved with the use of the total bonding technique in case of canines. The geometry of the cavity preparation, which was unfavorable for selective bonding without beveling, may have provided the benefits of total bonding at insertion. However, the total bonding technique cannot be recommended for molars [11]. For these box-shaped cavity preparations, an increase of the bonded surface resulted in severely diminished flow. The contractive stresses can exceed adhesive strength and cause marginal imperfections after loading.

The marginal quality attained for molars with selective bonding can still be compared with the marginal quality of composite inlays. C-factor (ratio of bonded to free, un-bonded restoration surfaces) is reduced with the use of the selective bonding technique. After the final post-curing, there are only a few carbon double bonds available for the bond between the resin-cement and the crowns.

Therefore, all systems recommend roughening and silane-coating of the inner-crown surface before their adhesive cementation [23,50,51]. Some authors state that glass fibers bond better to silane coupling agents than to a composite surface. The composite surface contains inorganic fillers which bond to silane-coupling agents, but the extent of the bonding area depends on the filler content [11].

The marginal discrepancy of each restoration may vary greatly at different location, due to the difference in the preparation geometry, marginal configurations and the location and orientation of tubules. The inlay-shaped retained FPD shows a significant higher vertical marginal gap measurements than all the other inlay retained FPD designs due to the fact that it possess a much longer perimeter than them [10].

The technique of construction also plays an important role in the marginal adaptation of the inlay retained FPD. In case of ceramic, the machinable ceramic showed a less marginal adaptation than pressable.

This may be attributed to geometrical design of the restoration and difficulties regarding scanning, digitization, and the milling process of brittle ceramic material. Moreover, the

adaptation of restorations made out of milled ceramic blanks may be affected by the size of milling burs, and material conditions during the milling procedure [52].

Retention

The longevity of fixed prostheses depends on the retention and marginal integrity of restorations. Many factors have been demonstrated to influence the retention of fixed prosthetic appliances, such as the size and shape of prepared teeth, manipulation of cement, retentive properties of cement, cement film thickness , relieving space or venting for cement, cement application , roughness of dentinal surface , the convergence and the preparation height [4,8,9,12]. Dental literature is poor on studying the retentive strength of the inlay retained ceramic FPDs. As regard the forces needed to dislodge the inlay retained FPDs, a significant difference was found between the different designs. The inlay-shaped design was significant higher than the other inlay retained FPDs designs due to the long surface area of bonding between the restoration and the tooth. In a recent studies, a comparison was carried out between the inlay retained FPD and the full coverage FPD who recorded much higher retention. These difference in retention between the two tested FPDs may be attributed to the fact that longer preparations (full coverage FPDs) have more surface area and therefore are more retentive than the shorter preparations (inlay retained FPDs). Another reason for these differences may be due to the frictional resistance between a prepared tooth and ceramic crown is as important as the adhesive bond strength [10]. To increase the bond between the restoration and the tooth, the author recommends to subject the inner surface of the restoration to surface treatments, the same used for resin bonded retainers.

Clinical Survival Rate

Clinical survival rate of the different deigns of inlay retained FPD is the main important factor to evaluate the success of this type of restoration. Strength and durability of inlay retained FPDs are highly dependent on the inlay designs, sizes, pontic span, connectors' size. All these variables are to be set according to the material used. Therefore, proper selection of the restorative materials and careful preparation designs are essential, especially in the posterior region. Ohlmann et al (2008) [12] in a preliminary clinical study on all-ceramic inlay-retained fixed partial dentures, reported that 6 out of 13 inlay retained FPDs were subjected to debonding.

Harder et al (2010) [53] in an eight-year outcome study of posterior inlay-retained all-ceramic fixed dental prostheses, reported that the percentage of debonding of this type of FPDs was 15%. In two clinical evaluations, Edelhoff et al. (2001) [3] and Edelhoff and Sorensen (2002) [7], reported that compared to crown retained FPDs, de-bonding of inlay retained FPDs appear to be much too high.

Conclusion

Inlay retained FPDs are conservative treatments for replacing a single missing tooth that can be constructed from metal, metal-ceramic, fiber-reinforced composites (FRC) and ceramic. With the evolution of ceramic and specially zirconia ceramic, it is possible to used ceramic inlay retained FPDs in the posterior quadrant. Although many preparation designs can be done for inlay retained FPDs, the inlay shaped preparation recorded the highest fracture resistance but it recorded the highest vertical marginal gap measurements. Retention of inlay retained FPDs is one of the drawbacks of this type of restoration, the author recommends to subject the inner surface of the restoration to surface treatments, the same used for resin bonded retainers. Few clinical survival rate studies were carried out showing that de-bonding of inlay retained FPDs is higher than crown retained FPDs.

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Chapter V

Removable Partial Dentures with Double Crowns – Biological and Prophylactic Value and Potential Complications

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Abstract

Correctly indicated and accurately made, partial denture with double crowns is a dental restoration of the highest biological, prophylactic and aesthetic values. However, insufficient knowledge of double crowns systems, as well as errors and omissions in the clinical and laboratory work invalidate this type of restoration and can have negative effects on the supporting tissues. Double crowns may come in form of telescope crowns and conical crowns.

Double crowns as connecting elements should provide: retention, stabilization, physiological transmission of occlusal loads through the abutment teeth as well as the prophylactic value, comfort for the patient, durability and aesthetics. In order to achieve these qualities, it is necessary, among other things: to make proper indication, to execute adequate tooth preparation (grinding), to make the choice of materials for the construction, to establish proper connection of the outer crown and the metal framework and to choose a suitable aesthetic material for veneering.

It is necessary to understand the mechanism of double crowns retention so that the optimal value of the retention force which should be 5-9 N per each patrix can be established. Insufficient retention force will reduce the comfort for the patient because would make the separation too easy, whereas an excessive force may negatively affect the periodontium of the abutment teeth.

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Retention force and durability of restorations with telescope and conical crowns depend also on the characteristics of the material they are made of. The most frequently used are gold and palladium-silver alloys. In recent years, titanium and the combination of ceramic and galvanized gold are used.

Prophylactic effect of double crowns is also provided by a proper planning that will enable the physiological transfer of the forces on the abutment teeth and the health of free gingiva. A special challenge is to plan the connection of outer crown with the metal framework. The best results showed optimized approximal extensions.

Double crown production demands experience of a clinician and dental technician in the performance of clinical and laboratory phases. A removal of sufficient tooth tissue during grinding in order to avoid getting oversized artificial teeth and a formation of the appropriate demarcation line which will provide sufficient stability of the system in the gingival area represent a particular challenge. Errors in laboratory work can be avoided with a good knowledge of the milling proceedings, a selection of a suitable material for the external crowns modeling and acquisition of precision castings.

Introduction

Regardless of the expansive use of dental implants, removable partial denture retains an important role in prosthetic rehabilitation of partial edentulous patients. Partial dentures may have clasps as connecting elements, and as such they are called conventional partial dentures. When connecting elements are attachment or double crowns, we talk about complex partial dentures. In terms of function and aesthetics, complex partial dentures meet the high demands of the profession, as they represent the combination of fixed and removable restoration, in which, using tooth reduction methods, abutment teeth are prepared to accept the elements of the removable partial denture [1]. While constructing these restorations, it is necessary to choose the retention elements, and plan stabilization and transfer of dental chewing pressure. In addition to offering comfort and good aesthetics, adequate retention and stabilization also affect the patient's feeling of confidence, providing him/her with adequate function.

The system of double crowns is one of the possible solutions for retention and stabilization of removable partial dentures. This system comprises of the male component of attachment or patrix, cemented to the abutment tooth, and the female component of attachment or matrix, which is the removable part of the restoration.

Double crowns in dentistry began to apply more than 100 years ago, and with many improvements over the decades, still continue to represent an effective system for rehabilitation of partial edentulousness. The cylindrical telescope system was first mentioned in the literature by James Dexter, (New York, 1883) and Water and Starr, (Philadelphia, 1886). First clinical application of the telescope system was described by Pess and Goosle (1924). However, at that time it was not accurately made and did not have adequate retention power. Soon the double crown systems began to improve (Häupl and Reichborn-Kjennerud, 1927) and a few years later Gründler and Böttger started to apply the milling technique in the preparation of the telescope system. The conus double crown system was first introduced by K.H.Körber, in 1957 in order to improve the telescope system deficiencies [2].

However, regardless of the highest biological and functional value of partial dentures with double crowns, they are rarely made today in everyday practice. The aim of this chapter is to explain the basic functional, prophylactic and aesthetic characteristics of double crowns

as well as to point out their shortcomings and the reasons for the lack of their practical application based on literature review and clinical experience.

Double Crowns - Characteristics

Definition, Indication, Types

Regardless of the double crown type, it always consists of two parts, one representing the fixed part of the dental restoration and the other that becomes a piece of the mobile part (Figures 1 and 2). Merged together, they form a complex which should represent the natural shape and size of the tooth. They separate only in one direction, the direction of the import and export of the restoration's mobile part [1].

An indication for a double crown is a partial edentulous dental arc, including a case of a maximum partial edentulous arch in cases where the remaining teeth are in favorable arrangement and with a preserved biological value. Periodontal status may reduce the possibility of making double crowns, bearing in mind that the long-term toothless rarely leaves periodontal tissue of remaining teeth intact. However, there are cases where the conservative and/or surgical periodontal procedures can prepare the abutment teeth for double crowns production.

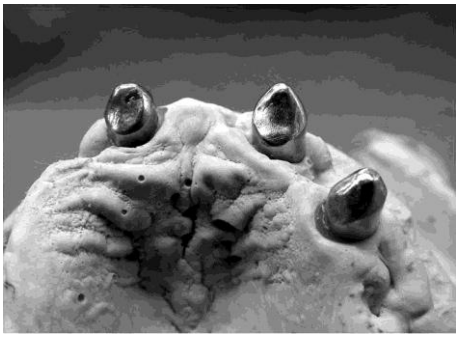

Figure 1. Inner crowns on retention teeth.

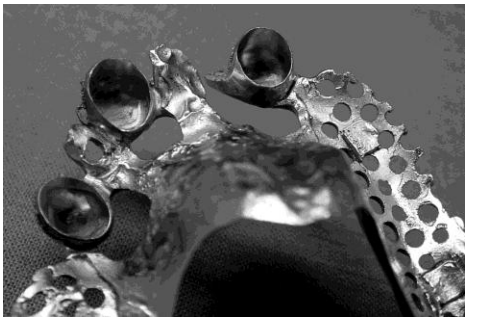

Figure 2. Outer crowns with partial denture.

This is particularly the case with the elderly patients whose periodontal disease is usually chronic with little functional problems and a low level of the tooth mobility [3]. In such cases, a properly made denture with double crowns will have a positive effect on the periodontium of the abutment teeth and can prolong their lifetime.

Also, there are situations when the specific arrangement of the abutment teeth directs to the partial denture with double crowns as the only possible solution for the dental rehabilitation. These are cases in which there are few remaining teeth with a wide span of edentulous fields. It is desirable that the abutments are on either side of median line because in that way it gets multiangular surface reliance. The most favorable abutment teeth for double crowns are premolars and molars, and the optimal number of crowns is 2-4 [4]. A clinical examination alone can not give a reliable answer to the question whether the position and shape of remaining teeth ensure the proper acceptance of partial denture elements. Therefore, the data obtained by clinical examination must be completed with an appropriate analysis of study model in the articulator and parallelometer. The analysis in parallelometer is done from the vertical direction and includes: the assessment of the amount of tooth tissue which will be removed by grinding, the estimation of parallelism of axial surfaces of abutment, the assessment of undercuts of residual alveolar ridge etc [1, 5].

There are two basic types of double crowns categorization. The first and most common is based on the types of the assemblies that the crowns form, classifying them on telescope and conus crowns. Telescope crowns represent cylindrical construction with parallel surfaces and they are characterized by equal gingival and occlusal diameter. Conus crowns are double cone-shaped assemblies in which the cone angles lie in the range of 4 to 8 degrees. Conical angle represents an angle which forms vertical surface of the cone with a central vertical axis of the teeth [1, 2, 6]. Because of the different type of the construction telescope and conus crowns have different ways of obtaining the retention for the partial denture and partially different characteristics and indications. Telescope systems are primarily indicated in maximum partially edentulous arch or in one with a small number of remaining teeth. Conus crowns can be applied in cases of more abutment teeth. In telescope crowns, due to a specific retention mechanism and method of production, the retention force is unpredictable until the delivery point of the prosthesis. Conus crowns, on the other hand, retain partial denture with a defined retention force. They also come to the basic position easily during the process of taking in the denture. Due to the specific cone assembly, it can be indicated in cases of unparallel or inclined abutment teeth [7]. Although there are many advantages of conus crowns over telescope systems described, each assemblies have their places in everyday practice if their characteristics and potential complications in the production process are known.

The other type of double crowns categorization is based on their morphological and functional characteristics with shell-type crowns as the most commonly applied. They are characterized by the inner crown reaching the abutment tooth demarcation line and outer crown which gives the tooth natural size and shape. Although telescope and conus crowns are the most used of all shell-type crowns, they can also come in form of resilient, open, partial crowns and crowns on the pins [1].

Resilient double telescope crowns are the crowns with a vertical horizontal space between the inner and outer crown. The vertical gap is about 3 mm high and corresponds to an average value of resilience of residual alveolar ridge mucosa. The horizontal space between the crowns is 0.03 mm in width and corresponds to an average tooth intrusion. The crowns are

parallel in the gingival area and slightly convergent in the occlusal area. Their function is reduced to the stabilization and leading the denture to the basic position. The retention is achieved as in complete dentures which means that the chewing pressure transmission mode is mucosal. As interocclusal gap is used for mucosa resilience compensation, an indication for resilient double crowns is a high resilience value and a small number of remaining teeth with a compromised state of periodontal tissue. They are indicated exclusively in the lower jaw. Although this system is well designed there are some open issues such as a lack of knowledge of the process in the abutment teeth periodontium under pressure if a tooth is axially pressured. Also, the size of the vertical interocclusal gap relating to the mucous resilience is not clearly defined, therefore making the primary indication for resilient double crowns questionable.

Open double crowns represent a system in which the inner crown is modeled with occlusal surface and the outer crown is in the form of a ring. They are indicated in the lateral region, where there is not enough space for two occlusal surfaces. The advantages of this system are a good stabilization, dental occlusal force transmission, lesser removal of tooth structure and a better hygiene. The lack of retention power is its weakness so that the existence of other retention elements is required.

Partial double crowns represent a system in which the inner crown is shaped as grinded teeth for partial crown with grooves on the axial and occlusal surfaces. The outer crown complements the inner to the shape of a partial crown. They have lost their importance and as such are no longer applied. Today, though rarely, a variant of partial double crown is made in which the inner crown is a veneered or a metal-ceramic crown with a space for outer partial crown made with milling technique.

Double crowns on pin are system in which the inner crown is in the form of pin cemented in the root canal and cap. The cap covers the occlusal surface of the root up to the demarcation line and has a wedge that is placed on the occlusal surface of the cap. The external crown, in the shape of a metal-ceramic or a veneered crown is set over the cap and pin. Frequency of different types of double crowns in everyday dental practice is not the same, with some rarely present and some not at all. As it is already mentioned, usually the telescope and conus crowns are indicated, with the other assemblies to much lesser extent. This is a result of the unfamiliarity with the precise mechanism of achieving the retention of certain double crowns types and the cases in which they should be indicated. In addition to this, lack of knowledge of some of the production phases of certain assemblies by a dental technician is quite common. The biggest criticism of the previously described circuits is the uncertainty in the realization of their fundamental roles [5]. All double crowns are expected to achieve the optimal retention, stabilization and guidance of the denture into its main position. However, regardless of the fact that when making most common double crowns (telescope and conus systems) problems related to the achieving optimal retention force can be experienced (as it will be explained in subsequent parts of the chapter), with the other assemblies it is logical to expect even larger errors.

Materials for Double Crowns

As the bonding mechanism of fixed and mobile part of restoration with double crowns is based on the friction and elastic properties of the material they are made of, it is

understandable that the functioning of double crowns, to a large extent, depends on the choice of the material. Dental alloys for double crown production should have the following characteristics:

- biocompatibility (non-toxic to oral and other tissues, not causing an immune response and not potentially carcinogenic);
- electrochemical stability and corrosion resistance to the living environment;
- good physical and mechanical properties (high strength, adequate hardness, abrasion resistance);
- good and easy workability and
- good bonding properties with veneering material [8, 9].

Until now, for double crown production, mainly the noble and base alloys were used as well as their combinations. Gold alloys which are used for double crowns are of type III and IV, characterized by a high content of gold (up to 88%) and platinum (up to 11%), and with a mechanical properties of very high strength, hardness and compressive strength. From the group of noble alloys, Ag-Pd alloys are also used. Their advantage over gold alloy is a much lower costs. They have physical and mechanical properties similar to the type III gold alloy. Their disadvantages compared to gold alloys are that the castings are generally less homogeneous and therefore less accurate [8]. That leads to the insufficient persistence in the mouth which contributes to a greater accumulation of dental plaque and soft tissue staining.

From the group of base alloys for making double crowns, an attempt has been made with Co-Cr-Mo alloys. However, they have many defects that affect the quality of the final product:

- low density and lack of fluidity in the molten condition and as a consequence less accurate castings than the noble alloys;
- greater contraction of castings during cooling;
- difficult processing of the castings;
- doubled values of modulus of the elasticity comparing to type IV Au alloy, which significantly increases the stiffness and results with very low retention and
- hardness two times higher than type IV Au alloy [1, 9].

In the case of both telescope and cone systems, the retention force depends on the materials that they are made of. According to research [6], conus crowns made in the same way but with different material have different retention force. Crowns made of Co-Cr-Mo alloy have lower coefficient of friction than those of Ag-Pd alloys and especially of Au-Pt. It leads to conclusion that the retention force of the conus crowns made of non-precious alloys is smaller. Bearing in mind these fact, it is necessary to adjust the milling angle according to type of alloy in order to achieve optimal retention force of 5-10N. More specifically, the optimal milling angle for Co-Cr-Mo alloy should be 5 °, for Ag-Pd is 5.5 °, and for Au-Pt 6 ° (Table 1.). The differences in static friction coefficient of Co-Cr-Mo alloy and gold alloy are showed by Ohida et al. [10]. Based on their results, a smaller cone angle of the conus crowns made of Co-Cr-Mo alloys is suggested due to a lower coefficient of friction.

Table 1. Conus angle depending on type of alloy

Type of alloy	Coefficient of friction	Conus angle
Co/Cr/Mo	0,17-0,19	5
Pd/Ag	0,20-0,22	5,5
Au/Pt	0,22-0,24	6

During the production process, the inner and outer crowns can be made of the same or different materials, making the frictional couple therefore homogeneous or heterogeneous. For homogeneous frictional couple, mainly noble gold alloy Type III and Type IV are used. Gold in these systems acts as a solid lubricant [8]. Base alloys are less desirable for homogeneous frictional couples due to the significantly higher modulus of elasticity, extremely hard alloy components and less precision castings. In heterogeneous frictional couples there is a rule that the internal crown should be made of base alloys due to the higher modulus of elasticity and the outer crown of gold alloy because of a lower modulus of elasticity. Heterogeneous frictional couples work better and longer than the homologous pairs of base alloys and worse than homologous pairs of noble alloys.

Recently, new materials have been introduced to the double crown production in order to improve desirable characteristics. Significant researches have been made investigating the combination of ceramic and gold. Weigl et al. conducted in vitro studies complemented by clinical studies on the subject of double conus where the inner crown was made of ceramic and outer crown of gold alloy obtained by galvanizing process. The results indicate that these materials have possibility to become materials of the future for double crowns production [11, 12]. The advantages of ceramics-galvanized gold system lay primarily in a simple laboratory production. The inner crown is made of CAD/CAM system and the external one using a galvanization device. The result is high accuracy and very precious fitting of inner and outer crown. The retention force is independent of the pressure that is to say, to the intensity of masticatory forces. Also, this system shows high resistance to abrasion (wear) which is very important in the function of time. In addition to reduced wearing, there is no phenomenon of "cold welding" in areas of intense contact and gold does not form a galvanic element with ceramics with no corrosion as a consequence. It is known that ceramic has small plaque susceptibility, resulting in good health of periodontal tissue of abutment teeth. Also, with these materials some shortcomings in aesthetics of conventional systems can be overcome. In the cases of the withdrawal of marginal gingiva the metal edge wouldn’t be exposed, but the tooth-colored ceramic.

Retention of Double Crowns

Double crowns as connecting elements should provide: retention, stabilization, physiological transmission of occlusal loads through the abutment teeth as well as the prophylactic value, comfort for the patient, durability and aesthetics. However, regardless of

the same roles they exercise, the manner in which the roles are exercised in telescope and conus crowns is basically different.

Perhaps the most important and most studied role of the double crown is retention. The reason for this is due to the fact that in achieving optimal retention lies a prophylactic effect of double crowns as well. Optimal retention of double crown is 5-10N for a single anchor [1, 2, 5, 13]. Any force that deviates from this optimum can have negative consequences for the entire structure. It is essential to understand the mechanism of retention with double crowns in order to establish the optimal value of the retention force.

The Mechanism of Achieving Telescope and Conus Crowns Retention

Mechanisms of retention of telescope and conical crowns differ. While the retention of the crown telescope is based on the dynamic-static friction, the retention of the conical crown is based on the static friction.

Telescope crowns have a form of a cylindrical structure characterized by gingival and occlusal equivalent circumference. The inner surfaces of outer crowns are adapted to the inner crown. The accuracy of this construction depends on the ratio of the radius or the diameter of the inner and outer part of the assembly. The difference between diameter of external and internal crown forms a gap. Depending on the size of the gap there are three types of the assembly: construction under tension, the transitional assembly and a loose assembly [5]. A construction under tension and a loose assembly, due to the elastic deformation of the outer part, and, for easy separation of cylinders, are not applicable. The size of the gap should be as near as possible to zero so that optimal frictional contact can be obtained; this is called the transitional assembly (Figure 3). Depending on the accuracy of the making, the friction effect appears when connecting or separating the outer from the inner crown. From the moment of the first touch of the inner surface of the outer crown and the outer surface of the inner crown until the final position, including the reverse process, this assembly is subjected to the laws of friction. In essence, the friction represents the resistance that occurs between two bonded atoms, molecules or bodies in relative motion under the influence of mechanical forces. The wear of the surfaces in contact is proportional to the force of pressure. In other words, if the gap is smaller, the force is greater and therefore the greater is the wear. This leads to the conclusion that parallel cylindrical constructions don't have the constant shape, the gap is increasing over time, and the transitional construction becomes loose. The presence of liquid between contact surfaces also has impact on the wear and geometrical shape of the construction [13]. The friction varies considerably according to whether it is a friction of wet, half-wet or dry surfaces. The size of the wear depends on the properties of the materials which are in contact (their hardness and roughness), the pressure and the number of cycles of the mergence and separation. The total separation (and merge) force of telescopic denture with more then one telescope crown equals the sum of all forces that correspond to each particular crown.

The outer surface of every solid body is rough and wavy. Even the ideally smooth surfaces of quartz crystals show elevations of 0.01μm. The smoothest metal surface has bumps from 0.05 to 0.1 μm [5].

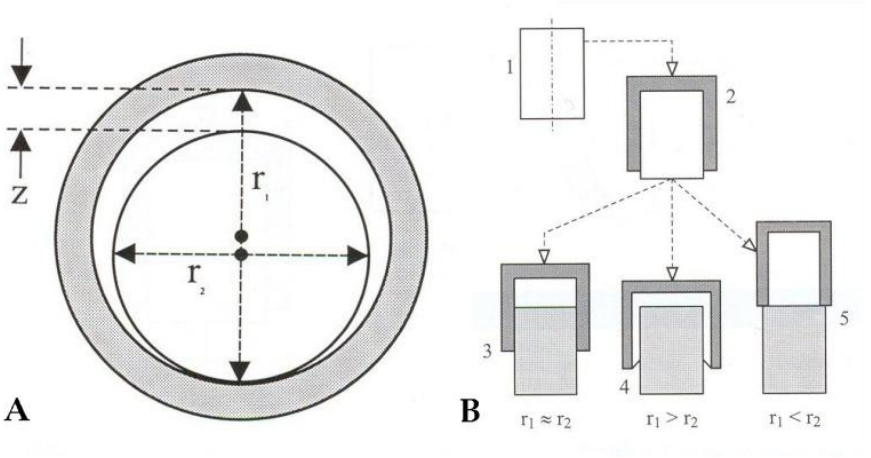

Figure 3. A. Gap is difference between diameters of secondary and primary crowns. B. Assemblies categories depending on gap size.

Inaccuracy, roughness and waviness of the outer surface of the inner crown and the inner surfaces of the outer crown cause their contact with each other only in certain small areas. The real contact area is several hundred times smaller than the geometric surface. The size of the actual contact area is always the sum of the individual contact surfaces. At points of intense contact cold welding phenomenon occurs as a result of heat generated during deformation. The result is a loss of substance and increase of surface roughness, which essentially allows the progression of the process of wear.

The local wear in a thin surface layer is particularly intense in the first phase of the friction process (the "initial wear" or "running-in phase") and is a result of the fatigue of this layer due to repeated elastic deformation and their transition into the plastic deformation. The consequence of the "initial wear" is that the final geometrical shape of telescopic crowns is accomplished only after a certain time of use [15]. The process of casting can not generally affect these processes, but the occurrence of reversible frictional connections can be influenced by choosing alloys with low elastic modulus for the inner crown and for the outer crown alloy with effect of solid lubricant (e.g. gold).

A system of double crowns with conical shape was developed with an aim to eliminate the disadvantages of cylindrical construction and retain its good qualities. Conus crowns have the following positive characteristics:

- the ability to retain the denture with defined retention force;
- a function based on the static coefficient of friction and
- the ability to allow the separation of the construction without the sliding friction, making them not subjected to wear [1, 16].

The conical construction is different from the cylindrical in the fact that it has a milling angle (conical angle or the angle of longitudinal surface treatment) other than 0˚. The inner crown is made at the angle of 6˚, so it takes the form of cone with a greater gingival diameter than the occlusal [2]. The outer crown with its internal surfaces follows the inner crown, completing it morphologically, forming a natural tooth shape and also becoming an integral

part of the partial denture. When placing external crown over the internal, the contact surfaces get into reaction, producing the posture force. According to Kerber, this represents a fine friction which occurs only in the final contact phase [14]. The maximum idle mode friction signifies the force which before the start of the movement must be overcame only by the force of separation during denture removal. During the chewing function, the pressure force is generated which acts perpendicular to the axis of the tooth. As a reaction to the pressure force, a new force is produced, of the same course but in the opposite direction, called the normal or reaction force. The normal force in conus crowns is a component localized at the contact surfaces, and it, the same as the chewing force, causes the idle mode friction (Figure 4.). Normal force can also be described as a force of a closed, ring-like spring, making it the force with which the individual parts of the outer conus exert the pressure on the inner conus. Parts of the outer cone, due to elastic deformation, exert pressure on the inner part, as if it was composed of many rings. The occlusal force acts in such manner that each ring, moving on an incline plane, is being elongated to some extent. The consequence of that is that the inner crown's analogue ring is being compressed (Figure 5.). Thus the occlusal force, which originates from the construction juncture and the appropriate occlusal forces originated during mastication, converts into a deformation and is stored as the force of friction mode [2, 5, 6].

There is a dependency between the friction force and the size of cone angle. For the cone angle of 6˚ the separation force is 5-10N. For standard conus crowns, the angle of 6˚ is recommended. A smaller cone angle gives a greater friction force and therefore stronger retention, which means that it will be harder to remove the denture [5, 7]. For example, for the angle of 2˚, eight times bigger force is needed than for the angle of 16˚. Having this in mind, it is possible to plan and make some double conus crowns with greater retention force, if the biological conditions (health of periodontal tissue) permit that. On the other hand, crown made with a larger cone angle will contribute more to the stabilization and transfer of chewing pressure. It is known that conus construction works if the outer part has a slightly larger diameter with a vertical interocclusal gap inside the closed cone construction. In order to achieve defined retention force it is necessary to have a strong touch of the internal lateral surfaces. Only then sufficient idle mode friction can be generated.

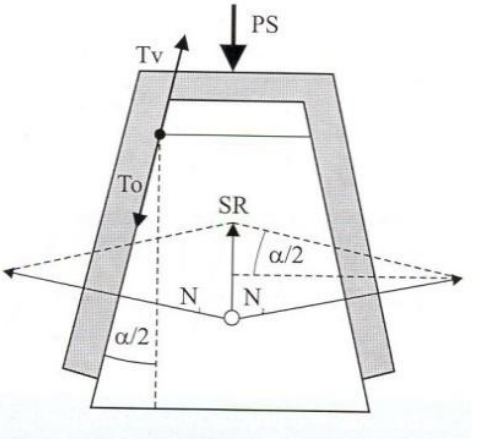

Figure 4. Schematic review of conus constitution forces: PS–pressure force, N-normal force, SR–disunion force, Tv–displacement force, To–maximum rest friction force.

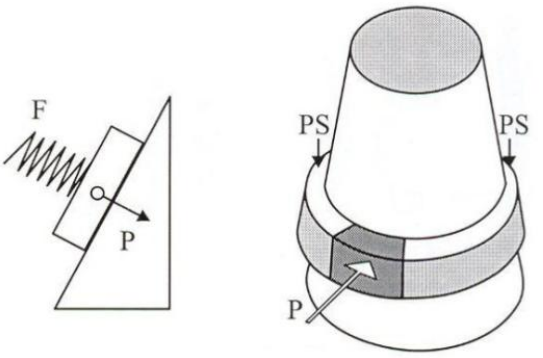

Figure 5. Scheme of secondary crown elastic ring effect on primary crown: PS–pressure force, P-rest friction force.

Also, it is necessary to make a minimum dimension of the inter-crown gap during the influence of maximum force with adequate deformation of the outer conus. That makes the conus construction elastic. According to the literature, this gap should be 0.1-0.3mm in the case of an unloaded system. During the activation of conus system, the inter-crown occlusal space is reduced for a few tens of microns depending on the nature of material, the force power and the geometrical parameters. At the termination of this action, the newly formed configuration can not be returned to its original state, although it is an elastic system, but remains under tension and the system works – it retains the denture [6, 14]. If the crowns are in direct occlusal contact, the occlusal forces are transmitted directly to the tooth and no part of the force can be converted into the elastic deformation of the outer crown.

Due to the different ways of achieving retention, the opinions of scientists and clinicians differ in terms of preferences of a particular system. Some senior scientists have favored the telescope system, primarily because of a better aesthetic effect, considering that its settlement on the gingival edge is much larger due to the zero-point milling angle [1, 17]. That way gingiva covers the veneered part of the crown in the visible region of the oral cavity better. The disadvantage of the conical system lies in the presence of an occlusal inter-crown space slightly larger than in the telescope parallel system, due to the structural characteristics of conus system. From the clinical aspect, this space is the weak point of the system because of the plaque accumulation and less resistance to lacunar corrosion [5]. However, the conus system has its advantages because its function is determined only by static rather than dynamic-static friction coefficient. Due to wear, which is of a slight intensity, the conus system has a longer clinical exploitation. In addition, there is a possibility of self-activation by the reason of its settlement as a result of contact surfaces wear [7]. Another benefit is the savings of the material compared to the telescope parallel system. This fact is based on the constructional characteristics of the conus construction which has a form much closer to the grinded tooth compared to telescope construction one.

Problems in the Retention of Double Crown

As it was previously mentioned, the optimal retention is one of the basic prerequisite for functionality, prophylactic effect and longevity of the partial denture with double crowns.

Insufficient retention force will reduce the comfort for the patient making the separation too easy, whereas an excessive force may negatively affect the periodontium of the abutment teeth. The double crown retention factors are the following:

- Number of abutment teeth. It directly affects the total retention force of the partial denture with double crowns. It should be always taken that into account and the force of a single construction adjusted to the number of constructions. This means that if more than a few construction are present, which is more often the case with conus crowns, it is not recommended to insist on an optimal retention force of 5-10N for each anchor. In the case of the conus crowns, the adjustment of the retention force shouldn't be a great problem, because it depends on the cone angle. In the case of telescope crowns, the retention force remains unpredictable until the delivery of the denture to the patient, which will be discussed below in this section. Therefore, the most common error in the retention of telescope dentures with more than three constructions is the excessive retention force which causes difficulties to the patient during denture separation.
- Retention force of each double crown construction. The force of each construction has a direct impact on the total retention force of the denture.
- Selection of alloys.
- Secondary factors. They also directly affect the retention force of the denture, although to a lesser extent. Secondary factors include physical and physiological factors. Physical factors are the surface tension, viscosity of the saliva, the adhesion and cohesion and the reduced air pressure. Physiological factors include the muscles of the cheeks, lips and tongue.

When planning the denture with double crowns, clinician can not be conducted only by physical and mechanical laws. Although the optimal retention force is proved to be 5-10N, it must be taken into account to which class the abutment tooth belongs as well as its biological value. Although the premolars and molars are the most desirable abutments for double crowns, the teeth of other classes can also serve very well. For example, if a central incisor's periodontium is preserved, it can certainly be included as a carrier of a double crown. However, due to its less periodontal surface, it can not receive the same dose of force as canines or molars. Therefore, a special attention should be paid that the retention force in incisors does not exceed the optimum level. Also, if the abutments have undergone periodontal treatment, it should be prevented that they suffer excessive force, even if it is only in the "running - in" phase.

Too weak or too strong retention force is the consequence of the discord between the inner and outer crown. This disharmony is a result of errors and variations (decrease or increase) of gingival and occlusal diameter.

The separation of telescope denture from the inner crowns depends also on the roughness of the contact surfaces, so that the gap has to be even wider if these values are higher [1, 13]. If this fact is overlooked, the telescope construction will succumb to rapid wear and smooth sliding motion would not be possible. As a standard procedure of the casting gives large differences in the dimensions of molded objects, an object with a smaller inner diameter of the secondary crown is obtained. In that way, a construction under tension in which both

crowns suffer from mechanical deformation is created. If the gap between the crowns is too wide, whether as a result of the incorrect production or due to wear, it will perform the opposite effect – the denture could not be retained and it will be moving during function. In order to achieve good characteristics of telescope or conus construction, all working processes and materials, from impression to polishing, must be well coordinated.

During the telescope crown production, the size of the gap depends on technical process and the degree of its reliability. On the casted inner part, which can be correctly made by milling, the outer part of the construction is modeled, so that the gap actually depends on the possibility of precise transformation of the wax model into the final form. In this procedure, several factors affect the accuracy: the properties of modeling wax and mass for investment, the modeling process, the method of casting, the characteristics of material for the outer part of the construction, the procedure for processing the cast etc, concluding with the always present human factor [5].

In a cylindrical construction, there is no insight into the value of the retention force during the process. In the final phase of denture delivery to the patient, with the use of different procedures for adjusting the force of separation, it can only be concluded whether the retention force is satisfactory or not, but its real value remains unknown [18, 19]. This can be a problem in the function, because when a clinician notice the eventual error, it is often difficult to eliminate. As a result of these problems, the telescope crowns retention measurement is often the subject of research.

The authors of this chapter carried out a similar research with the aim to measure individual and total retention force of the telescope dentures [18]. The research sample included 50 cylindrical structures fabricated at the Clinic for Prosthetic Dentistry, Faculty of Dentistry, Belgrade University. Retention force was measured on each structure. In addition, further measurements were carried out: the total retention force on 12 removable partial dentures with two cylindrical structures, on five dentures with three structures on three and four structures with dentures was measured. Double crowns were made of noble alloy type IV, in other words, a homogeneous frictional couple. Cylindrical structures were constructed for all classes of teeth, with the largest number, 55% for canine teeth. Measurements were carried out with the Bredent dynamometer (friktionsmeßgerät fmg 20; Bredent, Senden, Germany) [21] (Figure 6.).

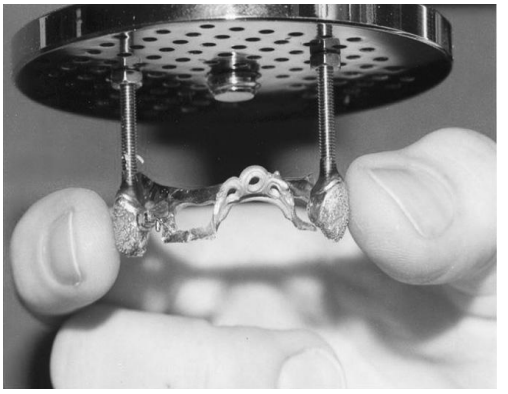

Figure 6. The separation of patrix from matrix by pulling it vertically.

Results of measuring the individual force retention showed that the average values of retention force were from the value of 1 to 10.7 N. In terms of tooth classification, the force value was largest for the canine tooth, amounting to 6.5 N, and smallest for the molar tooth - 3 N. The results were derived by comparing the data collected from the individual matrix-patrix components: the optimal value was present in 50% of the cases, the force was too strong in 15% of the cases and was inadequate in 35% of the cases. The advantage of the method described in this report is that it provides the opportunity to measure the total retention force of a removable partial denture with a cylindrical design. Such a method allows observation of the change of the force depending on the varying number of components of the denture. Of the 20 removable partial dentures for which retention force was measured, only six (36%) had values within the limits of optimal values, whilst a reduced force was not recorded for any in this group. In the largest number of cases (70%) retention force was too strong. The lowest value for the total force was 5 N, and the largest 32.5 N.

Bearing in mind that the measurement was made under in vitro conditions, one should take into consideration the lack of a lubrication effect, which is present in the oral cavity. However, Bayer et al. showed that there was no significant difference between the measurements of retention force of double crowns with and without saliva lubrication [20]. As previously discussed in the mechanism of retention of the double crowns, crown definite geometric shape is reached after "running-in" phase. This is evidenced by this study because it has been noted that, while separating inner and outer telescopic crowns, the largest force value was observed during the initial separation.

The results of this study suggest that retention force is not suitable in 50% of cases of individual force and 70% of cases where the collective force is involved. This shows that a large percentage of the telescope constructions are actually dysfunctional, and that is why it is necessary to introduce some system for checking and measurement of retention force during the telescope denture production. Bayer et al. examined the average retention force of telescope crowns [20]. The retention force of 140 telescopic crowns was measured in the study. The retention force was measured with and without lubrication using saliva substitute. The minimum retention force was 12:08 N and the maximum retention force was 29.98 N. For all the lubricated specimens a median retention force value of 1.93 N was reached and an interquartile distance of 4.35 N was calculated.

If the retention force is not of optimal range a correction must be undertook. In the case of insufficient force, it is necessary to line the cylindrical matrix component with a composite material. If the force is too strong, it may be necessary to repeat the fabrication of the matrix or framework to polish some contact segments of the patrix and matrix.

Insufficient retention force is a serious problem because it produces movement of the denture in the function [19, 22]. Relining with composites materials is a good solution, because the process is simple and gives good results. The composite that is used for this purpose must have a minimum of wear. The procedure can be performed directly on the patient or in the laboratory. It is also possible to improve retention when the denture is in operation for a while reducing the retention due to excessive wear. Retention improvement with composite materials lies in the fact that in this way, a new type of construction is made. The insertion of composite between the outer and inner crown creates a metal-resin construction which replaces the metal-metal complex [21]. The metal on resin fit offers the benefit of a considerably greater coefficient of friction than the one of a pure metal fit. Consequently, increased resistance to wear and an extended service life are obtained.

The Advantages of Partial Denture with Double Crowns – The Prophylactic Effect and Longevity

The advantages of partial denture with double crowns are numerous. The very fact that these systems have survived in practice more than 100 years speaks about their effectiveness in the prosthetic rehabilitation of partially edentulous patients. Properly indicated and accurately produced partial denture with double crowns represents a dental restoration of the highest biological and aesthetic values. Conversely, a poor indication and certain shortcomings in work, devalues this restoration to the point in which not only there is no more preventive and biological value, but it represents a threat to its supporting tissues.

The main advantages of double crowns are the prophylactic effect on the supporting tissues, longevity (persistence) and comfort, with the precondition that the protocol is respected in the planning of this kind of dental restoration. Prophylactic effect is reflected in:

- abutment teeth - extending their life;
- alveolar bone - reducing its absorption in the function of time and
- free gingiva - maintaining its health by appropriate design of the outer crown and metal framework relationship.

If the double crowns are properly planned and designed, they physiologically transfer the accepted masticatory forces to the abutment teeth. It will extend the lifetime of abutment teeth even if they were periodontally compromised to a certain degree. This of course includes the cases where the conservative and/or surgical periodontal treatment has been performed and abutment teeth are stabilized. Double crowns continue the functional stimulation and have a positive effect on the recovery and further stabilization of the periodontal tissues of the abutment teeth [1, 4]. Therefore, this also creates the prophylaxis effect together with positive effects on oral mucosa in the contact with denture and alveolar bone. The principles of tooth preservation are based on a rigid connection between the abutment teeth and the denture with mainly axial loading, which reduces any existing mobility [7]. The positive effect on abutment teeth is a result of a lack of traction and other forces and tooth movement during functioning, which occurs in the case when the connecting elements are clasps. The loads are directed to the longitudinal axis of the tooth, i.e. in the direction in which large numbers of periodontal fibers are engaged. In addition, if the retention force is optimal, it also positively affects the supporting tissues as a functional stimulus.

Prophylactic effect of partial denture with double crowns is also provided by appropriate design of restoration that will allow the health of gingiva of abutment teeth and ability to maintain adequate hygiene. This design is very important to establish in the area of the connection of the outer crowns with metal framework of partial denture. However, this link can have both positive and very negative effect on periodontal tissue of abutment if it is not properly planned. The connection of the outer crown with the metal framework can be achieved in several ways:

- direct connection by soldering;
- connection through the approximal extensions and
- casting in one piece.

The connection of external crown with the metal framework through the collars of framework prepared on the oral side of abutments has been a method of choice for a long time. The collars are connected with the metal framework by soldering. Although this relationship is reliable from the mechanical aspects, free gingiva is mechanically injured due to dead spaces and denture sinking. Also, when this connection is done with a larger number of conus crowns, it can lead to changes in axial dimensions of the external surfaces of crowns, which reflects on the cone effect realization and retention. Elastic deformation of certain parts of the outer crowns is disabled as a result of the increase of the crown wall because of the soldering with metal framework [1, 23]. In addition to endangering the retention effect, this can lead to falling aesthetic veneers.

The best results in terms of prophylaxis shows a connection through the approximal extensions on the outer crowns over which riders of the metal framework are placed. The riders are analogue part of the metal framework which fit the approximal extensions accurately. They can be connected to the metal framework by soldering with acrylic resin or composites. Besides the prophylactic effect, bonding through the approximal extensions also has a positive effect on the preservation of retention because the dimensions of outer crowns are unchanged [24]. Also, in this way, the cast is kept from further heat exposure in additional warming, especially if it has already been thermally and mechanically processed.

However, the standard approximal extensions so far have shown some disadvantages, especially if they have not been well planned. The consequences of poor planning are sharp corners that cause high concentration of tension as a result of which the connection may break. If acrylic resin is used for bonding this type of connection it often leads to separation of mobile and fixed compensation. Also, during the check-ups, the inflammation and thickening of the free gingiva of the abutment teeth are observed especially if there are dead angles where there is an accumulation of dental plaque, as this makes the oral hygiene maintenance difficult [24].

Based on years of clinical experience, the advice of authors of this chapter is to take the registration impression over the internal crowns and to plan and model the outer crowns on that plaster cast.

Although in this way the procedure is extended for one more impression and casting, this is negligible comparing to the positive effect. The positive effect is that the exact position of free gingiva around the inner crowns is visible allowing a very accurate modelation of outer crown with approximal extensions. The approximal extensions should be in the slight touch with the free gingiva, brought maximally close to the interdental papilla and creating enough space for the metal framework and artificial teeth. All this requires the use of articulators in this particular segment.

Today, many more modern forms of approximal extensions appear in the market, in order to overcome the shortcomings of conventional ones. In this aspect, the term optimization of the approximal extensions appears in literature [24]. It indicates an individual approach in creating the geometrical shape of the crowns with denture connection (Figure 7). (Stančić I, patent solution No. P-0758/04, 2004, decision of the Institute of the Intellectual Property Office granted patent on RS no. 50 205).

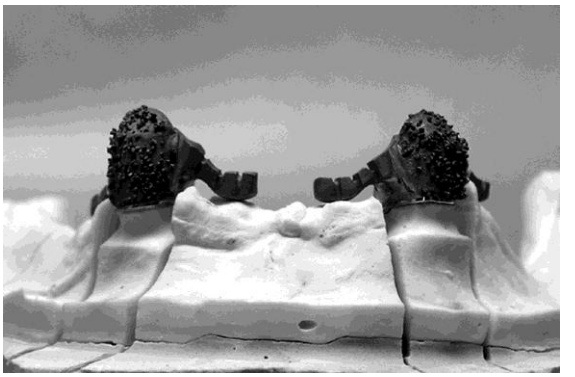

Figure 7. Optimized approximal extensions of outer crowns.

Comfort creates a sense of stability to the patient, because the system cannot be separated by the action of surrounding muscles, sticky foods or gravity. Horizontal forces that lead to high stress of the periodontal tissue can be successfully stabilized by double crowns. Complete coverage of the abutment teeth and the direct contact of the vertical surfaces in the main position of the denture is the primary basis of stabilization of these systems. Of course, in addition to overall stabilization, it is necessary to stabilize the occlusal forces. There is no uniform occlusal scheme; however, some general principles must be followed:

- provision of stable contacts in central occlusion;
- undisturbed conduction in the eccentric positions and
- optimum interocclusal space in the physiological rest position [3, 25].

Also, the comfort is provided by the fact that the system can easily be connected and separated when necessary, whereas the patient feels that the fixed and mobile part are connected into the one whole.

Beside the sense of comfort, stabilization provides the prophylactic effect on the alveolar bone. Reduced movement in function will reduce bone resorption in time. Also, the previously mentioned stabilized and balanced occlusion will have stimulatory effect on the alveolar bone and osteoblasts function. Of course, in order to maintain this function, it is necessary to carry out regular controls of occlusion and to perform reoccludation or relining if there is need.

It is known that properly made denture with double crowns are reconstructive solutions with longevity. In everyday practice, patients who have successfully used these dental restorations over 20 years can be seen. The main reasons for partial dentures ruin in general are problems with abutment teeth or technical failures. Abutment teeth may face large periodontal problems, fractures or caries after a few years [26]. The mobile part of the restoration may suffer stress that can lead to fractures. This is usually a result of errors in work. Fractures are complicated to repair, depending on localization; some parts, such as an occlusal rest or minor connector, are very complex and expensive to repair. When a partial denture with double crowns is well made, the abutments will not be exposed to excessive forces as previously discussed, but instead, these forces will have a stimulating effect on the periodontal tissue. This causes abutment teeth longevity. Also, if the homologous frictional couple of precious alloys (primarily gold alloy) is used, the longevity will be also provided by

good qualities of these alloys such as biocompatibility, less plaque receptivity and good physical and mechanical properties. All this provides a greater asset of double crowns compared to the other connecting elements of the partial denture.

Longevity of partial denture with double crowns was the subject of many researches. Wöstmann et al. examined in a retrospective longitudinal study the long-term survival of telescopic partial denture, taking into consideration possible influencing factors as well as treatment needs within the functional period [27]. The observation period was 5.3 ± 2.9 years. The examinations were comprised of caries diagnoses, tooth sensitivity and mobility, friction of the telescopic crowns in congruency between denture saddles and soft tissues, the state of the facings, the acrylic denture base and the metal framework. During the observation period 4.7 % of telescopic dentures required replacement, 3.8% of the abutment teeth were extracted. The survival probability after 5 years was calculated as 95.1% for the telescopic dentures and as 95.3% for the abutment teeth. The estimated 5-year survival rate for dentures with only one abutment was only 70.9% compared to 90.4% (two abutments), 95.0% (three abutments) and 97.9% (four abutments). Denture with no more than four abutments had to be replaced during the observation period. The most frequent technical failures were damages or loss of facings (26.9%) and loss of cementation (20.6%).

In a similar study of Behr et al. [28], the longevity of telescope and conus systems was investigated. The average observation time of parallel-sided retained dentures was 4.6 ± 1.6 years, and for conical dentures retained 5.2 ± 1.3 years. The first technical failures observed were recorded, such as fracture of the denture base metal, fracture of the saddle resin, fracture of the soldering, the loss of abutment teeth, loss of cementation, loss of artificial teeth, or loss of facings. During the observation time, 48.8% of the patients with conical crown-retained dentures and 34.2% of those with parallel-sided crown-retained dentures experienced complications. Loss of cementation occurred most frequently, in 26% of the parallel-sided double crowns and in 18.6% of the conical crowns. Loss of cementation and loss of artificial teeth were observed most often. The loss of cementation was the other most frequent technical failure in conical crowns but it occurred more than five years after insertion of the dentures.

These studies demonstrate durability of partial denture with double crowns showing that with these restorations there is relatively small percentage of complications in a long period. The most common complications are a loss of cementation and facing, which are relatively easy and inexpensive to solve [29].

Failures and Problems in Double Crowns Production

Regardless the numerous advantages of double crowns, they are now less and less frequently used in rehabilitation of partially edentulous patients, even when they are the only possible solution left. Possible reasons for this are complex production, lack of familiarity with the making process, inadequate laboratory, absence of dental technicians' training and previous bad experiences. For the partial denture with double crowns to exhibit all its positive features all clinical and laboratory phases must be properly planned and performed. Errors can occur during the whole process, from the bad indication to the failure in the cementation.

At whatever stage they occur, omissions and errors may devalue the entire dental restoration and adversely affect the supporting tissues.

In addition to issues of retention and prophylactic effect of double crowns, as described in previous sections, potential problems can also occur in different clinical and laboratory stages. Problems with the veneering can often put clinicians in dilemma as well.

Potential Problems and Mistakes in Clinical Phases of Double Crowns Production

The main characteristic of the clinical phases of fixed part of denture with double crowns is significantly higher reduction of the tooth structure compared to conventional metal-ceramic crowns. This happens because enough space for the cement, inner crown, outer crown and veneering material must be provided. As a consequence, the extension of the clinical crown and endodontic treatment of abutment teeth is often indicated. Not removing enough tooth structure can cause aesthetic problems, since the artificial teeth will be larger than natural teeth [1].

Grinding and impression of the fixed part of restoration take place as usual, similarly to the process in other complexes dentures, but it is very important to establish a clear demarcation line of sufficient width to ensure the stability of both crowns in the gingival area [4]. This requires a certain amount of skill and experience of clinician.

A tryout of the inner crown includes the examination of the gingival edge leaning on the demarcation and control of the occlusal space. As previously stated, it is best to take the registration impression over the internal crowns in this phase in order to make the outer crowns in accordance to the requirements of prophylaxis, or without negative effect on the free gingiva. The impression for the denture is taken over the double crowns and it is important that they have a secure position on the grinded abutments. Therefore, it is sometimes necessary to fix them with a paste for temporary cementation or elastomer. For the impression making, elastomers are used and priority is given to “one-phase” technique. The deformation during the impression removal after the polymerization of elastomers should be particularly taken into account. The following clinical stages take place in the usual way.

The phase of denture delivery to the patient is similar to one in any complex denture. Before the cementation of the inner crowns it is important to check the path of denture input, denture boundaries and occlusion. It is also necessary to isolate well the contact areas of double crowns, so that mobile part could be separated later without the use of excessive force. The separation is done after 24 hours at which time the first control is also performed. The first separation is usually more difficult because of the "running-in phase” [18].

Potential Problems and Errors in the Laboratory Stages of Double Crowns Production

Before the start of the inner crown modeling, it is necessary to determine the direction of denture input. For direction of input, the most important is the position of the abutment teeth in the frontal and sagittal planes. The procedure includes the choice of the middle position of

abutment teeth in both planes, and the orientation of the model first in the frontal and then in sagittal plane. This procedure not only determines the direction of import and export of the prosthesis, but also the direction of paralleling the inner crowns. If there are no undercuts in the area of residual alveolar ridge, then only centre lines of abutments are taken into account. The inner crowns are made by milling process.

The precision of laboratory work in double crown production mainly depends on the accuracy obtained by casting. The contraction of casting is inevitable, but it can be directed, including by the expansion of investment mass. For accurate casting the following is important: a precise measurement of fireproof mass and expansion fluid, thermal removal of tension/relax of the wax model, the possibility of expanding investment mass, the thickness of casting canals, the object's position in the refractory block, the thickness of the investment mass around the object, the object's position in relation to the direction of casting, the vacuum investment of wax object, respect of the preheating time and the use of precise equipment for casting [5].

Casting accuracy affects the size of the gap. Inaccurate cast causes excessive gap and, in addition to the impact on retention, has a negative impact on inter-jaws relation and increased accumulation of plaque.

Gap depends on:

- properties of modeling wax and mass for investment;
- modeling process;
- way of casting;
- materials for the outer crown;
- proceedings in the casting processing and
- human factors.

Materials for the external crown modeling are:

- wax;
- two-component plastic materials (a combination of plastic and wax materials) – self-polymerized acrylates and
- heliopolimerized materials (acrylates as fillers based on wax - LIWA program).

Self-polymerized acrylate has many advantages such as quick and easy creation and exceptional dimensional stability. Also, during the polymerization, a contraction is negligible because there is no thermal reaction, resin burns without residue and is eliminated in the T of 480°C. Molded surfaces are smooth and precise. Photopolimerized acrylate has advantages in terms of constant plasticity which allows safe and easy operation without time limit. It is easy for use because the material is one-component in the form, ready for use immediately. It has minimal contraction and therefore ensures the optimum edge closure. It is dimensionally accurate, because there is no deformation. Also, transparency allows control of layer depth.

The outer surfaces of the inner crowns and the inner surfaces of the outer crowns occupy particular attention in the laboratory work. Since the outer crown exhibits elastic deformation during the setting over the inner crown, it is important to take into account the dimensions of its walls. The most vulnerable area is the area of gingival margin.

Finishing process involves the inner crown polishing to a high shine. The impact of quality of finish is great. Well-polished surface has as a result lower static and dynamic coefficient of friction. The inner surface of the outer crown is not polished, but its treatment ends with sandblasting. The degree of processing significantly affects the size of the friction and the wear volume and thus the retention as well.

Aesthetics of Partial Denture with Double Crowns - Problems with the Veneering

The aesthetics of partial denture with double crowns generally shows two problems. The first is the inadequate removal of tooth substance by grinding, resulting in oversized crowns, as described in the section related to the clinical stages. The second problem is related to the veneers. Usually, the type of veneering material and dental technician incompetence can result in poor aesthetics, but an additional problem is the lack of retention of the veneer. As noted earlier, the fallout of the veneer is one of the most common complications of the use of partial denture with double crowns. Although it's not complicated for correction, for patients it can be an aesthetic and financial problem if it is frequent. As veneering materials the following can be used:

- ceramic materials;
- acrylate materials and
- composite materials.

Ceramic materials can be used as veneering material for double crowns, but due to the very high modulus of elasticity of ceramics, loss of veneers are often. For this reason and because of the prices of ceramics, it is rarely used for veneering. The acrylic materials can be used, but it must be taken into account their poor physical properties:

- softness;
- low resistance to abrasion;
- low impact resistance;
- low modulus of elasticity and
- insufficient strength.

The connection of acrylic with the metal of exterior crown is purely mechanical and often insufficient. Part of the metal that is covered with veneer is sandblasted with aluminum oxide particles of 110-250μm at a pressure of 3 to 3.5 atmosphere, depending on the type of alloy. In this way the contact surface between acrylate and crown is increased and the mechanical connection gets stronger.

Nowadays, composite materials are mostly used for veneering in double crowns. Their benefits are more favorable mechanical and aesthetic properties:

- abrasion resistance;
- high degree of hardness;

- high impact resistance;
- modulus of elasticity harmonized with module of the alloy;
- coefficient of thermal expansion (CTE) harmonized with the CTE of the alloy and
- excellent aesthetic results [30, 31].

A good aesthetic effect of a composite is reflected in its ability to achieve a high gloss with polishing, wide range color choice and the possibility for the crown's individualization. In order to obtain the best possible resistance of veneers, it should be provided with a minimum thickness of 1.5 mm. Also, it should be noted that alloys with more than 90% of gold, palladium or platinum produce small amount of oxide for binding, thus making the retention smaller. Every day, composite materials are more developed to achieve better and better aesthetic and mechanical characteristics. Composites with increased filler content are more stable and convenient for veneers in double crowns. They improve double crowns' properties in terms of high resistance to shock, ultra-low brittleness, greater resistance to abrasion and outstanding aesthetics.

The importance of composite veneers has been tested in numerous studies. It was proved that the wear of composite materials for veneering is lesser comparing to the conventional light-cured composites but higher than the gold alloy and ceramic. Also, they showed excellent color harmonization and long-term stability [30]. Matsumura et al. compared the hybrid composites with an increased amount of inorganic fillers and composites with micro-fillers, where the hybrid composites showed significant improvement of mechanical properties [31].

Conclusion

In order to achieve functionality, biological and prophylactic effect of denture with double crowns, dental team who participate in the process of its making is subjected to many challenges. Years of clinical experience suggest that successful production of double crown depends on the following:

- adequate indication;
- adequate preparation of the tooth for fix part of the restoration;
- selection of materials for telescopic or conical construction;
- quality of outer crown and denture framework connection;
- prophylactic value of restoration (to avoid overlap and mechanical irritation of the free gingiva);
- ability to maintain adequate oral hygiene;
- quality of the connection of the aesthetic restoration and alloys and
- retention force of the construction.

Qualification and experience of a clinician and dental technician allow detecting mistakes and correcting them on time, because later reparations are usually unsuccessful and costly. If

the clinical and laboratory procedures are obeyed, the result is the maximum functional and aesthetic rehabilitation of the patient and his satisfaction.

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Chapter VI

Systemic Changes of Interest for Rehabilitation with Complete Dentures: Manufacture and Maintenance

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Abstract

The aging population has profoundly transformed the profile of patients seeking oral rehabilitation. Care delivery to these patients, who present with multiple comorbidities and are usually being treated with various drugs, is becoming increasingly more frequent. Systemic changes prompted by the use of many medications may impose limitations to clinical practice with regard to indication, planning, materials, preparation techniques, and maintenance of prosthetic rehabilitation. Unfortunately, the dental literature is lacking in scientific papers reporting oral manifestations of systemic diseases, as well as in works describing the type of assistance that is necessary to treat such patients. The reported findings are limited to the description of techniques, which are sometimes adapted, for complete denture treatment in patients with neurological diseases, such as Alzheimer's and Parkinson's syndrome, and burning mouth in cases of allergy to dental materials. Several systemic conditions and different treatments should be taken into

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account when it comes to the correct time for prosthetic rehabilitation completion, the materials and technique to be used, and the maintenance procedures to be employed. It is known that in the case of patients with severe immunosuppression, whose origin can be constitutional (senile), pathological (hematological, immune, or endocrine), or prompted by medication (use of immunosuppressants, corticosteroids, chemotherapy, among others), there is higher incidence of oral infections by fungi, especially opportunistic infections such as aspergillosis and mucormycosis, whose incidence may increase due to badly fitted and poorly cleaned dentures. Another group of autoimmune diseases, the so-called pemphigus vulgaris, may have repercussions in the oral mucosa. This disease predisposes the oral cavity to serious injury by lack of adherence of epithelial tissue and by infection due to the constant utilization of immunosuppressants, making the use of dentures very difficult. In addition, patients with renal failure and severe liver disease may present changes in both oral mucosa and salivary glands, which demands manufacture and use of dentures. Treatments such as radiotherapy and the chronic use of bisphosphonates imply in severe changes in both the bone and soft tissues. The common denominator of all these diseases or therapeutic protocols is that they have temporary or permanent contraindications for rehabilitation with conventional dentures or implant overdentures. Thus, on the basis of literature and a 10-year clinical group experience in a dental hospital service, this book chapter aims to describe major diseases and drug therapies that directly or indirectly reflect on the oral cavity, including the necessary adjustments in materials, manufacturing techniques, and maintenance of complete dentures.

Introduction

The development of technologies and methods in health care has become increasingly common the early diagnosis of diseases before unknown, besides of allowing a better monitoring of responses to treatment and disease evolution, often at the molecular level. Allied to these factors, the improvement of treatments using surgical and microsurgical techniques and more effective drugs are responsible for the increase in life expectancy worldwide. Faced with this scenario, it is increasingly common the dentist to meet, at the dentist office, patients with chronic diseases and comorbidities using different drugs [1-5].

Several pathologies and treatments may predispose to important changes in the stomatognathic system involving the oral mucosa, salivary glands, nerves, muscles and bone structure. These changes place the dental surgeon as a major agent in the early diagnosis of some diseases (such as tumors, diabetes, AIDS, among others), in the control of the effectiveness of treatment (pemphigus vulgaris and Behçet's disease, for example), and in the prevention and treatment of oral complications resulting from pathology or drugs, such as osteonecrosis by bisphosphonates and bleeding due to the use of anticoagulants.

Despite a worldwide trend in the reduction of edentulism, some of these chronic diseases and their treatments cause directly or indirectly the loss of dental elements in response to oral complications. These patients often have no systemic or psychological conditions for the rehabilitation with implants or have temporary or permanent contraindication for this type of rehabilitation due to the risks of failure and pathological complications in the bone tissue, not to mention the financial limitation that is imperative in deciding which type of prosthesis should to be used [6-8].

The rehabilitation with conventional complete dentures is often the best option for treatment in these patients; and local or systemic changes brought by these conditions require special care in the manufacture, installation and maintenance of prosthetic devices. Thus, this chapter aims to present the systemic changes and the most common side effects that interfere directly or indirectly in the indication for complete dentures, in its manufacture and maintenance. Unfortunately the literature is scarce in terms of dental management of these patients; the studies found are restricted to literature reviews, and to presentations of clinical case. Techniques and therapeutics showed here are based on the findings from the literature and 10 years of experience in hospital dentistry.

Immunosuppressive Changes

The microflora found in the oral cavity is known as one of the richest and most diverse in the human body. Although bacteria are the most abundant microorganisms in its composition, fungi are the most important causative agents of complications in immunosuppressed patients that make use of prosthetic devices [9-13]. Such microorganisms are organized in the form of biofilms; and, in healthy individuals, they rarely cause infectious complications because local barriers and immune system provide a protection that prevent the development of these infectious complications in the oral mucosa [14, 15].

Some fungi are common inhabitants of the oral cavity. The species most commonly found belong to the genus *Candida* and usually they are present in low concentration and do not cause disease [10, 16]. The identification and quantification of these pathogens have been routinely performed by conventional culture, but methods such as Polymerase Chain Reaction (PCR), REAL-time PCR, and Checkerboard CNA- DNA hybridization have made the recognition and quantification of microorganisms quickly and efficiently [9, 17, 18]. A literature review accomplished by Odds in 1988 found a prevalence of fungal colonization ranging from 20% to 71% in healthy patients [19], as confirmed by recent studies [20, 21]. The species most commonly found in descending order are: *C. albicans, C. glabrata, C. dubliniensis, C. tropicalis, C. Krusei, C. parapsilosis, C. famara,* and *C. guilliermondii*.

Changes that lead to local or systemic immunosuppression are associated with significant increase in oral fungal infections concomitant with the increase of these yeasts both in saliva and in tissues. Figure 1 presents a case of Aspergillosis infection in an imunossupressed patient.

Several studies have shown a high incidence of *Candida* species infections in immunosuppressed patients, and the complications observed in these cases are closely related to the degree of immunosuppression, the integrity of the oral mucosa, and the amount of fungi present in the infected sites. The superficial candidiasis is the most frequent disease and, if untreated, it can raise to systemic infections mainly in severely immunosuppressed individuals, putting at risk the survival of these patients [22-27].

The emergence of fungi resistant to drugs has been reported in the literature [9, 28-31], and the factors responsible for this occurrence are: the recurrent use of low-doses of antifungal agents, changes in protein metabolism, and other genetic events. The biofilm formation has been appointed as an important factor in the increased emergence of resistance to azole drugs [11, 32-35]. In this context, the complete denture has an important role as

carrier of infectious agents because they act as reservoir of fungi in the form of biofilm [36, 37].

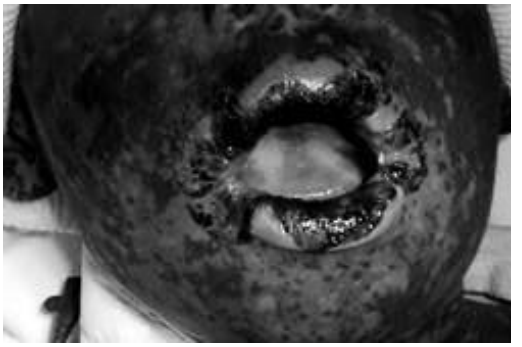

Figure 1. Aspergillosis infection in an imunossupressed patient after allogenic bone marrow transplantation for leukemia.

The immunosuppressive conditions most commonly associated with the increase of oral candidiasis are: AIDS, hematological diseases, diabetes, use of immunosuppressants after transplantation, cancer treatments (surgery, radiotherapy, and chemotherapy), and chronic use of corticosteroids and of immunosuppressants to control autoimmune diseases, among others. The immunosuppression caused by disease will be discussed in this topic, and the drug immunosuppression will be discussed in each specific diseases.

Acquired Immune Deficiency Syndrome (AIDS)

The recurrent oral candidiasis without local causative factors and difficult to control are still considered one of the first signs of the AIDS. The dentist must be aware of this finding and request for serology and evaluation by a specialist in infectious diseases.

Although the incidence of oral candidiasis were significantly reduced after the advent of antiretroviral therapy (ART), its occurrence in HIV/AIDS patients is still frequent and well above that found in the general population.

In 2008, Earlandsen and collaborators evaluated 122 patients on ART and found colonization by species of the genus *Candida* in 81.1% of them. The authors also observed that 33.3% of the individuals examined had symptomatic infection, while 25.3% of the colonized patients had yeasts resistant to fluconazole. The resistance to azole was frequent among HIV/AIDS patients which made it difficult to control the disease. With the use of ART and reducing the use of azoles, the frequency of resistance of germs to drugs has reduced, but it remains in patients with advanced AIDS, in whom other species are often found (*C. glabrata; C. krusei; C. tropicalis; C. parapsilosis; and C. Dubliners*) [38].

The risk of developing oropharyngeal candidiasis is closely related to the absolute count of CD4+T-lymphocte <200cell/μL. However, current findings suggest that the occurrence and severity of candidiasis are most associated to the viral load; and values of count greater than 10000 copies/mL seems to expose the patient to increased risk of developing such infection [13, 39-43].

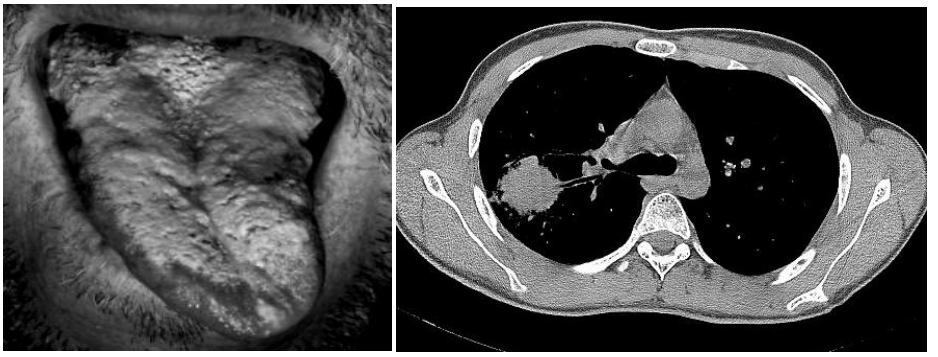

Figure 2. Terminal AIDS patient with oral and pulmonary infection (clinical aspect and tomography) caused by *Candida albicans.*

Diseases	Patient stable CD4+> 500 cells/µL and or VL<1000 copies/mL	Patient stable CD4+ from 200 to 500 cells/µL and or VL <5000 copies/mL	Patient stable CD4+ <200 cells/µL and or VL> 5000 copies/mL
Oral candidiasis	- Professional cleaning of CD and Immersion in 0.2% Clrx solution for 5minutes -Daily immersion in 0.2% Clrx for 2 minutes/14 days -Nystatin 100,000 IU 4 times/day for 14 days or oral gel of miconazole 4 times/day	- Professional cleaning of CD and Immersion in 0.2% Clrx solution for 5minutes -Daily immersion in 0.2% Clrx for 2 minutes/ 14 days -Fluconazole 100mg/day for 7-14 days	- Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes -Daily immersion in 0.2% Clrx for 2 minutes/ 14 days - Use of the CD only during the meals until the resolution of the disease -Fluconazole 100mg/day for 7-14 days
Oropharyngeal Candidiasis	- Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes - Use of the CD only during the meals until the resolution of the disease -Fluconazole 100mg/day for 7-14 days	- Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes - Use of the CD only during the meals until the resolution of the disease -Fluconazole 100mg/day for 7-14 days	- Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes - Use of the CD only during the meals until the resolution of the disease -Fluconazole 100mg/day for 7-14 days
Failure after Fluconazole	- Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes - Use of the CD only during the meals until the resolution of the disease -Itraconazole 200mg/day for 14-21 days	- Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes - Use of the CD only during the meals until the resolution of the disease -Itraconazole 200mg/day for 14-21 days	-Cleaning of the CD and Immersion in 0.2% Clrx solution for 5minutes - Use of the CD only during the meals until the resolution of the disease -Itraconazole 200mg/day for 14-21 days
Refractoriness	- Change of the prosthesis - Hygiene Care -Use of Echinocandins	- Change of the prosthesis - Hygiene Care -Use of Echinocandins	- Change of the prosthesis - Hygiene Care -Use of Echinocandins

Figure 3. Treatment protocol of oral and oropharyngeal candidiasis in HIV/AIDS patients. (VL: viral loud; CD: complete denture; Clrx: chlorhexidine).

The dentist responsible for the manufacture and maintenance of complete dentures in these patients should be upgraded about the medical situation, adherence to treatment, use of medications such as antibiotics (which also predisposes to fungal infections), and results of laboratory exams (mainly viral load and count of CD4). Complete dentures can be made in a conventional way since the patient does not present lesion or infection in the oral mucosa. Figure 2 presents a clinical case of a patient with oral and pulmonary infections by yeast, and with terminal AIDS.

The adoption of an appropriate denture maintenance plan is very important for the success of the treatment. Auxiliary hygiene methods such as cleaning solutions and specific toothpastes should be used only for cases of poor hygiene denture or previous candidiasis [44-46]. If diagnosed candidiasis, the use of denture should be reduced as much as possible, until solving the disease. The use of rebasing material to reduce the trauma of oral mucosa can also be considered important, but it must be remembered that in the presence of candidiasis, it can serve as a reservoir of yeasts. Prophylaxis is not routinely used, but daily doses of fluconazole (100mg) can be used in cases of frequent or severe re-infection, until it reaches a count of CD4+ higher than 200 cells/μL [13, 47].

Figure 3 shows the protocol used for treatment of candidiasis in the Dentistry Service of the *Hospital das Clínicas* of the University of São Paulo at Ribeirão Preto Medical School. Other protocols can be found in the literature.

Every therapeutic choice should be discussed and decided together with the specialist in infectious disease who is responsible for the case. Cases with signs of dysphasia and doubts related to the esophageal involvement should be treated by the medical team. In all cases the denture reline is recommended when the denture does not fit, and this procedure should be done after a professional rigorous cleaning and chemical disinfection of the prosthetic device.

Hematologic Diseases

There are a variety of hematologic diseases that course with immunosuppression due to the lymphocyte commitment and/or severe neutropenia. Treatments of these pathologies often involve the use of chemotherapy agents highly myelotoxic and stomatotoxic, which can result in oral mucositis associated with severe neutropenia, thrombocytopenia and anemia [48,49]. Some of these diseases have oral manifestations as a primary signal (Figures 4 and 5).

Figure 4. Gingival lesion caused by Lymphoma – it was the unic signal of the disease in this patient.

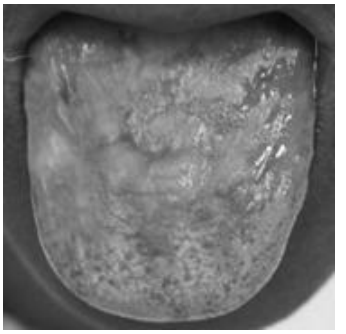

Figure 5. Atrophy of tongue mucosa secondary to anemia.

There are no reports comparing the incidence of oral candidiasis in these patients and HIV/AIDS carriers. However, the presence of severe neutropenia exposes these patients to serious systemic infections associated with risk of death in a more critical way than in patients with AIDS [50-52]. Therefore, treatment should be more aggressive, and the use of removable dentures is entirely dispensed in the most severe cases.

The diagnosis of candidiasis is clinical and confirmed by direct identification of hyphae by exfoliative cytology or biopsy. Culture and assessment by PCR may facilitate the differential diagnosis among the types of *Candida*, but they are not routinely performed due to the large amount of surface contaminant found in the sample. Treatment depends on the extent of lesion, symptomatology and especially the degree of neutropenia (Figure 6).

The forms of superficial infection most commonly found in patients with onco-hematological diseases are pseudomembranous, which is characterized by white plaques that can be removed by scraping, and atrophic or erythematous, in which there is mucosal atrophy accompanied by local erythema. Disease progression is most often asymptomatic.

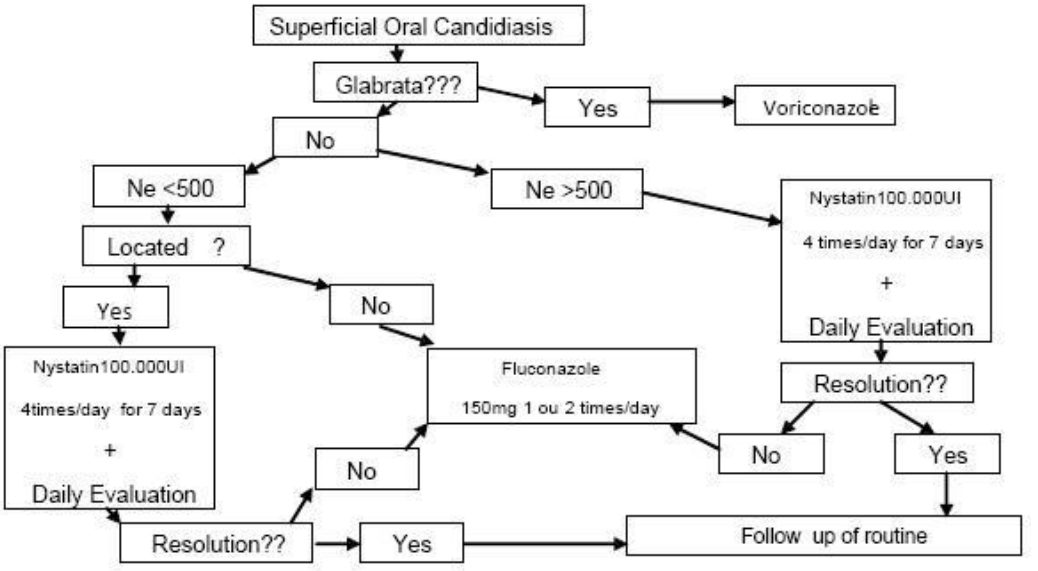

Figure 6. Flow chart showing the treatment for superficial oral candidiasis in patients with hematologic disease (Ne: Neutrophils, represented in $X10^3$ cel./µl; IU: International Units).

Figure 7. Bleeding in a patient with thrombocytopenia after chemotherapy to treat leukemia.

At our service, it has been observed an increased incidence of oral candidiasis caused by *C. glabrata.* Infections caused by these microorganisms generally have specific clinical manifestations, characterized by the presence of scraped membrane associated with necrotic tissue, local bleeding and pain. Treatment of choice is voriconazole and another option is to use Amphotericin B, since this yeast has been shown to be resistant to fluconazole [53].

Thrombocytopenia rarely brings bleeding complications in patients with complete denture, except in cases of trauma and laceration due to prosthesis associated with mucositis (Figure 7). In cases of platelet (PLQ) count greater than $50{,}000x10^3$cells/μL, the bleeding is usually controlled with local methods, such as suturing and compression. It is indicated the transfusion and use of antifibrinolytic agents for refractory bleeding or in cases of PLQ<$40{,}000x10^3$ cells/μl. This decision must be taken together with the hematologist.

Patients with acute hematologic diseases such as leukemia and lymphomas hardly seek a dentist for the manufacture or maintenance of prostheses, which is usually performed in hospitals. But those with long-term diseases such as myelodysplastic syndromes, aplastic anemia, Fanconi anemia, multiple myeloma, among others, may be submitted to the construction of conventional complete dentures, being essential to take care of using flexible molding materials such as silicones to reduce the risk of tissue damage. In addition, a full care should be taken with the disinfection of models, base plate, and other devices produced by the prosthetic.

Special attention should be given to patients with multiple myeloma because of the possibility of developing plasmacytomas, which are locally destructive bone lesions that can affect the mandible and jaw, causing risk of fracture. This situation requires change in hematologic treatment, with indication of radiotherapy in some circumstances. Thus, the panoramic X-ray should be taken in the beginning of treatment and whenever there is need. Moreover, it is common for these patients to take bisphosphonates which increase the risk of bone necrosis and contraindicate the use of the implant.

As for HIV/AIDS patients, the maintenance of prosthesis must be rigorous and the dentist must know in detail the patient's clinical condition. The dentist should be aware about laboratory tests (such as complete blood count), medication and chemotherapy treatment to predict the risk of complications in each moment. Patients who have neutrophil count less than $500x10^3$cells/μLl should be treated by professionals.

Diabetes

The patient with diabetes, a metabolic syndrome with autoimmune feature, may have local or systemic immunosuppression and difficulties in the healing of oral lesions. These findings have been related to the progression of the disease and its control. Patients who are users of complete denture and with bad glycemic control may have increased risk for the development of oral candidiasis, especially in cases of failure in the adaptation of the prosthetic device [54].

Some studies show that *C. albicans* isolated from diabetic patients showed higher adherence to fibronectin and epithelial cells [55, 56]. This finding associated with a greater amount of hyphae in the oral cavity related to the higher concentration of glucose in saliva increases the risk of candidiasis in these patients [57-59].

The clinical framework, with rare exceptions, tends to be localized, less invasive, and should be treated with topical agents devoid of sugar such as miconazole oral gel (4 times/day for 14 days).

The use of nystatin should be avoided due to the large amount of sugar in its composition. The cleaning of the prosthesis by a qualified professional and the relining should be performed and, after the resolution of the infection, new prosthesis needs to be made if the old one is inadequate. In cases of maintenance of infection, after the seventh day of treatment with topical antifungals, the use of fluconazole is indicated (100 mg/day from 7 to 14 days).

It is important to highlight that the prosthesis may be the agent responsible for maintaining the fungal disease even after the rebasing. If the infection persists, the use of dentures should be discontinued until the resolution of the infection.

Immunosuppressive Drugs and Treatments

Several autoimmune diseases are treated with chronic corticosteroid regimens associated with or without immunosuppressive drugs. In all cases the care of the maintenance of prostheses and treatment of oral candidiasis should be performed similarly to that described for the diabetic patient.

Special attention should be given to the treatments that may cause neutropenia, such as chemotherapy treatments. Each case must be evaluated separately and the conduct should be taken depending on the degree of neutropenia and extent of the lesion, as shown in Figure 6.

Diseases with Direct Impact in the Oral Cavity

Several pathologies have direct repercussion in the oral cavity, and the first clinical symptoms often affect the oral mucosa. In the following, the diseases that most require special care or changes in treatment regarding the rehabilitation with complete dentures will be shown.

Phemphigus Vulgaris and Cicatricial Pemphigoid (Mucous Membrane Pemphigoid)

Despite having different histological features, clinical evolution and extent of involvement of tissues, the phemphigus vulgaris and cicatricial pemphigoid can cause serious lesions in the oral mucosa that often restrict the use of removable dentures. They are autoimmune blistering disorders characterized by the production of antibodies directed at different regions of the epithelium [57].

The mucous membrane pemphigoid or cicatricial pemphigoid is characterized by subepithelial bullous lesions with a predilection for the elderly, mean age 62 to 66 years [58-60]. The most commonly affected areas are the oral and ocular mucosa; but it may also presents lesions in genito-urinary, gastroesophageal and respiratory tracts. Severe complications such as upper airway obstruction, loss of vision, urinary, and sexual dysfunction can occur [61].

The dental surgeon is an important agent in the diagnosis and in the support for treatment of this pathology since the oral mucosa is involved in almost 100% of cases, being often the only affected area [62]. Cutaneous involvement can occur, though more rare. The oral cavity presents recurrent superficial exfoliative lesions, especially in areas of trauma, and the diagnosis can be confirmed by biopsy that presents subepithelial lesion associated with linear deposition of IgA, IgG and/or C3 along the epidermal basement membrane zone [61].

On the other hand, pemphigus vulgaris is characterized by intraepithelial blistering and affects the skin and oral mucosa. The initial lesions are often attenuated and attack the oral cavity, followed by an aggressive skin picture. The disease is precipitated by IgG autoantibodies binding to desmoglein 3. As the lesions are more superficial, the oral mucosa presents desquamative process with areas of scrub and, luckily, bullous lesions may be observed before its outbreak. From seventy to ninety percent of patients develop erosions in the oral cavity [57] (Figures 8, 9, and 10).

The rehabilitation of edentulous patients who have pemphigoid secondary oral lesions is a challenge in the sense that the conventional prostheses may worsen the case due to the trauma on the tissue. However, there are no studies reporting the peri-implant health in patients with these pathologies, since the cleaning of protocol-type prosthesis would be an important traumatic factor to the mucosa.

Figure 8. Tongue lesions in a patient with mucous membrane pemphigoid.

Figure 9. Pemphigus vulgaris: initial lesion.

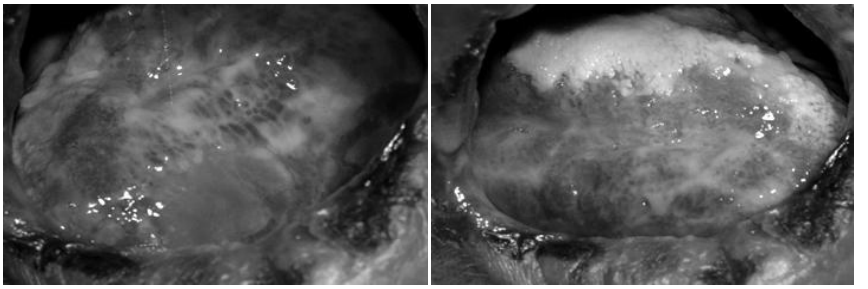

Figure 10. Oral advanced involvement of pemphigus vulgaris.

In our clinic there are two patients who were using this type of prosthesis when the diagnosis of cicatricial pemphigoid was made. They had to stop the use of the prosthesis due to the recurrent bacterial infections and peri-implant lesions.

The attempt to manufacture conventional complete denture is suitable in those cases well controlled; in these situations, care must be taken in order to avoid trauma to the tissue during the manufacture of prostheses. The molding should be atraumatic and with the use of elastic materials, such as silicones (the materials of choice). The maximum adaptation should be obtained. The use of resilient reline seems to reduce lesions on the mucosa, and the occlusal adjustment should be carefully conducted. All possible interferences and overload to tissues should be adjusted. At our service, during the first 14 days, patients are reviewed daily for adjustments. In cases in which the patients do not use topical corticosteroids, we have initiated the use of a combination of hydrocortisone, neomycin, troxerrutin, and ascorbic acid in oral ointment administration, three times a day, on the surface of contact, 14 days before the installation of the prosthesis and with apparent success in reducing complications.

In cases of recurrent injuries which are difficult to control we have proposed the use of removable implant-prosthesis, in order to reduce the overload to tissues and to facilitate the cleaning. Unfortunately, there are no reports in the literature regarding the rehabilitation of these patients.

Whatever the case, the use of prosthesis should be suspended in the presence of extensive lesions and/or associated candidiasis. Local treatment consists of the use of topical corticosteroids in the form of pastes and gels. Orabase formulations are little employed because most patients report discomfort with their use. Refractory cases may be treated with

topical immunosuppressants such as tacrolimus, and in this case it is interesting the serum titration of drug concentration, since there are reports of immunosuppressive concentrations with the use in ulcerated mucosa. In cases involving other organs or poor control of lesions, the treatment becomes systemic with the use of corticosteroids and/or immunosuppressive drugs.

Behcet's Disease

Behcet's disease is an inflammatory alteration of probable autoimmune origin, characterized by recurrent oral ulcers and other systemic manifestations, which characterize the Behcet's Syndrome. This disease usually has calm and acute episodes and affects young adults between 25 and 30 years [63-64]. The oral ulcers tend to be deeper and more painful than those found in pemphigus and cicatricial pemphigoid, and produce scarring in up to 10 days [65].

Diagnosis is difficult and usually perilesional microscopic evaluation shows vasculitis. Formations of venous and arterial thrombosis may be occurs; and active lesions are infiltrated by neutrophils [63, 66]. The presence of oral, genital and ocular lesions associated with absence of typical changes of pemphigoid enables the diagnosis of disease. The treatment is controversial and there is no established protocol. The use of topical corticosteroids in oral lesions has shown disparate responses among patients [63].

Because the disease usually has periods of remission and the lesions are usually localized, the use of complete dentures is more peaceful than that described for cases of pemphigus and pemphigoid. However, constant acute lesions impose restrictions on the use of prosthesis due to the pain in the areas of lesions. The use of topical anesthetic lidocaine and vaseline in the area of lesion has shown adequate to our patients.

The manufacture of complete dentures can be performed routinely since the appearance of lesions is not associated with local trauma, and the care related to the adaptation and installation are the same as for patients with pemphigus and pemphigoid, with the exception of the use of corticosteroids prior to installation, which is not usually employed.

At our service, there is a patient with Behcet's disease who has important limitation of opening the mouth caused by fibrosis in the lip commissure, due to recurrent lesions in this area. In this case, the dental treatment is extremely committed and the possibility of lip commissurotomy should be discussed in a multidisciplinary team.

Sjögren's Syndrome

Sjögren's syndrome is a chronic inflammatory disease of probable autoimmune etiology, characterized by xerostomia (dry mouth), xerophthalmia and lymphocytic infiltration into fragments of minor salivary glands [67-71]. The impairment can affect other exocrine glands such as pancreas and sweat glands.

The degree of xerostomia may vary among patients but the symptoms usually described are dysphagia for solids, aphthous lesions in oral cavity, and secondary infections - candidiasis (especially in users of complete denture). Treatment is usually symptomatic with the replacement of saliva through artificial solutions and use of sugarless chewing gum. The

use of muscarinic agonists such as pilocarpine has been described as effective to stimulate saliva production, yet its benefit is still controversial [72-74].

The manufacture of complete dentures should be performed in a conventional technique, and in case of lesions or lack of retention of the prosthesis, the use of artificial saliva in the inner surface of the prosthetic device usually facilitates its use. Maintenance should be done carefully and frequently, repeating needed rebasing and reinforcing hygiene as a preventive method against fungal infection.

In case of oral candidiasis, the treatment may be conservative with the use of topical solutions of nystatin or miconazole oral gel, as described before, associated with the hygiene of the prosthesis. The manufacture of implant-supported prosthesis is not contraindicated and may be a good alternative to the difficulty in adapting to conventional prosthesis.

Chronic Renal Failure (CRF)

It has been described a number of secondary oral changes to disease of base and to treatments for patients with chronic renal failure [75]. The treatment in these patients may be expectant such as dietary changes and drug control of complications; or invasive, resulting in dialysis and renal transplantation. Some medications such as cyclosporine and calcium channel-blocker have been associated with gingival enlargement in patients with teeth; however, it is not found in complete edentulous, so this topic will not be addressed [76-81].

Xerostomia can arise in individuals receiving dialysis, probably due to the restriction of liquid intake or as a side effect of drugs. This change is associated with the difficulty in adapting to complete dentures, dysphagia for solids and dysgeusia [82-84]. Care in the manufacture and maintenance of complete dentures are the same presented for the cases of Sjögren syndrome. However, it seems that the life expectancy of the implants may be reduced in these patients due to changes in bone remodeling [85-89].

It is important to highlight that individuals with chronic renal failure may have an ammonia-like odor and important changes such as metallic taste [83]. Sometimes patients seek dental causes for such changes. Other lesions described in the oral cavity are ulcerations, lichen-planus-like disease and hairy leukoplakia. Uremic syndromes were associated with hairy leukoplakia without the presence of Epstein-Barr virus [90, 91].

The incidence of fungal infection in transplant patients is not higher than in the general population, probably by the use of secondary prophylaxis [90]. Special attention should be given to the prevention of lip cancer and Kaposi's sarcoma that seem to have an increased incidence probably due to immunosuppression [92, 93].

Coagulation Disorders

This item was placed in the chapter because it is frequent that dental surgeon does not accept the care of patients with coagulation disorders. Regardless of the presented disorder (hereditary bleeding disorders, hemophilia, deficiency of other factors, platelet diseases; use of anticoagulants or antiplatelet, among others), there are no restrictions or special care in the manufacture or maintenance of complete dentures in this patients.

When mucosal lesion occurs during the manufacture of dentures, it will hardly have major bleeding, since in most cases it is superficial. In this case, local compression with gauze soaked in antifibrinolytic solutions (such as ε-aminocaproic acid and tranexamic acid) for 5 minutes usually contains minor bleeding.

Neurological Disorders and Dementia

Among neurological diseases and dementia, Parkinson's and Alzheimer's will be treated separately due to their incidence, prevalence in the elderly, and direct and indirect impairment of the oral cavity. However, regardless of the disease, the dental treatment and care should be decided case by case depending on the degree of psychomotor impairment, family structure and evolution of the disease. In these cases, the good sense of the professional and the detailed knowledge of patient conditions are imperative in deciding about the best type of rehabilitation in complete edentulous.

Parkinson's Disease

Parkinson's disease is a neurodegenerative disorder characterized by changes in movement and muscle control due to loss of dopaminergic neurons in the substantia nigra [94]. Its incidence is estimated between 1% and 5% of the population over 65 years, second only to Alzheimer's disease [95]. Despite its predilection for age above 40 years, it can also affect younger individuals.

Initially symptoms usually are bradykinesia and rigidity, and even with the replacement of dopamine and other drugs, after years, the disease tend to progress to dyskinesia and motor fluctuations. Dementia can affect up to 20% of terminal cases [96-98].

The moderate and advanced phases of the disease show important changes to the maintenance of oral health, especially with regard to the rehabilitation of complete edentulous patients. In 2011, Bakke et al. evaluated and compared 15 patients who had a moderate or advanced disease with a control group presenting similar oral characteristics and age to the studied group, and found a significant deterioration in performance and masticatory efficiency, reduction of oral functions, reduction of mouth opening, and difficulty to perform oral hygiene [99]. Other changes have been reported such as dysphonia, dysphagia, drooling, bruxism, xerostomia and increased complications with complete dentures [100-102].

The rehabilitation of complete edentulous patients should be discussed with the patient and family and scheduled for the possible evolution of the disease. In the absence of significant motor impairment, there are no restrictions or special care in the use of conventional prosthesis. However, in the moderate or severe phases, the lack of muscle control precludes the use of this type of rehabilitation due to the difficulty of adaptation and the worsening of dysphagia, since the control of the oral phase of digestion is often precarious. In these cases, a viable option is the manufacture of implant-retained removable prosthesis because they offer greater safety in use and facilitate cleaning. The patient often has difficulty in cleaning, then it is essential the education of the caregiver.

Despite to deserve attention, upper prosthesis generally can be made through conventional techniques at any stage of the disease. During terminal phase, with the presence of dyskinesia, the manufacture and use of dentures is usually not possible.

Alzheimer's Disease

Alzheimer's disease is also a progressive neurodegenerative disorder; however, it is different from Parkinson's disease because, in the initial phase, Alzheimer's disease is characterized by memory failure, and progresses slowly to severe and disabling dementia. Neuromotor changes, when occur, are found in advanced phase of disease. The infectious pulmonary complications resulting from aspirations for dysphagia associated with poor hygiene, malnutrition and inanition are usually the causes of death in these patients [103-107].

Alzheimer's has been showed as the most common dementing disorder in the world with a prevalence of 3% between the ages of 65 and 74 years, 19% between 75 and 84 years, and 47% in individuals over 85 years [108]. The literature provides reports of serious complications due to the precariousness of oral cavity hygiene in more advanced dementia. In a prospective evaluation, Friedlander et al (2006) described frequent forgetfulness of the removal of the prostheses for up to 3 consecutive days, patients with food debris on the bottom of the vestibule, and higher incidence of prosthetic stomatitis and secondary lesions due to the use of conventional dentures [106].

Regarding the manufacture of new prosthesis and the type of rehabilitation to be used in complete edentulous, the decision should be taken, as well as for Parkinson's disease, based on the clinical situation of the patient, and social and family structure in which he/she is inserted, since in many cases the presence of a caregiver is essential. Usually during advanced phases, the manufacture of new prosthesis is impracticable due to the impossibility of patient’s cooperation; in these cases, the maintenance of the old reline denture is a good choice. At any phase of the disease, the appointments to evaluate the adequacy of hygiene and cognitive and motor skills for the use of dental prostheses should be done frequently with returns every 30 or 60 days [106, 107, 109-115].

It is important to highlight that a variety of drugs used to control the disease have dangerous medication interactions with dental drugs such as local anesthetics. Of interest to the management of complete dentures is the possibility of unwanted interaction of itraconazole with donepezil, galantamine, rivastigmine, quetiapine, carbamazepine and divalproex; for this reason, its use should be avoided in the treatment of fungal infections. There are no reports on interactions with fluconazole [116-119].

Secondary Oral Changes due to Treatment

Radiotherapy of Head and Neck Regions

Among the acute complications of radiotherapy, oral mucositis (Figure 11) has been reported to be the most frequent, debilitating, dose-dependent and dose-limiting, being

considered an inevitable side effect of radiation in head and neck [120-126]. Studies show that the incidence varies from 50% to 97% in patients undergoing radiotherapy of head and neck, and doubling the incidence of grade 3 mucositis when chemotherapy is associated [127-134]. Besides increasing the cost of treating, this complication is associated with increased morbidity and mortality, being the main factor responsible for the interruption and alteration in the *radiotherapy management in head and neck [135, 136].*

Moreover, a high rate of oral infection by *Candida* associated with mucositis has been reported in the literature. Apparently, mucositis predisposes to infection due to the loss of epithelial barrier, while the installed candidiasis provides the appearance of ulcers, making the epithelial repair more difficult [137-141].

Assessments of oral microflora during and after radiotherapy have shown a "shift" in both the variety and amount of microorganisms [141-143]. Prospective studies have demonstrated a high incidence of colonization (more than 93%) and infection (between 30 and 52%) by *Candida* in the oral cavity of patients undergoing radiotherapy of head and neck [139, 142, 144]. An important participation of non-albicans species in the colonization and oral infections in these patients has been demonstrated [139, 143].

Xerostomia is one of the most frequent chronic complications and responsible for damaging the quality of life of these patients [129, 145-148]. Studies have shown lower levels of xerostomia in patients undergoing conformal radiotherapy and IMRT, with reduction of irradiation in contra-lateral parotid gland when compared to patients undergoing conventional treatment [129].

Related to what was exposed, the complete dentures can be a complicating agent in the development of oral mucositis and candidiasis during radiotherapy. The patient should receive adjustments in the prosthesis and oral hygiene instructions prior the beginning of radiotherapy with the aim of reducing the trauma and local contamination. Other important information is the requirement that the prosthesis is removed during the manufacture of the mask and during all radiotherapy sessions. In the cases which it is not possible to obtain well-adapted and decontaminated prostheses, their use should be discontinued prior the beginning of treatment.

The patient should receive weekly follow-up and, in the first sign of tissue injury, the use of the prosthesis should be reduced, since each session of radiotherapy is expected worsening of the fragility of the oral mucosa. Specific treatments for the prevention and control of mucositis can be used [149-152].

Figure 11. Oral mucositis after radiotherapy.

In the post-radiotherapy, patients can and should receive well-adapted complete dentures; at our service, the manufacture of new prosthesis is only initiated after the clinical resolution of secondary oral lesions due to radiotherapy. Care in the manufacture and maintenance of the prosthesis are the same used for the previously described cases of xerostomia.

Chemotherapy

The chemotherapy regimens used today are the most diverse possible depending on the histologic type, tumor location and clinical performance of patients. Thus, the oral complications presented in each regime is directly associated with the type of drug and dosage used in the treatment [22, 25].

Possible complications in the oral cavity are the development of mucositis and oral infections; the first one depends on the presence of stomatotoxic agents and the second of myelotoxic agents capable of causing neutropenia [48, 49].

The necessary care with the prosthesis in the prevention and control of mucositis are the same presented for radiotherapy. And the management of infectious complications and the risk of bleeding are the same presented for the hematological diseases.

Use of Bisphosphonates

The use of bisphosphonates, particularly intravenous, has increased because of its important role in controlling tumor bone lesions (tumors of the prostate, breast, multiple myeloma, among others). Unfortunately, there are reports of its widespread use for control of no severe osteoporosis due to the ease of dosing [153, 154].

These drugs have been associated with extensive *osteonecrosis* of the jaws, difficult to control, and with severe infectious complications (Figures 12 and 13). The pathogenesis of the disease is still not completely understood, but it seems to be associated with the failure in the activation of osteoblasts by reducing the number and activity of osteoclasts. In addition, its anti-angiogenic effect seems to develop an essential role in the process of necrosis [155-158].

Although the majority of osteonecroses are associated with triggering events, such as dental extractions, periodontal surgery, and prosthetic trauma, their occurrence may also happen spontaneously. The risk of necrosis is directly related to the type of bisphosphonate, application form, dosage, time of use, pathology of base, and oral conditions. However, some genetic component seems to play key role in its development [157, 158]. In general, the user of injectable presentations has significantly higher risk to develop a lesion than the user of oral formulations, due to its potency and bioavailability [153, 154].

The dental extractions should be avoided in patients who use or have used intravenous bisphosphonates and its indication and realization should be provided by professionals with experience in dealing with these patients. Regarding the conventional complete dentures, special care have to be taken in their manufacture and maintenance, aiming at the minimization of lesion in the oral mucosa, since its laceration can serve as a trigger for necrosis.

Figure 12. Biphosphonate-relate osteonecrosis of the jaw (from left to right: oral lesion, panoramic radiography, and bone removed after surgery).

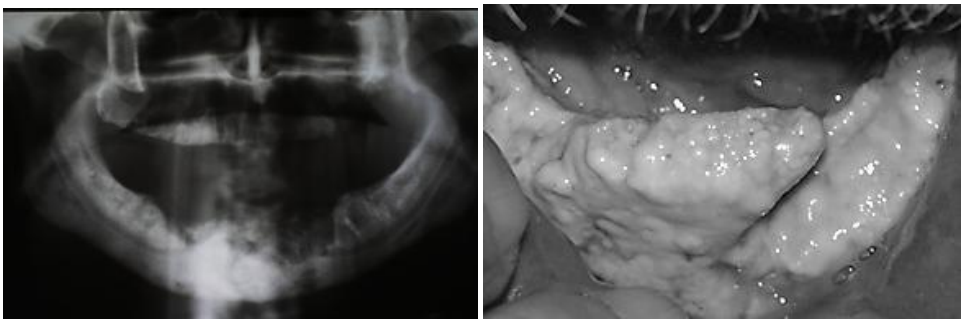

Figure 13. Biphosphonate-relate osteonecrosis of the jaw (from left to right: panoramic radiography, oral lesion showing the exposed jawbone). This patient had myeloma and died due to infectious complication in necrotic area.

The manufacture of the prosthesis in areas operated by necrosis should be made with extra caution; and in the presence of any sign of suppuration or bone exposure, its use should be discontinued. Osseointegrated implants so far are contraindicated in users of injectable forms of the drug.

Conclusion

The world population is aging and, associated with this event, there is an increased incidence of chronic and autoimmune diseases. Dentists have a key role in early detection and treatment of such diseases. Due to this fact, it is important to performed a detailed medical history and learn about the pathophysiology of each case, as well as to dominate the therapy applied and its possible complications. This knowledge is necessary to indicate the best type of prosthetic rehabilitation and care need to prevent and treat possible complications of the treatment.

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Chapter VII

Laboratory Improvement of the Clinical Performance of Complete Dentures – A Review

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Abstract

Laboratory processing techniques have been refined in an attempt to achieve complete dentures with better clinical performance. Regardless of the type of denture base material (microwave-, light-, or heat-polymerized polymethyl methacrylate, for example), materials as well as handling and polymerization methods have been continuously modified with a view to obtaining more resistant dentures. In an attempt to improve the mechanical properties of base materials and to try to overcome the low impact and flexural strength of currently available dentures, which often results in clinical failure, various laboratory treatments have been proposed. The incorporation of reinforcing structures such as glass fiber, carbon fiber, Kevlar, aramid, and fiber-reinforced composite, which can be found in different sizes and shapes and are sometimes impregnated with substances such as silanes, has been successfully tested in some cases. However, incorporation of such compounds can culminate in undesirable effects such as larger amount of residual monomer, difficult polishing, and unsatisfactory aesthetics. Metal wires have also been used over time for this purpose, as well as substances such as methyl acetate and methyl formate. The increased bond strength between artificial teeth and the denture base material has also been relentlessly pursued.

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New positive results are being obtained by means of techniques that promote interpenetration of the polymer networks of the two materials and make use of substances such as dichloromethane. To improve the biological properties of dentures, simple procedures such as immersion in water for defined time periods has been evaluated, in order to reduce their totoxicity. Studies have shown that dibenzoyl peroxide, used as initiator in polymethyl methacrylate resin and associated with allergic processes, is released from conventional dentures after polymerization, but this event can be substantially reduced with completion of an additional polymerization cycle. Still, in order to reduce dentures contamination, several antimicrobial agents such as silver have been incorporated into the base material, which has led to positive effects with regard to their antimicrobial action. However, decrease in flexural and impact strength has sometimes been observed. In this context, this book chapter intends to update the reader on materials and laboratory techniques that can optimize the physical, mechanical, and biological properties of dentures that are considered to be the most relevant to the clinical performance of complete dentures.

Introduction

The best clinical performance of dentures has been pursued relentlessly over time. Among the factors responsible for the success of the rehabilitation treatment can be highlighted the materials selection and processing laboratory techniques, that can be controlled by professionals involved in the construction and repair of these prostheses.

Regardless of the material selected, the working parameters must be strictly defined and directed to obtain a higher conversion of monomers into polymers, since the presence of residual monomer affect the clinical performance of dentures by changing its physical, mechanical and biological properties [1-6]. Unsatisfactory results of flexural strength, for example, may be related to recurrent fractures of the middle line, as well as low impact strength values increase the likelihood of prosthesis fracture when it collides with hard surfaces [4-7]. High values of sorption and solubility can compromise the dimensional stability of the prosthesis, submit the material to an internal stress and decrease the values of mechanical strength [8], depending on the plasticizer effect of the polymer matrix [9]. In addition, the solubility releases toxic substances to the environment, which may cause negative reactions in oral tissues [4,10].Thus, in addition to improving the working parameters for each material, researchers have evaluated the performance of reinforcing structures for acrylic resin to optimize the values of resistance and reduce the chances of fracture. Moreover, some alternatives to improve the adhesion of artificial teeth to the base material have been tested successfully. Given the above, some considerations on the denture laboratory techniques recently presented in scientific literature and its clinical consequences have been briefly reviewed below.

Reinforcement of Acrylic Resin

The use of reinforcement structures to improve the mechanical properties of denture base resins is not new. Over time, different materials were developed and put into practice, but until today questions about which material is most effective still remain.

Glass fibers, aramid and nylon were tested as reinforcement materials of acrylic resins and their benefits were proven through the improvement of flexural strength; however, the first one still promote the best results [11]. Reinforcement steel structures have also been used with success for a long time in order to reinforce the mechanical resistance of acrylic resins [12]. However, due to the predictability of clinical performance and the ease of application, glass fibers have been widely used than other types of reinforcement structures. Therefore, some considerations on the use of glass fibers are made in the following.

It is known that glass fibers promote the improvement of the mechanical properties of acrylic resins because their modulus of elasticity is high, which allows that the stress of chewing is absorbed with less deformation of the denture [11]. As a result, the flexural strength of resins reinforced by glass fibers is from 1.54 to 1.75 times higher than the unreinforced resins [13]. It was also reported that the use of glass fibers is able to promote a mechanical reinforcement of complete denture in a significant way (with average values of 919 N compared to 677 N for unreinforced materials) [14].

However, the positive clinical results are dependent on factors such as the stable union in the interface resin/fiber. Silane contributes notoriously to increase the adhesion between the resin and reinforcement fibers and promotes surface protection of these fibers, preventing damage during the handling [15]. Like the silane, the monomers also increase the adhesive strength of fibers, but this substance may remain without reacting inside the resin, having a negative influence on the mechanical properties of the material [16].

Fibers pre-impregnated by the manufacturer with polymers and silanes are available in the commercial market; others called pure or not impregnated fibers require a previously surface treatment made by the dental surgeon or dental prosthesis technician [17]. It is highlighted that in the latter case should have the maximum of care related to the complete wetting of the fibers by the bonding agent [18]. Contamination of the fiber reactive surface during handling, especially in the case of impregnated fibers, should also be carefully prevented.

The preference for pre-impregnated systems is because they eliminate the clinical stages which can result in errors, besides being easier to manipulate due to the decrease of their elastic memory and minor fraying of the fibers in the handling [19,20]. The pre-impregnated fibers also provide the highest values of flexural strength [21].

There are reports of clinical follow up for up to 5 years which showed that polymer pre-impregnated E-glass unidirectional fibers and pre-impregnated E-glass fiber nets promote successfully the reinforcement of acrylic resin complete dentures, especially for patients with high occlusal load [22]. Regarding the type of fiber glass, there is no scientific consensus on the subject, however some authors affirm that the unidirectional fibers promote a structural reinforcement more efficient than the braided ones [23,24].

The ideal positioning of the reinforcement fibers in the denture base resins diverges in the literature. A recent study demonstrated that the location (anterior region, middle region, anterior and posterior regions, and under the ridge lap) of the glass fibers reinforcement does not seems to influence in the flexural strength of acrylic resins [13]. However, a previous study revealed that the orientation of reinforcement fibers has significant influence on the prognosis of rehabilitation treatment with complete dentures, being an angle of 90° its ideal position in relation to the potential area for fracture and closer to the surface of the prosthesis [20,25]. There is also indication of placement of the reinforcement fibers at polished side to reduce the risk of fractures due to stress concentration in this region [26]. The amount of

fibers may also affect the structural reinforcement, having reports that the application of 1.0% of fibers promotes ideally the obtained effect [27].

The success of the use of reinforcement fibers in the manufacture of complete dentures is established; however, it depends on the strict following of the guidelines recommended for each material, both in clinical and laboratory stages.

Denture Repair

Fractures in complete denture bases are a relatively common clinical occurrence. Therefore, the need to develop effective repair techniques is justified. However, what is seen clinically is that this region is weaker and subject to re-fracture, which occurs predominantly between the base material and that used to repair, setting a fracture of adhesive nature predominantly. Factors such as the type of material used for repair and its surface contour as well as the treatment given to the denture base resin before the repair material application influence on the clinical results [28].

The desirable requirements of a material used for repair of complete denture bases are: color stability, flexural strength, dimensional stability, ease to work and accessible cost [29,30]. Among the materials indicated for the repair of denture base, the glass fibers are highlighted. However, regardless the materials selected for repair, it is known that repaired resins have lower flexural strength than intact resins, without fractures or repairs [31].

In the repair of heat-polymerized acrylic resins, which are the most commonly used for making removable dentures bases, a study showed that the use of autopolymerized resin reinforced with unidirectional and woven glass fibers is the most effective method to restore the mechanical properties of these materials [32].

Some alternatives to increase the bond strength between the repair and the base material have been evaluated such as the application of acetone, methylene chloride, or metilmetacrylate for periods from 30 to 180 seconds [33].

The continuity of the search for an effective and durable mechanism of denture repair is justified since the complete denture will be submitted with intensity to occlusal loads and their variations.

Bond Strength between Tooth and Base

The bond of artificial teeth to the denture base resins is a recurring problem in dental clinic. There is information in the literature that certain chemical [34-36] or mechanical treatment [37] in the ridge-lap artificial tooth surface may increase its adhesive strength to denture base materials.

The application of dichloromethane in artificial teeth, in the area of contact with the base resin, potentiates its bond with auto- and heat-cured resins [34,35]. The use of an acrylate bonding agent to enhance the shear bond strength was also recommended as a resource to promote the bond of highly cross-linked artificial teeth and light-polymerized urethane dimethacrylate [36]. However, there is information in the literature that the realization of

mechanical retention potentiates the shear bond strength values of resin and artificial tooth bond more than the surface treatment with monomers [37].

The parameters of the polymerized cycles also influence in the results of adhesion, being the shortest responsible for the lowest bond strength values [38,39]. Regarding the characteristics of laboratory manipulation, it should take special care in removing the wax residue, so there is no reduction in the values of adhesion between artificial tooth and base material [40].

Regarding the type of complete denture base resin, it is known that cross-linked artificial teeth (IPN), widely used nowadays due to their enhanced physical and mechanical properties; adheres easier with the heat-cured polymethilmetacrylate than with the microwave-polymerized materials [35].

Another aspect that has been highlighted as a factor that contributes to the adhesion of artificial teeth to the base material refers to the selection of both from the same manufacturer [41]. Ideally, manufacturers should indicate the compatibility of the denture base materials with the artificial teeth as well as the laboratory treatments indicated to improve the adhesive strength, then more favorable clinical results would be obtained.

Biocompatibility

The polymers used for the manufacture of denture base have shown different degrees of cytotoxicity, caused by their unreacted components and byproducts remaining after the polymerization process [42-44]. Clinically, the signs and symptoms most often associated with this fact are erythema, erosion of the oral mucosa and burning sensation of the mucosa and tongue [45].

In the prosthetic laboratories, the acrylic resin is the material that presents the occurrence of the highest number of adverse reactions, being responsible for developing contact dermatitis in the hands of 61% of the dental technicians [46].

Among the components released into the oral environment and which have relations with adverse effects, the dimethylaminoethyl methacrylate (DMAEMA) and its degradation products, such as dimethylethanolamine, are vasoactive and induce relaxation and contraction of blood vessels, exerting an important role in homeostasis [47]. Methyl methacrylate, the main component of acrylic resins, is associated with dermal sensitization and respiratory irritation; and besides this substance, the formaldehyde is also released into the environment, mainly from autopolymerized resins [43,48].

The biocompatibility of different types of denture base resins has been evaluated over time, in an attempt to define the best operating parameters for each material [49, 50]. In an attempt to reduce aggression to the tissues of the oral cavity, the hypoallergenic resins were developed. These materials have lower amounts of residual methyl methacrylate than conventional heat-polymerized acrylic resins [51]. Trials show that hypoallergenic resins have smaller sorption and solubility values than conventional acrylic resins, which is a significant advantage of these materials since these properties influence on the dimensional stability of the material, among other [52]. However, the poor availability of information on their mechanical properties does not give security to be definitely used in place of conventional polymethylmethacrylate.

It is well known that the handling characteristics have fundamental influence on the biological properties of base material. The polymer/monomer ratio is one of the variables that significantly influence the cytotoxicity of acrylic resins, and the more monomer added to the mixture, the greater the amount of its residual effect and cytotoxicity. However, the correct establishment of this relationship which should be proposed by the material manufacturer also takes into account the conditions of clinical work [53].

Polymerization method is decisive in the cytotoxicity of polymeric materials, since, from them, result in different residual monomer concentrations [53]. The literature shows that chemically-activated resins have lower biological compatibility than microwave-activated and heat-polymerized resins, since they have lower conversion ratio of monomers into polymers and, consequently, greater amount of residual monomer [54-56].

Depending on the characteristics of the polymerization cycle, such as temperature and time, the different amounts of residual monomer are maintained in the polymer, resulting in various degrees of cytotoxicity. Thus, in general, a longer polymerization cycle results in a lower cytotoxic effect [53,57].

Given the above, various post-polymerization treatments have been evaluated and recommended in order to minimize the cytotoxicity reactions, such as those that aim primarily to increase the degree of polymer conversion [44,58-61].

Additional microwave polymerization cycles may provide a reduction of the residual monomer content of up to 25% [58], are technically easy and quick to run, and produce little heat [59]. Due to the high conversion of monomer to polymer, these cycles potentiates the mechanical strength of these materials [44,58,59,60].

Water-bath post-polymerization also contribute to the reduction of cytotoxicity of denture base and reline acrylic resins, since in this early period occurs the biggest release of toxic components [44]. Besides the significant reduction of the amount of residual monomer, this treatment increases the hardness of the rigid reline resins [62]. Several protocols have been devised for this purpose with success, such as the permanence of the prosthesis for 10 minutes at 55°C [62] and 24/48 hours at 37°C [54].

Reduction of Prosthesis Contamination by the Addition of Antimicrobial Substances

Complete dentures act as microbial niches [63-65] and may accumulate respiratory pathogens that favor the onset of pneumonia; this disease is the largest geriatric problem [66,67]. It is possible that complete dentures collaborate to re-infection of their users, especially in cases which the hygiene of the prosthesis is not performed properly. This condition becomes alarming when considered that many patients with immune deficiency are users of these prosthetic devices [64]. The accumulation of microorganisms in dentures is favored even by the own characteristics of acrylic resin whose porosity, roughness and sorption facilitate the deposition of biofilm [64,68].

Mechanical and chemical methods are traditionally employed in order to remove the biofilm of dentures [69]. The former are essential for microbial displacement; however, there is evidence that this action alone is not sufficient for a perfect hygiene, especially for elderly

patients with reduced motor skills, being necessary its association with chemical methods, among which the antimicrobials are highlighted [70,71].

Currently, the application of antimicrobial agents in the complete dentures can be accomplished in the form of solutions for immersion, either conventional or specific to prostheses toothpastes [72,73]. However, in search of greater effectiveness and functionality, other forms of the use of antimicrobials have been evaluated in scientific research.

For the convenience provided to users, the incorporation of these agents on the materials by manufacturers is presented as a current trend [64,74,75]. With this method, regardless of the antimicrobial agent selected, it is possible to manipulate the variables so that the release is controlled and occurs over time, which is desirable due to the longevity of the accomplished works. This condition would be also favorable for acrylic resins for the reasons given above. However, the feasibility of the inclusion of antimicrobials in dental materials also depends on the preservation of their physical, mechanical and biological properties. Unfortunately, these incorporations have resulted not only in benefits but also in significant changes in these properties [76].

Among the materials tested as antimicrobial additives of acrylic resins, those based on silver, which act on cell walls of microorganism, interrupt the replication process of its RNA and block the cellular respiration of the microorganism are highlighted [77]. In addition, the active silver has low toxicity to human cells and broad antimicrobial activity, which explains its widespread use at this time [78].

In the last years, products impregnated with silver which has been more incorporated into denture base materials are zeolites [64,79,80]. These crystalline structures of aluminosilicate have thermal resistance and do not suffer disintegration even at high temperatures, enabling the success of its association with heat-polymerized materials [64].

The effects of this association have revealed that the viscoelastic properties of tissue conditioners are not changed compared to those presented at the pure materials [79]. Regarding the toxicology, which is essential due to the constant contact between the tissue conditioner and the oral mucosa, the addition of silver zeolite does not affect the cell viability when compared to the material without antimicrobial agents [80]. A scientific study showed that the incorporation of 2.5% of silver- and zinc-containing zeolite potentiates the action of heat-polymerized acrylic resins activated by microwave energy against *Candida albicans* and *Streptococcus mutans*; however, it reduces negatively the flexural strength and the impact of these materials [64]. Among the possible explanations for the reduction of resistance values of the resins which in general contain antimicrobial agents are the reduction of the degree of conversion and the consequent increase in the amount of residual monomer [81], dilution of components in the liquid and the molecular interaction [82].

Quaternary ammonium at different percentages (2-50%) has also been added to heat-polymerized acrylic resins in an attempt to reduce its contamination by different microorganisms, and it was observed the action of the compost formed for up to four weeks [83]. Nevertheless, the reduction of the hardness and elastic modulus of a cold-cured acrylic resin added of 10% w/w of chlorhexidine acetate was again reported by researchers [76].

Another attempt made to reduce the contamination of denture resins occurred through the coverage of these materials with titanium dioxide, that make the adhesion of *Candida albicans* and *Streptococcus sanguinis* more difficult [84].

Monomers have also been used for the purpose of conferring the antimicrobial action in resins for denture base. The effect of adding more than 1.75% of 2-tert-butylaminoethyl

methacrylate in these materials decreased their flexural strength values, possibly by causing the softening of resin. Clinically, this incorporation could result in the increase of the incidence of fractures in complete dentures bases [85].

The microbial adhesion to the resins can also be reduced by the incorporation of polar radicals, such as methacrylic acid, with the aim of increasing its hydrophilic. It was observed a significantly reduction of *Candida albicans* adhesion compared to control group (resin without treatment) [86].

Permanently there is an attempt to incorporate antifungal agents such as nystatin to tissue conditioners. It was observed that the addition of concentrations of 10% of the agent confers action against micro-organisms and preserves the mechanical properties of materials [87].

Surface treatments have proven to be promising alternatives to reduce the microbial adhesion to denture base materials. For example, the application of plasma on the surface of acrylic resin to change its hydrophobicity results in the reduction of the adhesion of *Candida albicans* to the material. However, this treatment does not have limitations resulting from the incorporation of antimicrobial agents in these materials [88], as already showed. Another proposed surface treatment was the application of a layer of light-cured glaze on the surface of acrylic resins; nevertheless, this protection was offered only for a limited period of time when its integrity was maintained [89].

Thus, the search for new materials or treatments that enable the reduction of contamination, which not cause adverse effects to oral tissues and have appropriate physical and mechanical properties should still continue. What should it have done while the problem is not solved is to control the variables of laboratory manipulation to reduce the porosity of resins, such as providing adequate monomer/polymer relation, perform the pressing and polymerization following the manufacturers' recommendations, and perform prosthesis polishing of good quality.

Conclusion

For better clinical performance of the complete dentures, it is suggested that clinical dentists and dental prosthesis technicians seek to manipulate the dental materials according to parameters set by their manufacturers. Additionally, the constant updating of these professionals should occur, since new materials and working techniques have been present often in literature.

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Chapter VIII

Alternatives to Removable Complete Dentures: Viability for Public Health Systems in Developing Countries

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Abstract

The global population is ageing at an unprecedented rate. The result of this process has produced an important change in the healthcare system, with the cure of acute diseases giving way to the treatment of chronic illnesses. The impact of this demographic change is of considerable concern due to the increase in the cost of healthcare systems, although the current correlation between health costs and the elderly population is weak. In the last ten years, Brazil has made considerable progress in the prevention and control of caries among children. However, the situation among adults and the elderly is among the poorest in the world. However, the rehabilitation of these individuals is hindered by a number of factors. The difficulty of retaining and adapting lower dentures is common and constitutes an obstacle to the complete success of prosthesis use, as reported in a number of studies. Moreover, the lack of information on the part of patients regarding the limitations of conventional complete dentures contributes toward dissatisfaction and the

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abandonment of complete lower denture use. The aim of this chapter is to carry out a systematic review of methods for the rehabilitation of individuals with an edentulous lower jaw in the search for an alternative solution that is biological, functional and financially viable. This review will consist of the treatment and options for edentulismo including the bone loss risk, the patient satisfaction, the masticatory efficiency, the number of implants and the economic cost/analysis. At the final presents a discussion on clinical decisions in the edentulous rehabilitation.

Introduction

The demographic shift that is taking place around the world, as a result of an aging population, has been attributed to increased life expectancy, birth control, and improvements made in the social and health areas (Lebrão, 2007). As a result of this phenomenon, there has also been a major change in the health care system that, today, confronts a growing ability to cure acute diseases and treat chronic illnesses (Bury, 2001; Turkyilmaz et al., 2010). Although the correlation between current spending on health care and the elderly population is weak (Niessen, 2000; Anderson and Hussey, 2000), the impact of this shift has caused great concern because of the possibility of rising costs in the health care systems.

Furthermore, the search for a better quality of life for this population group needs to focus on healthy aging that includes a low risk of contracting diseases and their resulting functional disabilities, a high degree of mental and physical functioning, and an active involvement with life (Cupertino et al., 2007). In this context, health is considered not as a life goal, but as a resource for life itself (WHO, 1986).

Oral health encompasses a range of biological and psychological conditions, which enables the human being to carry out functions such as chewing, swallowing, and talking. It also comprises an aesthetic dimension, which plays a role in self-esteem and social relationships, without inhibition or embarrassment. It is a health field that, when problems arise, inevitably affects the quality of a person's life. However, the current state of oral health, especially in adults and the elderly in developing countries, is still a long way from facilitating healthy aging. In fact, the model of care focused on healing and disabling practices was one of the determinants of this panorama (Moreira et al., 2005; Vargas and Paixão, 2005). A high degree of edentulism has a negative impact on the quality of life, particularly in terms of the psychological distress caused by the difficulty of being accepted by others and a sense of humiliation that a toothless person often experiences (Silva et al., 2010/b). The complete loss of teeth results in negative consequences such as shame, difficulty in eating, impairment of social relationships, and a sense of incompleteness (Silva et al., 2010/a).

Using Brazil as an example, in recent decades, there has been a major advance in the prevention and control of dental caries in children and adolescents. However, the situation in adults and the elderly is among the worst in the world. According to the National Survey of Oral Health sponsored by the Ministry of Health, three million people between the ages of 65 and 74 require complete dentures in both arches (15%) and 4 million are in need of a complete denture in one of the arches (23%) (Roncalli, 2011). Edentation has become a public health problem, engendering a growing demand in the population and need for

prosthetic treatment (Colussi and Freitas, 2002, Moreira et al., 2005; Vargas and Paixão, 2005; Campostrini et al., 2007; Ferreira et al., 2007).

Facing the possibility of the prosthetic replacement of teeth triggers anxiety in many people, but the thought of returning to a generally accepted social standard and regaining their self image motivates them (Silva et al., 2010/a). The benefit of using a prosthesis is undermined when the person fails to achieve sufficient stability for chewing, especially in the mandibles. The resulting dissatisfaction often leads the user to abandon the prosthesis, as has been frequently observed in the case of removable dentures (De Souza e Silva et al., 2009).

Consequently, the search for alternatives, which could be implemented with safe protocols, especially in public services, is being driven by need and urgency.

Treatment Options for Edentulism

Edentulism associated with poor access to treatment and its limitations produces functional and psychosocial disorders that tend to segregate the individual and burden the health care system.

The successful rehabilitation of this patient by means of prosthesis should result in an improved functional and aesthetic gain in the quality of life. The prosthetic options for this purpose include: conventional dentures (CD), the fixed implant-supported prosthesis (FISP), and the implant-retained overdenture (IRO).

Conventional Denture

A conventional denture (CD) consists of a removable denture, made of acrylic resin and on the mucosa. It is the most widely used therapeutic modality for the rehabilitation of edentulous patients, having been accepted until recently as the prosthesis of choice for this purpose. With its low cost and technical simplicity, it was an unprecedented success, rehabilitating millions of people around the world (Raghoebar, et al., 2003; Turkyilmaz et al., 2010).

The fact of relying on the mucosa for support causes problems for the patient, such as increased bone resorption, adjustment difficulties, pain, discomfort, low stability and retention of the prosthesis, and struggling while eating, especially as related to the lower dentures (Raghoebar, et al., 2003; Allen and McMillan, 2003). In addition, the reduced salivary flow, motor abnormalities of the tongue, reduction in bite force, and decreased sensory function contribute to its functional loss (Wolff et al., 2003; Allen and McMillan, 2003; Ikebe et al., 2006).

The weakened act of chewing can lead to the development of disease and lead to a reduced expectation and quality of life (Slagter et al.,1993; Slagter et al.,1992; Shinkai, et al., 2002; Emami, et al., 2009). Patient disinformation with regard to the limitations of this type of prosthesis also contributes to the increased rate of dissatisfaction and the abandonment of the use of the lower denture (Vervoorn, et al., 1988; Raghoebar et al., 2003; Silva et al., 2010/a).

Patient satisfaction is the yardstick in the professional's clinical planning. The satisfied patient does not come looking for treatment often or return to have the existing prosthesis replaced. However, the dissatisfied patient, whether due to the inefficiency of their current prosthesis or emotional problems, needs alternatives that facilitate his/her oral rehabilitation.

Observation and confirmation of the osseointegration phenomenon by Brånemark in the mid-1960s provided a new rehabilitative dimension for these edentulous individuals. The use of osseointegrated implants in their different ways suggests and encourages the conclusion that the patient's quality of life is significantly enhanced by prosthesis over implant (Heydenrijk, et al., 2002; Zarb and Bolender, 2006).

Fixed Implant-Supported Prosthesis

The fixed implant-supported prosthesis (FISP) originated with the Brånemark protocol, which was the first use of implants in the treatment of the edentulous mandible and consisted of a fixed denture on implants in 4 to 6 regions between the mental foramen. It is characterized by a metal infrastructure, in resin, associated with the teeth and gums, and a bilateral distal cantilever that should not exceed two teeth (15mm) screwed into the implants. The surgery was performed in two stages (installation and re-opening of the implants) with a spacing of 3 to 4 months between the stages, at which time the prosthetic (loading) phase was begun (Brånemark et al., 1969 and 1977).

The success of these prostheses in the rehabilitation of edentulous mandibles was confirmed by longitudinal studies (Brånemark et al., 1977; Adell, et al., 1981; Albrektsson et al., 1987).

Subsequently, changes took place in the Brånemark protocol due to patient-related factors. These changes deal with the number and location of implants, type of prosthesis fixation (cemented and screwed), and load (conventional, early, and immediate).

The impossibility of placing the implants in suitable number and arrangement, with or without economic reasons, led to the resurgence of overdentures (removable dentures), which are now on implants and no longer only by the residual roots (Naert et al., 1997; Awad et al., 2003).

Implant Retained Overdenture

The implant-retained overtendure (IRO) is an acrylic resin removable denture, retained by implants, and may or may not be on mucosa. The number and location of the implants, along with the various types of attachments, determine the variations in this type of prosthesis. According to Fitzpatrick (2006), this is a less invasive, cheaper, and equally effective treatment option when compared to the fixed implant-supported prosthesis.

The choice between an implant-retained overdenture and a fixed implant-supported prosthesis as an alternative to conventional dentures in edentulous mandibles suggests some questions, such as implant survival, bone loss, patient satisfaction and quality of life as related oral health, chewing efficiency, the number of implants, and cost, all of which will guide the decision (see also below).

Implant Survival and Bone Loss

Implant Survival

Bryant et al., (2007), suggest, in a systematic review that included meta-analysis, that the survival of implants in the fixed mandibular implant-supported prostheses is 6.6% higher than in fixed maxillary implant-supported prostheses. They conclude that the implant's survival and success are not affected by prosthesis type.

Bone Loss

With regard to bone loss, the first aspect to be discussed is the relationship between peri-implant bone loss and the different types of loading and prostheses. Sunyoung and Payne (2010) cite three types of loading for implant-retained overdentures on two implants: the conventional load, in which the prosthesis is attached after a second surgical procedure following a healing period ranging from three to four months, early loading, in which the prosthesis, along with the fastening system, is installed 48 hours after the implant, in up to 3 months, and immediate loading, in which the prosthesis, along with the fastening system, is installed up to 48 hours of the implant installation. This study suggests that, in the short term, there are no harmful effects on the marginal bone level using the immediate or early loading protociols, and the long-term results still need to be obtained. They conclude that recommending immediate loading protocols in mandibular overdentures on two implants may still be premature.

Jokstad and Carr (2007) analyzed the influence of loading time on the different types of prostheses on implants and concluded that there is no evidence that early or immediate loading is not a safe procedure.

The success rate of immediate loading (up to 1 week), early (from 1 week to 2 months), and conventional (after 2 months) showed that it is possible to succeed with the different load types, with the degree of the implant's primary stability appearing to be a prerequisite for success with immediate and early loading (Esposito et al., 2007).

Alsabeeha et al., (2010) also suggest that both immediate and early loading protocols using 2, 3, and 4 implants supporting or retaining mandibular overdentures may achieve comparable success to that obtained with the conventional load for more than two years. They suggest, however, that long-term studies are needed to validate the early and immediate loading protocol. The second aspect to be considered in terms of bone loss is the relationship between resorption of the posterior mandibular residual ridge and the different types of prostheses.

Jacobs et al., (1992) related the subsequent bone resorption to the different types of prostheses. In fixed implant-supported prosthesis for 4 to 6 implants, there was minimum resorption, while in implant-retained overdentures on 2 implants, it was found to be from 2 to 3 times higher than in conventional dentures in a six-month period of post-extraction remodeling. In patients wo have been edentulous for more than 10 years, the difference in absorption rates for the latter two groups disappeared. The use of implant-retained

overdentures in younger patients should be carefully evaluated from a long-term perspective, although it is an option that offers advantages from a financial standpoint.

Kordatzis et al., (2003) compared conventional dentures and implant-retained overdentures on two implants and found 1.62-mm bone loss in dentures, when compared with 0.69 mm in implant-retained overdentures over a five-year period in patients who had been edentulous for more than twenty-two years.

The degree of residual ridge resorption differed when the number of implants in implant-retained overdentures ranged from 2 to 4, which is 4% lower when a larger number of implants were used in the ten-year control study (Meijer et al., 2010).

Patient Satisfaction

Numerous studies have focused on understanding the impact that different types of treatment for mandibular edentulism have on the patient's life. Despite the conventional denture's known and prevailing limitations, such as instability, poor mastication, decreased self-confidence, quality of life, satisfaction, and social relations, and the positive impact of implant therapy, the satisfaction-based results need to be better understood. Edentulous patients have highly variable, individual functional requirements that are influenced by social, cultural, and financial factors, along with their capacity to adapt (Fitzpatrick, 2006).

Thomason et al., (2007) found strong evidence that the quality of life could be improved through the use of implant-retained overdentures; however, there was no perceivable difference with regard to patient satisfaction. Emami et al., (2009) found evidence showing that overall satisfaction and quality of life associated with oral health are higher in users of implant-retained overdentures when compared with conventional dentures, although the magnitude of these effects remains uncertain. This study suggests that an implant-retained overdenture on two implants should be the minimum offered to mandibular edentulous patients as a first treatment option. Evaluations of satisfaction, stability, comfort, and masticatory efficiency were significantly better in patients treated with implant-retained overdentures on two and four implants when compared with conventional denture users. The authors concluded that both the implant-retained overdentures and the fixed implant-supported prostheses significantly improve the quality of life of edentulous patients when compared with conventional dentures (Turkilmaz et al., 2010).

Masticatory Efficiency

Users' masticatory efficiency with CD in the upper and lower arches is less than 20% when compared with that of the natural tooth (Kapur and Soman, 1964; Heath, 1982). Functional loss is linked to low stability and support, but may also be affected by reduced salivary flow, motor control of the tongue, reduced bite force, and decreased sensory function (Koshino et al., 1997; Wolff et al., 2003; Allen and McMillan, 2003; Ikebe et al., 2006). Many studies relate the reduction in bite force to masticatory muscle atrophy, reduced masticatory ability, and nutritional status (Kapur and Soman, 1964; Wayler and Chauncey, 1983; Slagter et al., 1992; Slagter et al., 1993; Shinkai et al., 2002).

Dentists and patients should be aware of the functional limitations and benefits of implant-retained overdentures and implant-supported bridges when making a well-informed treatment choice (Fueki et al., 2007).

The combination of an implant-retained overdenture or fixed mandibular implant-supported prosthesis with a conventional denture provides significant improvement in masticatory efficiency when compared to the use of dentures in both arches. This applies to conventional mandibular denture users with functional problems attributable to persistent severe resorption (Fueki et al., 2007).

Van der Bilt et al., (2010) evaluated the long-term effects of treatment with implant-retained mandibular overdentures on two implants on oral function. The authors quantified the maximum bite force and masticatory performance 10 years after implant treatment. The study concludes that treatment with implant-retained mandibular overdentures significantly improves oral function and that after 10 years of practice, the maximum bite force and masticatory performance remained unchanged.

The various types of attachments in implant-retained mandibular overdentures have limited impact on masticatory performance (Çehreli et al., 2010).

Number of Implants

In a longitudinal study, Branemark et al., (1995) concluded that the use of four or six 10-mm long implants in the area between the mental foramen is highly likely to support a fixed implant-supported prosthesis. A minimum of four 7-mm long implants is suggested by Lekholm (1998) for the same reason. However, the author recommends that, whenever possible, five implants, preferably longer, be used. The same number of implants has also been suggested for a fixed implant-supported prosthesis (Zarb and Bolender, 2006). To support an implant-retained overdenture, two implants, whether splinted or not, are a generally accepted treatment option (Naert et al., 2004; Carlsson et al., 2004; Meijer et al., 2010). The use of a single implant to support this type of prosthesis has also been employed (Krennmair and Ulm, 2001; Walton et al., 2009; Kronström et al., 2010).

Klemetti (2008) carried out a systematic review to evaluate whether there is an optimal number of implants for retaining implant-retained mandibular overdentures. The results showed that patient satisfaction and prosthesis performance do not seem to be dependent on the number of implants or type of attachment. However, an implant-retained overdenture with two implants and a bar appears to have fewer complications.

Cost and Economic Analysis

The cost greatly influences the choice of prosthesis, especially when it comes to public services. The financial issue is the most frequent reason for the choice of implant-retained overdentures rather than a fixed implant-supported prosthesis. In a number of countries, the amounts charged for fixed implant-supported prostheses seem to be higher than necessary when analyzing the clinical, laboratory, and material costs. Palmqvist et al., (2004) report that the implant-supported fixed prosthesis can be provided at the same cost as an implant-

retained overdenture when carried out in the All -in –One concept and that the choice between a fixed implant-supported prosthesis and implant-retained overdenture need not be an economic issue any longer.

In the long term, little is known about the cost-effectiveness of conventional dentures, implant-retained overdentures, and fixed implant-supported prostheses in edentulous patients (Heydecker et al., 2005). In most studies, the estimated costs and/or effects have been restricted to monitoring during the trial period (Jönsson and Karlsson, 1990; Tang et al., 1997; Palmqvist et al., 2004; Takanashi et al., 2004). However, most of the costs for prosthetic restorations typically accumulate during the first year, while their benefits are usually seen throughout the prosthetic's functional period (Attard and Zarb, 2004).

A study by Zitzmann et al., (2006) analyzed the cost-effectiveness of three different treatments: conventional dentures, implant-retained overdentures on two implants, and implant-retained overdentures on four implants on an edentulous mandible. They prepared a cost projection over a ten-year period using a mathematical model and came to the conclusion that an implant-retained overdenture on two implants is the most cost-effective treatment option when compared to conventional dentures and the implant-retained overdenture on four implants. The cost of treatment rose substantially with the increasing number of implants, becoming 3 to 6 times higher when the number of implants jumps from 2 to 4 in implant-retained overdentures, as compared with treatment using conventional dentures. The proportion of maintenance costs in relation to initial costs decreased with the increased number of implants used, i.e., 46% of the initial costs for conventional dentures, 28% for implant-retained overdentures on two implants, and 13% in implant-retained overdentures on four implants.

Attard et al., (2005) reported that the cost of initial treatment and maintenance costs during the study's observation period were higher for fixed implant-supported prostheses when compared with implant-retained overdentures. The fixed implant-supported prosthesis, however, presented a greater reduction in maintenance costs with respect to the initial cost. Furthermore, maintenance costs indicate that implant-retained overdenture treatment was cheaper when compared with fixed implant-supported prostheses.

Emami et al., (2009) reported that additional meta-analyses are needed in well-controlled randomized clinical trials that include relevant economic assessments to provide policymakers and insurance companies with the help they need when making decisions about the adoption of implant therapies.

Discussion for Guidance in Clinical Decisions Regarding Edentulous Rehabilitation

Making a decision concerning the rehabilitation of edentulous patients initially involves identifying their profiles and getting answers related to their complaints and expectations. The denture's low retention and stability, especially in the mandible, result in functional deficiency, which in turn has a negative impact on the patient's satisfaction and quality of life. Prostheses supported or retained by an implant partially overcome these limitations and may even approach the functional performance of dentate subjects, thereby improving patient satisfaction and quality of life as related to oral health.

Table 1.Comparison among the decision factors regarding the choice of the type of total prosthesis

Factors	CD	IOD	FISP
Stability/ Retention	Lowest	Average	Greatest
Masticatory efficiency	Lowest	Average	Greatest
Patient satisfaction	Lowest	Improved	Improved
Quality of life	-	Improved	Improved
Number of implants	-	Fewer	Greater
Implant survival	-	Same	Same
Peri-implant resorption	-	Same	Same
Subsequent bone resorption*	Same	Same	Lowest
Soft tissue abrasion	More	Less	Absent
Initial cost	Lowest	Average	Highest
Maintenance /Initial cost	46%	28%	13%

(* = In patients who have been edentulous for more than 10 years).

The number of implants used for this purpose varies with the type of prosthetic option, being higher in fixed implant-supported prostheses than in implant-retained overdentures and inversely proportional to the rate of residual ridge resorption and soft tissue abrasion, especially when looking at conventional dentures. However, implant survival and peri-implant bone loss are not altered by the type of prosthesis. It should be noted that the implants under mandibular overdentures survive longer when compared with the maxillary. The cost aspect is be treated last of all because it is currently the primary deciding factor in choosing among these rehabilitation options. The conventional denture has a low initial cost (clinical hours, laboratory, and material), followed by the implant-retained overdenture, and finally the implant-supported fixed prosthesis. However, maintenance costs decrease as the number of implants increases. Maintenance on a conventional removable prosthesis represents 46% of its initial cost, while maintenance on an implant-retained overdenture represents 28%, and on the fixed implant-supported prosthesis, 13%. Table 1 presents a summary of the deciding factors for choosing the type of prosthesis.

Longitudinal follow-up studies would facilitate a better evaluation of these aspects and the possible associations with individual conditions, such as length of time of edentulism, health conditions, and other pertinent factors.

Conclusion

In developing countries, edentulism is regarded as a public health problem. Among the therapeutic options available for the rehabilitation of these patients, the conventional denture is the most frequently used prosthesis.

However, difficulties in the retention of and adaptation to the lower prosthesis are common and represent a major obstacle to the successful use of conventional prostheses. Therapies using implants have increased the range of prosthetic options for treating these

patients. Within the scope of this review, there is no evidence of a single universal treatment modality for edentulous mandibles. Long-term studies are needed to further explore the differences in patient acceptance for each intervention.

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Chapter IX

Denture Adhesives – A Boon or a Bane

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Abstract

Denture Adhesives have always been surrounded by an infinite number of controversies. Prosthodontists and dentists in general have never really accepted the role of denture adhesives in improving denture retention, stability and function. Despite substantial and significant records encouraging the use of adhesives, the dental fraternity by large still considers adhesive use as a poor echo of their treatments and prosthetic proficiencies. However, in view of a longer-living population with an increasing rate of chronic residual ridge resorption and a consequent increase in dentures that are unsteady because of parameters beyond the control of the patient or dentist, denture adhesives deserve a place in removable prosthodontics as an effective and active aide in denture treatment and denture aftercare.

Complete dentures constitute one of the most important treatment options in prosthodontics, more so with an increase in average life expectancy of the individual. However, retention of complete dentures has always posed to be a problem for the dentist and the dental industry. Solutions to the problem, over the years have included overdentures, implants, and denture adhesives. From time immemorial adhesives have been used by denture wearers and advertised commercially, however these dental materials have not been given their due place in prosthetic dentistry. These materials are specially promoted in certain special conditions such as complicated prostheses– obturators, dry mouth, difficult and exacting patients (e.g. Parkinson's disease, Alzheimer's disease), compromised ridges, single complete denture or in public figures. Besides, adhesives are also normally used by denture wearers to psychologically support the patient so as to make the complete dentures more acceptable.

Conflicting views still persist. The ancient views regard these materials as a poor replacement for a proper fit and adjustment of dentures. However, existing literature supports the use of denture adhesives i.e. if properly used. Adhesives can be a valuable aid in management of challenging denture patients. Therefore, the following article aims

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to solve this dilemma regarding the use denture adhesives, oust some of the myths related to adhesives in order to allow good use and avoid misuse of the same.

Introduction

One of the biggest challenges in complete denture Prosthodontics is undoubtedly the oral rehabilitation of a patient with resorbed ridges. One alternative which has been most commonly used by the patients is denture adhesives. In spite of this, little scientific information is available on them and most of the data that is available is based upon patients' verdict, opinion and experiences. Therefore, Dental clinicians have always been in a predicament regarding the use and abuse of denture adhesives, their use has been and still is paralleled to poorly fabricated dentures. Subsequently, the clinicians are still doubtful and not very inclined to prescribe adhesives to denture wearers as a means to boost retention, stability and comfort.

Dentistry has grown exponentially in the last few decades. With the development of implant dentistry, Conventional removable Prosthodontics has taken a back seat. Despite this complete dentures treatment is still considered to be an integral part of prosthodontics, especially with an increase in average life expectancy of the individual. The objectives of impression making (i.e. for retention, support and stability) are designed to accomplish a full coverage of denture bearing areas, a close tissue to denture contact, and an operative peripheral seal. However, in certain situations, the same may not be probable. In these instances patients frequently choose to use denture adhesives for e.g. in circumstances of immediate or single complete dentures, complicated maxillofacial prostheses (obturators, testing patients), hysterical patients, patients suffering from systemic diseases (like myasthenia gravis or parkinsonism etc.), in cases of compromised ridge structures, or public figures (such as attorneys, actors, and public speakers where denture wobble cannot be tolerated). Besides this the adhesives are also usually used as a support during the fabrication phase of a denture and as a means to aid in the application of drugs to the oral mucosa e.g. radiation carriers.

"Denture adhesive" [1] is a commercially available, non toxic, soluble material that when applied to the tissue surface of the denture enhance their retention, stability and performance. These are available as powder, paste, tape or cushion. Soluble adhesives [2] i.e., the powder and paste forms are universally accepted now because they do not damage the soft tissues.

Composition and Mechanism of Action

Stafford in 1970 [3] has given the basic composition of denture adhesives which has also been reported by the manufacturers and the American Dental Composition. The ingredients fall mainly into three categories:

1.: Those materials that swell gel and show increasing and varying degrees of viscosity in water (e.g. gum karaya, gelatin and pectin). These materials also suspend insoluble powders in aqueous preparations and act as emulsifying, dispersing and thickening agents (e.g. sodium carboxy methyl cellulose, hydroxy ethyl cellulose, and methyl cellulose).

2.: Those materials that act as antibacterial/ antiseptic agents (e.g. methyl salicylate, sodium borate, sodium tetraborate, hexachlorophene). These materials are added by some manufacturers but it is doubtful whether these materials serve any real purpose.

3.: Additional materials like sodium lauryl sulphate. This reduces the surface tension and acts as a wetting agent. Propyl hydroxy benzene (propyl paraben) acts as a preservative and is mildly active against Candida albicans. Magnesium oxide is a filler. Peppermint oil has flavoring properties with mild antiseptic actions. Petrolatum is used as an emollient.

These materials basically increase the forces of adhesion and cohesion between the intaglio surface of the denture and basal tissues allowing complete wetting and eliminating the voids between the two. Shay [4] described the mechanism of action of adhesives in 1991. These materials swell 50% to 150% by volume in the presence of water, filling the spaces between the prosthesis and the tissues. As water is absorbed by the adhesive agents, the resulting cations are attracted to anions in mucous membrane proteins, producing the stickiness. The properties of current adhesives depend upon the combination of both physical and chemical properties, saliva increases the viscosity of the adhesive thereby increasing the force required to separate the prosthesis from the tissue surface. Most adhesives use ingredients that provide bioadhesion via carboxyl groups. As the adhesive hydrates, free carboxyl groups form electrovalent bonds that produce stickiness. Polymethyl vinyl ether – maleic anhydride (PVM - MA) is a synthetic compound widely used in denture adhesives because of high levels of carboxyl groups. Sodium carboxymethyl cellulose has the advantage of being more soluble, beginning in the early 1970's manufacturers combined divalent salts of PVM-MA, specifically calcium salts with CMC to make denture adhesive. The divalent salt increased product performance by reducing the rate of dissolution and also increasing the cohesive strength of overall material.

In the late 1980s, companies introduced products that combined PVM-MA zinc and calcium salts with carboxy methyl cellulose. These materials provided an even greater cohesive strength for longer duration because of stronger covalent bond that develops via divalent zinc cation. Commercial denture adhesives that contain these materials have clinically proved to provide stronger, longer hold than products containing calcium salts of PVM-MA copolymer alone.

Denture Adhesives – Myth and Reality

It is now accepted that denture adhesives if used sensibly and under supervision can aid in retention of complete dentures. Even though, the ancient former views regard these materials as a poor substitute for a proper fit and adjustment of dentures and their use was equated to poor denture skills and lack of prosthetic expertise [5, 6]. In 1967, Kapur [7] conducted a study on 26 denture wearers and devised a method for scoring denture retention and stability as ill, fair and well fitting prosthesis. He concluded that denture adhesives unequivocally increased denture retention thereby increasing denture wearers' incisive ability.

Tarbet et al. [8, 9] addressed the role of denture adhesives in retention and stability by counting denture dislodgements in patients eating standardized portions of food with and without denture adhesive. Results showed a significant reduction in dislodgement when an adhesive was used. Researchers have devised new techniques such as the cineradiographic

technique and a hydraulic and electrical transducer to measure maximum retentive force and to compare the effects of materials during chewing. A decrease in dislodgement of dentures while chewing was observed [10, 11]. Radiotelemetry and gnathodynamometry have also been used in this field and results have shown that the use of denture adhesives, in patients with poor bone support, improve the retention and stability comparable to that in patients with good bone support [9].

Most recently, a multi-channel magnetometer tracking system has been used to study the effect of denture adhesives on mandibular movement during chewing. The subjects were made to chew dried apricots and fresh white bread. It was concluded from the study that the use of denture adhesives resulted in a faster and more natural rate of chewing [12].

In spite of all the studies done, negative attitude regarding denture adhesives still prevails and a lot of literature focuses on the harmful effects of these materials i.e.: *I.*: enhancing the prolonged use of ill fitting dentures thus promoting residual ridge resorption,; *II.*: interfering with the occlusion as a result of uneven and uncontrolled thickness of intervening adhesive; *III.*: act as allergens [13]. This is especially true for cushion type of denture adhesives which are insoluble adhesives and involve a greater risk of inducing alveolar ridge resorption. These "home reliners" are not accepted by ADA. The soluble adhesives cannot be abused to the extent of changing vertical dimension since they rapidly absorb water becoming gelatinous and spreading over the denture through chewing stress [2, 14, 15].

In 1980, Tarbet and Grossman [16] reported a six-month investigation on incidence and severity of mucosal irritation in a group of 111 denture wearers using adhesive materials. No increased incidence of mucosal irritation was observed, on the contrary the irritation present at the time of insertion of dentures showed a definite decline. However, at the same time denture adhesive should not be prescribed on a regular basis as they do increase the wearing time of ill-fitting dentures leading to deterioration of bony support [16].

Use or Abuse

Denture Adhesives act as a cushion, reduce the collection of food under the denture flanges, hinder the growth of Candida. They help to distribute the occlusal load during various centric and eccentric movements. Adisman [2] in 1989 said that dentists may prescribe and use denture adhesives as a legitimate, therapeutic and effective procedure in denture treatment and denture after care. The patients should be instructed in its proper use and cautioned against misuse. The use of denture adhesives in ill fitting dentures is contraindicated. All denture patients should be advised to consult their dentists for periodic examinations of their dentures and the health of the oral cavity.

Denture Adhesives are commonly available in paste and powder forms. The paste forms of denture adhesives are more retentive than powder forms which has been attributed to an increased viscosity of the pastes. This was demonstrated by Chew [17] in 1990 and was later confirmed by Ghani et al. [18] who demonstrated that the liquid / paste form of denture adhesive rendered the ill-fitting dentures almost as retentive as well fitting one.

Retention and stability of dentures has been a continuing problem for dentists in clinical practice. Retention of dentures in the oral cavity is a multifactorial phenomenon which relies upon a number of variables namely adhesion, cohesion, atmospheric pressure, surface tension

and viscosity, these are in turn determined by the quantity and quality of saliva interspersed between the mucosal surface and the hard acrylic of the corresponding surface of the dentures. Studies conducted in the past, have distinctly shown that the denture adhesives significantly augment the retentive ability of complete dentures. This rise could probably be explained by the consequent rise in viscosity of the intervening film of saliva existing between the acrylic dentures and the mucosal surface. Thus, denture adhesives can be used to improve denture retention, offering security, certainty, assurance, and function to the patient but at the same time it must be noted that denture adhesives improve denture retention only if the principal properties of the complete denture such as retention, stability and close adaptation of the denture base to the underlying tissues are satisfactory. An ill-fitting, poorly fabricated complete denture that does not satisfy the basic requirements of retention and stability will not become retentive with the mere use of adhesive materials. On the contrary, the unwise, imprudent use of such materials may lead to undesirable harm and deterioration of supporting structures, which may be permanent and irreversible.

Dentists should caution the patient against the misuse of such materials and insist upon the regular recall visits for evaluation of their dentures and health of the oral cavity. Woelfel et al. [19] in 1965 investigated the hazards of additives sold over the counter and they concluded that a longer than normal wearing period of complete dentures is encouraged by the sale of over-the-counter denture additives, adhesives, cushions, pads, reliners etc. A four-fold program was suggested in an effort to promote better denture health among denture wearers: *I.*: Educate the public to the full benefits of professional dental care, including essential periodic recalls while wearing complete dentures; *II.*: Warn patients against buying or using any do-it-yourself additives on their dentures; *III.*: Prohibit the promotion and public sale of all over the counter reliners, cushions and repair kits; *IV.*: Place the sale of denture adherent powders and pastes on a basis whereby a prescription from a dentist would be required to obtain them from a pharmacist. Most recently Tezvergil - Mutluay, have reported an increase in serum zinc levels and decrease in serum copper levels in denture patients overusing denture adhesives or rather misusing denture adhesives. This condition is known to cause bone marrow suppression and widespread sensory and motor neuropathies. Epidemiologic studies have revealed the source of excessive zinc from overuse of denture adhesives [20].

Conclusion

Denture adhesives are commonly used by denture wearers to increase the retention and stability of the dentures, to improve the chewing and masticatory efficiency, and to psychologically support the patient so as to make the complete dentures more acceptable. In 1965, Great Britain alone produced about 88 tons of denture adhesives, 12% of population included women and 10% men [3] and in the U.S more than 5 million denture wearers use denture adhesives [2]. This number is on a continuous rise because of the advances in the medical field which has led to an increase in average life expectancy of the individual. Literature review has revealed the use of mechanical devices like springs, suction cups, suction chambers, magnets, undercuts, overdentures and implants to alleviate retention problems in the difficult aforementioned conditions. Although most of premised devices may

increase the retention, but many of them either cause further damage to the foundation tissues, or are rather expensive (i.e. implants, magnets). Therefore, denture adhesives being commercially and readily available, has emerged as an acceptable solution to meet the challenges of retention in such patients. Numerous surveys have been conducted in the past taking into consideration the patient's opinion on the effectiveness of adhesive materials. In general, most of the patients responded positively indicating that the retention was little better or much better with the use of adhesive materials [21].

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Chapter X

Changes in the Mycological Ecology of Dentures

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Abstract

A wide range of medical devices used in elderly patients shown to support colonization and biofilm formation by *Candida spp*. Among them, more attention must be paid to denture plaque because similar to dental plaque it also serves as a reservoir of potentially infectious microorganisms. Continuous swallowing or aspiration of microorganisms from denture plaque exposes elderly patients to the risk of unexpected infections. The level of oral hygiene in elderly people, especially those living in long-term care institutions, has been reported to be poor, both for dentures and remaining teeth. The upper denture has been suggested to be the major source of infection in long term hospital care patients. It has also been reported that larger quantities of *Candida spp.* reside in the denture base and not in the palate.

The most frequent isolated yeast species in dentures is *C. albicans*. Although, recent reports show high proportions of *non-albicans Candida* spp., thus showing a shift from *C. albicans* towards *non-albicans* spp. This shift has already been reported over the last years with *C. glabrata* emerging as the second most prevalent species found in dentures. Infections related to *C. glabrata* can lead to systemic infections with high mortality rates. The increased inadequate use of topical and systemic antifungals has been proposed to contribute to this fungal profile change.

Several studies show a correlation between poor denture hygiene and prevalence of *Candida* species and also a statistically significant relationship between denture related

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stomatitis (DRS), presence of *Candida* and denture cleanliness. High frequency and quantity of *Candida spp.* detection is sometimes associated with few clinically detectable cases of DRS. Hyphae detection by microscopy is now the gold standard (with the exception of *C. glabrata*) for the diagnosis of oropharyngeal fungal infections (OFI). Presence of oral lesions associated with OFI has been reported only in one third of microscopically affected patients.

Frequent use of toothpaste to clean dentures has an influence on dentures surface roughness due to the presence of abrasives. Surface roughness being positively correlated with the rate of fungal colonization of biomaterials, a rougher surface may be a risk factor for microorganism adhesion and biofilm formation.

Conclusion: High levels of *Candida spp.* are reported on dentures of elderly patients. A high frequency of *non-albicans Candida spp.* (particularly *C. glabrata*) has been detected in recent studies. This seems to confirm a change in the mycological ecology involved in yeast denture colonization and DRS. Keywords: *Candida* spp., dentures, elderly.

Introduction

Oropharyngeal candidosis and the particular form of denture related stomatitis (DRS) are a main concern among denture users and oral health practitioners. Poor fitting and/or prolonged use of the denture are the most common factors related to denture related stomatitis *(Budtz-Jørgensen, 1981)*. The upper denture has been suggested to be the major source of infection in long term hospital care patients *(Wilkieson et al., 1991)*. Denture plaque and poor oral hygiene are commonly associated with *Candida* infection *(Coulthwaite and Verran, 2007)*. Moreover, dentures may serve as a reservoir of other potentially infectious pathogens *(Sumi et al., 2003)*. Continuous swallowing or aspiration of microorganisms from denture plaque for example, exposes elderly patients to the risk of unexpected infections *(Nikawa et al., 1998)*.

Among elderly patients, especially those in a frail situation, the lack of instructions concerning oral and denture hygiene is long past reported *(Arendorf and Walker, 1987)*. The level of oral hygiene in elderly people living in long-term care institutions has been reported to be poor, both for dentures and remaining teeth *(De Visschere et al., 2006)*. Recently, *Kossioni* confirms a common belief among the patients that after provision of dentures, elderly patients assume that regular recall is not necessary anymore *(Kossioni, 2010)*. Several studies show a correlation between poor denture hygiene and prevalence of *Candida* spp. They also demonstrate a statistically significant relationship between DRS, presence of *Candida* and denture cleanliness *(Kanli et al., 2005, Kulak-Ozkan et al., 2002)*. Besides, the frequency of denture brushing does not mean effective cleansing. Cognitive deficits, loss of visual acuity and lack of manual dexterity are a common issue in older people, and this strongly influences the effectiveness of brushing *(Nevalainen et al., 1997, Darwazeh et al., 2001)*. Dentures night – wearing is also a common habit within the elderly. In a group of 150 complete denture wearers, 64% (96 subjects) had the habit to sleep with their dentures *(de Castellucci Barbosa et al., 2008)*.

Gendreau and Loewy published a systematic review focused on epidemiology of DRS. Data from several countries around the world were collected and presented. The usual assessment method of DRS in the different studies was generally based on the scales

developed by *Newton* or *Budtz-Jorgensen and Bertman*, meaning that oral examinations (some of them standardized) were performed by a trained dentist or by an undefined examinator. The number of subjects wearing dentures in the different studies varies between 37 (Scottish study) and 3450 (a US - NHANES III study). DRS prevalence among the different studies varies between 14.7% (Slovenian study/ n=163) and 77.5% (Canadian study/ n=40), and for the larger studied population in Finland the prevalence of DRS was of 48%, distributed in 43.2% for males and 50.6% for females *(Gendreau and Loewy, 2011)*.

*Candida o*n Dentures and other Implantable Medical Devices

Candida spp. may develop as biofilm on a wide range of artificial materials used in medicine. These biofilms protect them from antifungal and host defenses. As a matter of fact, shunts, prostheses (valve, knee, etc.), stents, implants, endotracheal tubes, pacemakers and catheters have been shown to support colonization by yeasts *(Ramage et al., 2006)*.

Many cases of infections related to medical devices by *Candida* spp. have been described in the literature: infections of peritoneal dialysis catheters leading to *Candida* peritonitis *(Bibashi et al., 2003)*; yeast infections in neurosurgical shunts, which have increased within the last few years *(Montero et al., 2000)*; and, even if scarce, knee and arthroplasties infections with *Candida* (which are mainly related to *C. albicans, C. parapsilosis and C. glabrata*) have also been reported *(Phelan et al., 2002)*.

Dentures and oral implants are also medical devices used in patients (mainly elderly). They too have shown to support colonization and biofilm formation by *Candida spp*. *(Douglas, 2002)*. Denture wearing is therefore commonly associated with DRS, which is characterized primarily by an inflamed mucosa *(Coco et al., 2008)*. Oropharyngeal candidosis have a high prevalence of 25% in partially or fully edentulous patients, with 68% of them suffering of DRS *(Madrid et al., 2008)*.

Adhesion and Colonization of Dentures by *Candida* Spp.

Candida, as well as other yeasts, has the ability to adhere and grow to synthetic materials in a similar way as they do to oral tissues *(Blankenship and Mitchell, 2006)*. Dentures are made principally of polymethylmetacrylate, sometimes associated to soft liners, tissue conditioners or dental adhesives, and all these materials are permeable and/or present depression. This means that yeasts may be easily retained and form complex biofilms *(Allison and Douglas, 1973)*.

Several publications of *Sumi and coworkers* show that respiratory pathogens preferentially colonize dentures rather than soft tissues like the palate *(Sumi et al., 2002, Sumi et al., 2003, Sumi et al., 2007)*.

Bacteria's proliferation has a close relationship with the development of *Candida* spp. in biofilm *(Hsu et al., 1990)*. At least in vitro, the adhesion of *C. albicans* to the acrylic would

be in presence of streptococci (*S. sanguis* and *S, salivarius*) previously colonizing an acrylic surface like the dentures. Another in vitro study has shown that colonization of the acrylic by *C. albicans* is improved if this occurs simultaneously with *S. mutans (Branting et al., 1989)*.

The different characteristics of free energy of a biomaterial surface, of surface roughness, and of hydrophobic modification influence both the quantity and quality of fungal adhesion *(Ramage et al., 2006, Klotz et al., 1985, Park et al., 2003)*. Surface roughness has been positively correlated with the rate of fungal colonization of biomaterials, so that a rougher surface may be a risk factor for microorganism adhesion and biofilm formation *(Pereira-Cenci et al., 2008, Quirynen et al., 1990)*. When the adhesion of *C. albicans* to a clear heat cured polymethylmetacrylate was compared with two different soft lining materials, each of them with varying degrees of surface roughness, it has been demonstrated that, of the 3 different tested materials, there was less adhesion of *Candida* to smooth surfaces than to rough surfaces. There was also less adhesion of *C. albicans* to acrylic surfaces than to the soft lining materials. Finally, adhesion of *Candida* was reduced by the presence of a salivary pellicle *(Radford et al., 1998)*.

As mentioned above, the ability of *Candida* to develop themselves on oral implants, which are commonly used to support dentures (e.g. overdentures), needs also to be considered, as *C. albicans* has shown to adhere and grow over different implant surfaces such as machined titanium, sand-blasted titanium, sand blasted and acid etched titanium and zirconia *(Bürgers et al., 2010)*.

Most patients suffering from chronic periodontitis wear partial or total dentures. Adhesion of *C. albicans* to epithelial cells (samples collected at subgingival sites) has been reported to be significantly higher in the periodontitis group when compared to a control group (periodontitis free). Even if the role of *Candida* spp. in periodontitis is still controversial and not yet entirely established, the periodontal pocket might serve as reservoir for regrowth of *Candida* in partial edentulous patients wearing dentures *(Machado et al., 2011a)*.

Denture Related Stomatitis: Clinical Manifestation and Diagnosis

Candida spp. are present in the normal oral flora of an important proportion of healthy individual *(Fotos et al., 1992)*. As commensal members of the oral microflora, they are present in 40% (range 20-60) of the human population *(Webb et al., 1998)*. Certain specific conditions like local factors (e.g., xerostomia or hyposalivation, steroid inhaler use, trauma provoked by the denture) and/or systemic factors (e.g., immunodeficiencies like HIV, systemic corticosteroid use, broad spectrum antibiotic use, malnutrition) increase the risk of overgrowth in older persons *(Gonsalves et al. 2008)*.

The clinical presentation of oral candidiasis ranges from no symptoms (for the majority of the cases) to a prominent burning sensation or an unpleasant salty or bitter taste. The most readily recognized clinical pattern, which is the acute pseudomembranous candidiasis (thrush), is characterized by adherent, curd-like plaques that can be removed with a tongue blade or gauze. Another clinical pattern is angular cheilitis, which is a manifestation of *Candida albicans* (but at times *Staphylococcus*) infection. *(Gonsalves et al., 2008)*.

In denture wearers, oral candidiasis may lead to an erythematous lesion (DRS) *(Coco et al., 2008)*. According to 1962 Newton's classification, revised by *Budtz-Jørgensen and Bertram* in *1970*, 3 types of DRS have been described, based on their clinical features: Type I (localized inflammation or hyperaemia), Type II (diffuse erythema), or Type III (papillary hyperplasia of the palate) *(Newton 1962, Budtz-Jorgense and Bertram, 1970)*.

Microbiologic diagnosis uses different samples and techniques, which include: oral rinses, imprint cultures, and swabbing of specific oral tissue sites (e.g., palate) or swabbing of the denture itself *(Bagg et al., 2003)*. However, hyphae detection (an important factor related to the invasiveness, adhesive capacity and virulence) by means of microscopy is now the gold standard for the diagnosis of DRS fungal infections *(Webb et al., 1998)*.

With regard to basic morphologic microscopic features, all yeasts are Gram-positive. The shapes of blastospores can vary from an ovoid to an elongated or spherical form. Size for the *C. albicans* varies between 3-7 x 3-14 μm *(Odds, 1988)*. Since *C. glabrata* cannot form pseudohyphae, this feature is one of the major identification differences with other *Candida* spp. Presence of germ tubes and chlamydospores are helpful in the identification of *C. albicans (Warren et al., 1991)*. Several phenotypic or molecular approaches have been developed for fast and accurate identification of *C. glabrata,* including gene sequence by PCR, restriction fragment length polymorphism (RFLP) or randomly amplified polymorphism DNA (RAPD) methods. However, molecular means are laborious, not very useful in large-scale epidemiological studies and they require expensive equipments (*Valerio et al., 2006, Li et al., 2006)*.

Mycological Changes in Dentures

Until today, the most frequent isolated yeast species in dentures is still *C. albicans,* due to its adhesion and proliferation ability on soft and hard tissues (e.g., dentures, implants) *(Ramage et al., 2005)*. *C. albicans* has been isolated from the palate mucosa (89,2%) and/or maxillary denture (78,5%) in patients suffering from DRS *(Gasparoto et al., 2009)*.

Nevertheless, a high proportion of *non albicans Candida spp*. has been detected in several studies throughout the last years, showing a shift from *C. albicans* towards *non albicans Candida spp.*, with *C. tropicalis, C. parapsilosis, C. glabrata, C. krusei and C. dubliniensis* isolated form diseased tissues *(Samaranayake and Samaranayake, 2001, Coleman et al., 1997, Samaranayake and Samaranayake, 1994)*. This shift has been already confirmed within the last years with *C. glabrata* emerging as the second most prevalent specie *(Coco et al., 2008, Vanden Abbeele et al., 2008)*. Systemic infections of immunosuppressed patients related to *C. glabrata* can lead to high mortality rates *(Krcmery, 1999)*. *Bagg et al.* have reported in cancer patients that 72% of strains of *C. glabrata* were resistant to fluconazole and itraconazole *(Bagg et al., 2003)*. The increased treatment of patients with some antifungal drugs has been proposed to contribute to this fungal profile change *(Martinez et al., 2002)*.

The presence of *C. dubliniensis* in dentures demands a special attention. *C. dubliniensis* was first obtained from oropharyngeal lesions of HIV positive patients *(Sullivan and Coleman, 1998)*. But diabetic patients also exhibit a high prevalence of *C. dubliniensis (Willis et al., 2000)*. This non-albicans species is commonly associated with immunosupressed

individuals *(Davies et al., 2002)*. Nevertheless, some non-immunosupressed populations have shown the presence of *C. dubliniensis (Madrid et al., 2010)*. Thus, the close phenotypic similarities of *C. albicans* and *C. dubliniensis* could probably led to the misidentification of this species in the past. The presence of *C. dubliniensis* was recently demonstrated by PCR or culture in palate and maxillary denture samples from denture wearers with or without DRS. *C. dubliniensis* was isolated at low rates from both palate (5.3 % and 10.7 %) and maxillary denture (5.3 % and 8.9 %) samples from wearers, regardless of the presence of the disease. However, when *C. dubliniensis* was detected in individuals with DRS, it was always associated with *C. albicans (Gasparoto et al., 2009)*.

Systemic Conditions, Aging and DRS

The principal germ implicated in oropharyngeal candidiasis is *C. albicans,* but the non *Candida* spp. (e.g. *C. tropicalis, C. glabrata*) are responsible for 46% of the systemic infections caused by this group of yeasts *(Samaranayake, 1992, Wingard, 1995)*.

At cellular level it is important to recognize that, because they are early recruited to sites of infections, neutrophiles have an influence on the establishment of Oral. Dis.eases like DRS *(Lükac et al., 2003)*. Neutrophiles are able to destroy yeasts by phagocytosis and by production of reactive oxygen species *(Shoham and Levitz, 2005)*. Impaired microbicidal capacity against *C. albicans* has been demonstrate in elderly patients *(Schroeder and Rink, 2003)*. *Gasparoto and co-workers* reported that individuals presenting DRS show a lower number of salivary neutrophiles and dysfunctions in the phagocytosis and in the killing of *C. albicans (Gasparoto et al., 2009)*.

People with HIV form a particular group of patients in DRS infections. The primary targets of virus HIV are CD4 + lymphocytes and cells of the monocyte/macrophage lineage. CD4+ lymphocytes are important in the defense against microorganisms such as *Candida (Perezous et al., 2005)*. Recurrent oropharyngeal candidiasis develops in the majority of HIV positive patients with CD4+ counts bellow 300 cells/mm^3 *(McCarthy et al., 1991)*. The denture surface can serve as a reservoir not only for local infection like DRS but also for disseminated ones (e.g. esophageal candidiasis). Even after the cleaning of the denture, this surface may influence the quantity and quality of fungal adhesion because of its roughness (Radford et al., 1998). Recent clinical data show that while *C. albicans* remains the most common etiological agent of oropharyngeal candidiasis in patients with advanced AIDS (54%), *C. dubliniensis* (17%) and *C. glabrata (*16%) are the second and third most frequently isolated species, which may exhibit decreased susceptibility or resistance to antifungal agents like fluconazole *(Thompson et al., 2011)*.

Malnutrition is frequent in frail older individuals. A poor oral status has been associated with malnutrition *(Sheiham, 2001)*. The relationship between oral candidiasis and nutritional deficiencies has been reported.

A high prevalence of undernutrition (lower leg circumference and lower serum nutritional protein levels) was reported in a population with candidal infection when compared to control a group without infection *(Paillaud et al., 2004)*.

Finally, nicotine addiction must be considered as a systemic condition with local effects on the oral cavity. It has been reported that DRS was facilitated by the presence of

histopathological alterations of oral tissues more frequent in smokers older than 75 years or in patients consuming more than 15 cigarettes/day *(MacEntee et al., 1998, Shulman et al., 2005)*.

Topical and Systemic Antifungal Therapy

Compared to the accessibility of antibiotics, few antifungal drugs are available. Because of increasing drug resistance, probably provoked by repeated or suppressive courses of low-dose of antifungal drugs, assessment of patient's medications must be performed before starting therapy, in order to modify the etiologic factor causing DRS, e.g. change of drugs provoking reduction of salivary flow *(Williams et al., 2011, Perezous et al., 2005)*. It is also essential to treat treating both the patient and the denture (need of rebase of merely make new dentures) the latter often acting as a reservoir of *Candida* isolates *(Tawara et al., 1996)*.

Topical alternatives to treat DRS are polyenes (nystatine, amphotericine B) or imidazoles (clotrimazole, miconazole or ketoconazole) for a period of 14 days. Topical administration is safe, with very few side effects *(Perezous et al., 2005)*. However, it must be noted that within immunocompromized patients relapses are common using this kind of administration *(Scully and McCarthy, 1992)*.

Because of its good systemically delivery and the good concentration in the saliva (similar to what is attained in the blood), fluconazole (100mg day/14 days) is the first choice to treat complex forms of DRS. Even if secondary effects of fluconazole are limited, important interactions do occur with coumarin anticoagulants and sulfonylurea antidiabetic agents *(Williams et al., 2011)*.

As topical alternative, chlorhexidine (CHX) mouth rinses are regularly used as antiseptic in oral care. In concentration of 0.2% CHX has a wide range spectrum of action against oral bacterias and yeasts like *Candida* spp., causing coagulation of nucleoproteins with inhibition of budding and cell changes. Furthermore, CHX also inhibits candidal adhesion to surfaces like dentures *(Ellepola and Samaranayake, 2001)*. One recent in vitro study shows that immersion of sterile dentures inoculated with an azole-resistant *C. albicans* strains in 2% CHX is effective as a disinfection method *(Mima et al., 2011)*. Also a clinical pilot study demonstrates that CHX gel 0.2% reduces by 68% the *Candida* spp. counts after 21 days of use in immunocompromized patients *(Machado et al., 2011)*. Essential oil mouthwashes have also anticandidal in vitro activity, but the clinical benefits of these agents against *Candida* spp. remain to be established in future studies *(Williams et al., 2011, Filoche et al., 2005)*.

C. glabrata, as abovementioned, associated with systemic infections having a high mortality rate is especially difficult to treat.

A mixed infection with *C. albicans* can cause even more severe symptoms and is therefore still more difficult to treat. *C. glabrata* is naturally resistant to a wide variety of antifungal drugs (innate or acquired) It also hosts derived molecules (e.g. defensins, histatins) compared to other *Candida* spp. Moreover, *C. glabrata* exhibits higher adherence to denture surfaces than *C. albicans (Luo and Samaranayake, 2002, Redding, 2001, Redding et al., 1999)*.

Disinfection and Maintenance of Dentures

The understanding of an effective antibiofilm approach is essential to achieve adequate cleaning of dentures. Tooth brushing is a basic method to combat biofilms if it is combined with non-abrasive products (e.g. toothpaste) *(Williams et al., 2011)*. Unfortunately, a low percentage of dentures worn by elderly people are properly cleaned and additionally older dentures tend to be dirtier than the newer ones *(Kanli et al., 2005)*. The institutionalized elderly patient often needs help with oral health care and in particular with the cleaning and disinfecting of dentures. Therefore, a weekly professional mechanical cleaning of the dentures and oral cavity can be an important strategy for the prevention of diseases like aspiration pneumonia *(Ishikawa et al., 2008)*.

Several disinfection methods have been proposed. However, in most of the cases the dentures underwent sanitization rather than sterilization. Many disinfection procedures have been proposed: mechanical cleansing, microwave with varying temperatures, sonicating dentures, immersing the dentures (e.g. in chlorhexidine), using a vacuum, photodynamic therapy etc. In general, all methods reported different degrees of reductions in the levels of microorganisms *(Glass et al., 2011, Machado et al., 2011, Ribeiro et al., 2011)*.

Dentures contaminated by *C. albicans* and irradiated using different microwave energy for different time intervals and power, exhibited reduction in number of counts of yeasts. As a result, surfaces with larger biofilm areas required longer irradiation exposure to be disinfected *(Senna et al., 2010)*. An increased roughness after several cycles of disinfection of the dentures has been reported, and till today there is no standardized method for this technique *(Izumida et al., 2011, Augusto Brondani et al., 2010)*.

Uludamar and coworkers tested different denture disinfection methods in patients with DRS by spraying different mouthwashes on their dentures, like CloSYSII/Chlorine dioxide (Portola Plaza Dental Group, Mission Viejo, CA, USA), and Corsodyl/0.2% chlorhexidine gluconate (GlaxoSmithKline Consumer, Health Group, Oakville, Ontario, Canada) or by using effervescent tablets of different denture cleaners like Polident (GlaxoSmithKline Consumer Health Group, Oakville, Ontario, Canada), Efferdent (Pfizer Consumer Health Care, Scarborough, Ontario, Canada) and Fittydent (Mag Hoeveler Co., Geinberg, Germany) placed in sterile distilled water where the dentures were immersed. Mouthwashes and the effervescent tablets were tested for different periods of time (15, 30 and 60 minutes). All materials tested showed a reduction in the number of *C. albicans*, but mouthwash-sprays are the most easy-to-use and effective method *(Uludamar et al., 2010)*. In general, denture cleansers are effective against *C. albicans* isolates. However, due to biofilm retention, regrowth on denture surface has been observed. This means that a mechanical cleansing will always be required *(Jose et al., 2010)*.

The American College of Prosthodontists published recently evidence-guidelines for care and maintenance of dentures, to reduce potentially harmful bacteria and fungi. For denture cleaning they suggest: the daily cleaning with non abrasive denture cleanser; cleansers should be used only to clean dentures outside the mouth; dentures should be stored in water only after efficient cleansing in order to avoid warping; even if the evidence is weak, the dentures should be cleaned annually by a dentist or dental professional using ultrasonic cleansers (for extensive review see *Felton et al., 2011*).

Conclusion

The world is facing a significant augmentation of the population older than 60 year-old. Even if there has been stabilization over the last years, an augmentation from 20% to 30% is to be expected in 2030 *(Bellomo et al., 2005)*.

In 2050 there is an estimation of 2 billion older people, and 80% of them will be patients in non-industrialized countries *(Erik Petersen, 2003)*. The increasing number of people who will be wearing dentures seems obvious then.

Edentulous patients represent a particular group. These patients report not to receive much instructions concerning oral and denture hygiene *(Arendorf and Walker, 1987)*. As mentioned above, DRS is a common problem among denture users. Additional measures, such as regular adjustment (rebase) and professional cleaning (in a dental laboratory) by means of mechanic - manual cleaning, polishing and decontamination of the denture, might contribute efficiently to eradicate microorganisms (e.g. *Candida* spp.) deeply lodged into the removable dentures. This approach may be far more effective that the inadequate use of antifungal agents.

The quality of life can be largely influenced by oral conditions. *Gagliardi* and co-workers focused on the relationship between oral care and quality of life, showing a significant improvement of it after oral rehabilitation in a population of 119 subjects ranging from 75 to 97 years old *(Gagliardi et al., 2008)*.

The prolonged use of dentures, and especially not removing them at night, associated with poor hygienic habits, a low daily cleansing frequency and inadequate techniques of cleansing (use of abrasive means) and disinfection methods are probably related to the frequent detection levels of *Candida* spp.

The high frequency of *non-albicans Candida* species (particularly *C. glabrata*) detected in different studies seems to confirm a change in the mycological ecology involved in yeast denture colonization.

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Chapter XI

Methods for the Treatment of Denture Induced Psychogenic Symptoms

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Abstract

Psychogenic denture intolerance (PDI) patients suffering from several denture induced psychogenic symptoms refuse to accept psychological background of their symptoms frequently. Instead of psychiatrists or psychotherapists, first they visit dentist and insist on the somatic origin of their symptoms. Since most of these patients refuse a referral to psychiatrist and/or psychotherapist, an initial psychosomatic therapy is needed, which is a scope of dental profession's duty. Initiation of a palliative dental care and gradual escalation of any kind of mind-body therapy (as "basic therapeutics" for psychosomatic disorders) are "cornerstones" of such dental psychosomatic interventions. Introduction of any method of complementary/alternative medicine may also be useful especially for the prevention of relapse. To carry out efficient palliative dental care useless repetition of previous dental treatment (or any further invasive dental treatment) should be avoided, certain psychotherapeutic approaches should be introduced and several other treatment modalities like physiotherapy, medication, medicinal herb therapy or acupuncture should also be administered. For mind-body therapies, relaxation, hypnosis, self-hypnosis, meditation, photo-acoustic stimulation or biofeedback may be used. For complementary and alternative medicine prayer, breathing exercises, Tai-Chi and Qigong, Yoga or several other therapies (i.e. sleep deprivation, vigil, fasting therapy etc.) may be considered.

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Introduction

Psychogenic denture intolerance (PDI) patients suffering from several denture induced psychogenic symptoms refuse to accept psychological background of their symptoms frequently [Ross et al 1953, Fábián et al. 2005, Schwichtenberg and Doering 2008, Fábián and Fejérdy 2010]. Instead of psychiatrists or psychotherapists, PDI patients usually visit dentists and insist on the somatic origin of their symptoms [Ross et al. 1953, Fábián et al. 2005, Fábián and Fejérdy 2010]. Major reason behind premised behavior of patients may be that most PDI manifestations (notwithstanding that they are primarily of psychogenic origin) are coupled with somatic type reactions like several pain symptoms, neuromuscular symptoms, TMJ manifestations, occlusal discomfort, allergic/irritative reactions, salivation problems (etc.) [Fábián and Fejérdy 2010].

Since most of these patients refuse a referral to psychiatrist and/or psychotherapist, an initial psychosomatic therapy is needed, which is a scope of dental profession's duty [Moulton et al. 1957, Pomp 1974, Fábián and Fejérdy 2010]. Initiation of a palliative dental care and gradual escalation of any mind-body therapy are "cornerstones" of such dental psychosomatic interventions. Introduction of any method of complementary/alternative medicine may also be useful.

To carry out efficient palliative dental care useless repetition of previous dental treatment (or any further invasive dental treatment) should be avoided [Brodine and Hartshorn 2004, Sarlani et al. 2005/b, Reewes and Merrill 2007, Baad-Hansen 2008], certain psychotherapeutic approaches should be introduced [Fábián and Fejérdy 2010] and several other treatment modalities like physiotherapy, medication, medicinal herb therapy or acupuncture should also be administered [Fábián and Fejérdy 2010]. For making decision that which premised treatment modality would be the best choice to administer in a concrete case, patient's major somatic type complaint should be considered first; and a method found to be efficient in the scientific literature to improve such complaint should be chosen.

Besides palliative dental care, any mind-body therapy should also be introduced and gradually escaled in the course of treatment. Mind-body therapies are "basic therapeutics" for psychosomatic disorders [Iversen 1989, Binder and Bider 1989, Krause 1994, Fábián et al. 2009, Fábián in press]. Mind-body therapies usually decrease anxiety and level of perceived stress [Fábián and Fejérdy 2010, Fábián in press], and advantageously improve patients' mood, vitality, sleep quality as well as psychoemotional and psychosocial functions [Fábián and Fejérdy 2010, Fábián in press]. For this purpose relaxation, hypnosis, self-hypnosis, meditation, photo-acoustic stimulation or biofeedback may be used. Mind-body therapies advantageously improve psychogenic symptoms in most of the cases leading either to a recovery or to an improvement coupled with increased motivation of patients to take part in a definitive psychosomatic therapy including psychiatric/psychotherapeutic treatment.

As mentioned above, introduction of any method of complementary/alternative medicine may also be useful, especially for the prevention of relapse [Fábián and Fejérdy 2010]. Complementary and alternative medicine (CAM) denotes a wide range of variable therapies, including also treatments with established benefits and few if any side effects. CAM therapies emphasize self-care, which can lead to advantageously decreased load of the much more expensive health care system. For complementary and alternative medicine prayer, breathing

exercises, Tai-Chi and Qigong, Yoga or other therapies (i.e. sleep deprivation, vigil, fasting therapy etc.) may be considered [Fábián and Fejérdy 2010].

Methods for Palliative Dental Care

Psychotherapeutic Approaches

To carry out efficient palliative dental care use of certain techniques of psychotherapy may be needed [Fábián and Fejérdy 2010]. Although in general there is no contraindication of psychotherapy, however level of qualification of the dentist should determine the depth of psychotherapeutic intervention used. Deeper psychotherapeutic interventions targeting psychological structural changes of the personality should be avoided in the absence of full psychotherapeutic qualification. Deeper psychotherapeutic interventions should also be avoided in the case of severe pathologies in the absence of psychiatric support and professional background. For dental psychosomatic therapies client centered approach may be offered as a basic approach, however, certain techniques of cognitive-behavioral therapy, and psychoanalytic therapy may also be used. Client-centered therapy emphasizes the autonomy of clients and the healing effect of the encounter during therapy [Rogers 1965]. It also emphasizes the attitudual qualities of the therapist such as warmth, empathy and genuineness (congruence) [Rogers 1965, Smith 2000] as well as the ability of therapist to emphatically recognize and reflect ("mirror") the real sense behind the client's communication [Rogers 1965]. Autonomy of client together with the encounter and the attitudual qualities of the therapist help patient (client) to remove inside obstacles of personality development, and to become their best possible self [Rogers 1965, Smith 2000].

Cognitive-behavioral therapy is highly advantageous combination of behavioral therapy and cognitive therapy. Behavioral therapy is an operationalized approach, which has its roots in classical learning theory and other findings of experimental psychology. It focuses on current determinants of behavior and draws on the principles of learning to develop individual treatment strategies [de Silva 2000, Smith 2000]. The focus in behavior therapy is the presenting problem itself; and it is not assumed that the presenting problem is a manifestation of an underlying primary problem [de Silva 2000, Smith 2000]. The aim of behavior therapy is to modify the problem behavior at a behavioral level [de Silva 2000, Smith 2000]. Cognitive therapy is based on the assumption that, the person's feelings and behavior are determined by the way in which their experiences are processed cognitively [Ellis 1962, Beck 1976]. In this approach, irrational determinants of thoughts (i.e. spontaneously appearing negative thoughts, errors of logical thoughts, and depressive cognitive schemes [Beck 1976]) are assumed as a major cause of several pathopsychological conditions [Ellis 1962, Beck 1976]. Therefore, cognitive therapy aims to decrease premised maladaptive irrational cognitions and to increase adaptive cognitions of patients.

Psychoanalytic therapies are based on various theoretical streams of psychoanalytic theory. Besides the fundamental libido-theory and ego-psychology, object-relationships theory and self-theory are the most important such theories. Major therapeutical interventions of psychoanalysis are analysis of free associations, analysis of resistance, analysis of

transference, analysis of counter-transference and the related interpretations. Although psychoanalysis is a dept-psychological theory, focusing on unconscious psychological processes [Freud 1900] there are several short-term forms of psychoanalytic therapy (referred to as brief dynamic psychotherapy) which are explicitly problem focused and focal, therefore may be used also for dental psychosomatic therapies.

Physiotherapies

Certain techniques of physiotherapy may also be used efficiently for palliative dental care [Fábián and Fejérdy 2010]. However, it should be considered that, there are some contraindications and precautions of physiotherapies. In general, physiotherapy is contraindicated in the case of patients with any severe systemic diseases and with strongly compromised health. In the case of such patients, use of physiotherapy should be avoided in the absence of a clear agreement of the medical professional(s) responsible for the treatment of the systemic disease(s) at issue (and/or responsible for the medical care of strongly compromised health). Similarly, physiotherapy is usually contraindicated in the cases of patients with any hemorrhagic diathesis, precancerosis, and malignancy as well as in the case of patients having any oncological treatment in the anamnesis (at least in the absence of a clear agreement of the oncologist or other responsible medical professional). Importantly, use of any physiotherapy should be strictly avoided near to a nevus. In the absence of clear evidences about the innocuity, several forms of physiotherapy may be contraindicated for patients with pacemaker (or with another implanted electric instruments) as well as in the case of patients with any implants including also dental implants. Similarly, physiotherapeutic treatment should be avoided near to the ear, eye, brain or spinal cord (i.e. temporal or paravertebral use) and in the condilar area during the growth period, in the absence of clear evidence about the innocuity of the chosen treatment modality. (Especially those modalities utilizing electric/electromagnetic impulses or irradiative energy with significant heat generating effect like laser or ultrasound should be considered for such contraindication.) The most frequently used physiotherapies for the treatment of denture induced psychogenic manifestations are massage combined with muscle exercises, occlusal splint therapy, transcutaneous electrical nerve stimulation (TENS), pulsed electromagnetic field therapy (PEMF), and low level laser (soft laser) therapy.

Massage combined with muscle exercises are aiming to re-train the incoordinated masticatory musculature [Boos 1959, Laney 1983, Schulte 1988, Lund et al. 2006] and to improve the metabolic processes of the muscles and other tissues. Massage is a therapeutic friction, stroking, kneading or shaking of a part of the body. Massage aid the return of venous blood, lymph, and catabolites into the main circulation and therefore may reduce muscle pain or other symptoms [Laskin and Block 1986]. Muscle exercises re-train the incoordinated masticatory musculature and also improve the metabolic processes of the muscles. For most cases, three patterns of sequential movements of the mandible may be used 4 times daily for periods of 2 to 3 minutes as follows [Boos 1959, Laney 1983]: (1) maximal opening position held for 30 seconds and followed by relaxation (without tooth contact); (2) jaw movements to the right (and subsequently to the left) in a slow continuous stretch held for 30 seconds and

followed by returning to the rest position; (3) the mandible is protruded held for 30 seconds and then retruded to the resting posture.

Ultrasound treatment produces vibrations within the tissue that cause particle collision and the release of energy resulting in the production of heat [Laskin and Block 1986]. Therefore, ultrasonic treatment induces a combined deep effect of vibration ("micromassage") and deep heat effect (to a dept of 4 - 5 cm) [Bell 1969/b, Laskin and Block 1986]. Ultrasound therapy may be used to reduce muscle tension and to improve myofascial pain symptoms. Ultrasound treatment also increases tissue elasticity and improve circulation. The sound head is used over the involved muscles (i.e. masseter or temporal muscles) and should be moved slowly to avoid excessive heat build up [Laskin and Block 1986]. Treatments last 10 to 15 minutes, and can be applied twice a day for 1 to 2 weeks [Laskin and Block 1986]. Ultrasound should not be applied over the eye, over the ear, over an area of acute inflammation [Bell 1969/b, Laskin and Block 1986] and over metallic implants [Laskin and Block 1986]; and great care should be taken to avoid heat build up when ultrasound is used near the brain and spinal cord (i.e. temporal or paravertebral use). Ultrasound therapy is also contraindicated in patients with cardiac pacemaker, vascular insufficiency and malignancy [Laskin and Block 1986]. Use of ultrasound should also be avoided in the condylar area during the growth period [Bell 1969/b]

Transcutaneous electrical nerve stimulation (TENS) refers to commercially available devices that apply electric impulses to the peripheral nerves via electrodes placed on the skin [Bishop 1986, Curcio et al. 1987]. Although electrodes of TENS devices were originally placed on the skin, in dentistry "intraoral TENS" (intraoral electrostimulation therapy) utilizing electrodes placed intraorally may also be used [Wilder-Smith and Zimmermann 1989, Wilder-Smith 1990]. Based on the gate-control theory [Melzack and Wall 1965] it is hypothesized that stimulation of the branches of the trigeminal nerve due to TENS creates an inhibitory effect on the trigeminal nucleus and thereby reduces awareness of pain and helps (indirectly) to induce muscle relaxation. It is also hypothesized that, TENS induces release of endorphins, norepinephrine and serotonin in the central nervous system, which may also be responsible for the clinical effects [Black 1986, Hochman 1988]. Further, TENS increases circulation in the areas where electrodes are placed and of those muscles, which belong to the stimulated nerve [Hochman 1988, Laskin and Block 1986]; and therefore reduces muscle pain and increases muscles' resistance to fatigue [Laskin and Block 1986]. There is also a rather significant placebo effect coupled with TENS therapy [Gold et al. 1983, Dahlström 1992, Green and Laskin 2000]. Patients are usually treated by placing the electrode directly over the area of most discomfort for 30 minutes daily [Laskin and Block 1986]. TENS is contraindicated for certain patients including pregnant patients and pacemaker patients as well as for patients with cerebral convulsive disorders (possibility of initiating seizure), with pathologic hypotension (TENS lowers blood pressure) and with cerebral vascular disorders (blood flow increases in the areas where electrodes are applied) [Hochman 1988].

Occlusal splints are also frequently used. Reflex splints (occlusal disengagement) trigger mouth opening reflex due to functioning as an "artificial early contact" and as such may be used for reducing stress induced muscle spasm and parafunction activity [Mikami 1977, Laskin and Block 1986]. Reflex splints should be used for short run (at maximum for 2 weeks [Freesmeyer 1995]), because if such a splint were worn too long, a "new series" of muscle

spasm and parafunction could be triggered [Freesmeyer 1995]. Further, there is a danger of elongation (supereruption) of teeth, remodeling of the temporomandibular joint [Griffin 1975], as well as other severe and irreversible complications [Widmalm 1999]. If reflex splints are not worn continuously, but only at night and for 5 to 6 hours during the day [Laskin and Block 1986], reflex splints may be used somewhat longer (at maximum for 4 to 6 weeks) under regular control [Bell 1969/b, Laskin and Block 1986]. Reflex splints may be equilibrated and transformed into equilibrated splints due to filling up the existing space between the molars [Green and Laskin 1972/a], followed by occlusal adjustment until simultaneous tooth contacts are achieved on the complete occlusal coverage of the arch. Such equilibrated splints may be used for harmonizing muscle function [McNamara 1976, Mikami 1977, Dahlström et al. 1982, 1985, Dahlström 1989]. Importantly, the efficiency of splint therapy is expected to be based (at least partially) on placebo effects [Green and Laskin 1972/a, 2000, Laskin and Block 1986, Molin 1999]. However certain kind of splints like repositioning appliances (due to positioning of condyles) clearly exerts certain specific therapeutic effects as well [Green and Laskin 1972/a, Dahlström 1992, Karppinen et al. 1999].

Pulsed electromagnetic field (PEMF) therapy seems to be a highly promising method for psychosomatic dentistry. PEMF induces local vasodilatation [Smith et al. 2004] and increases angiogenesis [Tepper et al. 2004]. PEMF also enhances healing of bone fractures [Gossling et al. 1992, Pienkowski et al. 1992, Inoue et al. 2002], decreases the rate of residual ridge resorption following tooth extraction [Ortman et al. 1992], increases the rate of orthodontic tooth movement and coupled bone deposition [Stark and Sinclair 1987, Darendeliler et al. 1995], and improves bone formation in bone defects and around dental implants (osteointegration of implants) [Matsumoto et al. 2000]. Osteoporotic symptoms and symptoms of osteoarthritis patients may also be improved using PEMF. Besides the important bone-related effects, PEMF also improves tendon inflammation and returns to histological normality as well [Binder et al. 1984, Lee et al. 1997]. PEMF also improves wound healing of the gastrointestinal mucosa [Mentes et al. 1996] and the skin [Patino et al. 1996, Scardino et al. 1998]. Similarly, ulcerations may also be improved due to PEMF therapy [Stiller et al. 1992]. PEMF also improves regeneration of injured nerve [Raji 1984, Zienowicz et al. 1991, Kanje et al. 1993], and improves clinical symptoms (i.e. pain, decrease of conductive function, decrease of reflex excitability) of several neuropathic conditions [Musaev et al. 2003, Weintraub and Cole 2004]. PEMF may also be used for acupuncture therapy. Patient are usually treated by placing the applicator directly over the area of most discomfort for 10-15 (up to 30-40) minutes at least once (or may be twice or three times) a week. There is no specific contraindication of PEMF therapy, but general contraindications should be considered also for PEMF therapy.

Low level laser therapy (LLLT; also referred to as soft laser therapy) is a treatment with athermic low power lasers. There are many different types of low level laser (LLL) may be used for LLLT including either pulsed or continuous LLL, and with wavelength in both visible and invisible range [Khullar et al. 1995, Kimura et al. 2000]. In general, increase of cell metabolism, collagen synthesis and activity of immune cells are the most important pathways behind the efficiency of low level laser therapy [Qadri et al. 2005]. LLLT also inducing long-lasting expression of HSP70/HSPA type stress proteins [Souil et al. 2001]. There is also a prominent placebo effect coupled with low level laser therapy [Kimura et al.

2000, Payer et al. 2005]. LLLT may be used advantageously to control periodontal inflammation [Qadri et al. 2005, Schwarz et al. 2008] and more severe inflammatory and/or necrotizing bone pathologies [Vescovi et al. 2008]. LLLT may also be used to improve implant-tissue interaction in the bone and at the implant-soft tissue interface [Khadra et al. 2005/a,b, Schwarz et al. 2005]. LLLT may also be used to facilitate orthodontic tooth movement and related alveolar bone remodeling as well [Kawasaki and Shimizu 2000, Fujita et al. 2008]. LLLT may also facilitate bone metabolism during healing of bone defects. Besides its advantageous effect in the bone, LLLT improves myofascial pain [de Medeiros et al. 2005, Shirani et al. in press] and temporomandibular joint pain [Dahlström 1992, Mazzetto et al. 2007]. LLLT may also be used to improve functional recovery of injured peripheral nerves [Khullar et al. 1995, Ozen et al. 2006]. LLLT also accelerates oral wound healing [Amorim et al. 2006, Ozcelik et al. 2008] as well as healing of oral ulcerations [Navarro et al. 2007]. Low level lasers may also be used for acupuncture therapy.

Medicamentous Therapies

Medicamentous therapies are frequently used for dental psychosomatic therapies. The most frequently used drugs are pain killers and non-steroidal anti-inflammatory drugs, muscle relaxants, anxiolytics, and antidepressants. There are various specific contraindications and possible side effects of medicamentous therapies, which should be considered very carefully [Bell 1969/b, Laskin and Block 1986, Friedlander et al. 2004]. Utilizing pharmacological databases and an up-to-date pharmacological knowledge, dentists should be familiar with the potential hazards before prescribing a medication [Bell 1969/b, Laskin and Block 1986, Friedlander et al. 2004]. Considering premised precautions, short run (1 to 2 weeks, or maximum 3 to 4 weeks) administration of several medicaments can be carried out by the dentist in the frame of initial psychosomatic therapy [Bell 1969/b, Miyamoto and Ziccardi 1998, Laskin and Block 1986, Toyofuku and Kikuta 2006]. However, long-run medicamentous treatment of long-standing symptoms is clearly a scope of medical professionals such as psychiatrists, neurologists, rheumatologists, internists, family doctors (etc.). Therefore, if long-run medication is needed because of any reasons, it is necessary to place the patient under physicians' care [Laskin and Block 1986].

Pain killers and non-steroidal anti-inflammatory drugs (NSAIDs) are used primarily for the initial therapy of not yet chronic cases, because there is frequently no significant improvement of chronic orofacial psychosomatic symptoms after treatment with pain killers and non-steroidal anti-inflammatory drugs (NSAIDs) [Gellrich et al. 2002]. Since most of the orofacial pain symptoms are also (at least partially) of inflammatory origin, in most cases NSAIDs (instead of exclusive pain killers) are used for such purposes. Importantly, NSAIDs can also be applied locally [King 1988]. There are numerous NSAID gels and plasters available for local application, which may be used advantageously when applied onto the skin surface over the painful area. Local application may prevent drug tolerance and dependence which may appear following per os application of these drugs [Israel and Scrivani 2000].

Muscle relaxants may be used, because spasm produces pain that in turn produces more spasm in many cases [Laskin and Block 1986]. Thus, muscle relaxants may be used to

interrupt this vicious cycle, especially when used in conjunction with a pain-relieving medication [Laskin and Block 1986]. Importantly, certain anxiolytics (especially benzodiazepines) also exert significant myorelaxant properties [Chaco, 1973, Laskin and Block 1986, Dahlström 1989, 1992]. Since tranquilizing (anxiolytic) properties can be beneficial in relieving muscle tension too [Laskin and Block 1986], premised anxiolytics (benzodiazepines) are the drugs most often prescribed as muscle relaxants [Laskin and Block 1986, Dahlström 1992]. Again, benzodiazepines should also be taken in conjunction with an analgesic for the best effect [Laskin and Block 1986]. Interestingly, drugs with only muscle relaxant properties (i.e. without any anxiolytic effects) seem to be not as successful as premised anxiolytics (benzodiazepines) for the treatment of myofascial pain [Laskin and Block 1986].

Anxiolytics (especially benzodiazepines) may be used as an adjunct for the initial treatment of patients with high background anxiety level [Bell 1969/b]. Because of their significant antidepressive properties [Köhler 2005] benzodiazepines may also be used advantageously for patients with depression [Bell 1969/a], although cases with severe depression can not be managed with the use of benzodiazepines by itself [Köhler 2005]. Based on their myorelaxant effect, benzodiazepines may also be used advantageously as an adjunct to the initial therapy of patients with myofascial pain [Bell 1969/b, Green and Laskin 1972/b, Ryan et al. 1985, Laskin and Block 1986] and denture related (denture induced neuromuscular dysfunction related) functional TMD problems [Bell 1969/b, Chaco 1973, Dahlström 1989]. Benzodiazepines may also be used for the treatment of burning mouth syndrome [Sarlani et al. 2005/b].

Antidepressants can be used for pain reduction even if there are no current symptoms of depression [Maina et al. 2003, Derra and Egle 2003]; because they also exert a significant direct analgesic effect which is likely to be independent from the antidepressive effect [Derra and Egle 2003]. In contrast to antidepressive effect (appearing earliest after 2-4 weeks at best [Köhler 2005]) premised analgesic effect appears after 3-7 days [Miyamoto and Ziccardi 1998, Derra and Egle 2003]; and importantly, low doses are also sufficient to reach the premised analgesic effect [Miyamoto and Ziccardi 1998, Derra and Egle 2003]. For such low dosage administration, especially serotonin-norepinephrine reuptake inhibitors may be useful [Miyamoto and Ziccardi 1998, Derra and Egle 2003], because their direct analgesic effect seems to be stronger comparing to other groups of antidepressants [Miyamoto and Ziccardi 1998, Derra and Egle 2003]. Similarly, serotonin-norepinephrine reuptake inhibitors exert a direct effect on the somatosensory system as well; which is also likely to be independent from the antidepressive effect [Toyofuku and Kikuta 2006] and can be utilized efficiently for treating occlusal dysesthesia [Toyofuku and Kikuta 2006]. Similarly to pain treatment, low doses are likely to be sufficient to reach this kind of somatosensory effect too [Toyofuku and Kikuta 2006], however, this effect likely appears somewhat later (after 2-4 weeks) [Toyofuku and Kikuta 2006]. Although a definitive medicamentous treatment of affective disorders (including depression) is clearly a scope of psychiatrist; short run (1 to 2 weeks, or maximum 3 to 4 weeks) administration of low doses antidepressants (see above) can be carried out also by the dentist in the frame of initial psychosomatic therapy [Miyamoto and Ziccardi 1998, Laskin and Block 1986, Toyofuku and Kikuta 2006]. Especially pain symptoms including

myofascial pain, atypical facial pain, atypical odontalgia, phantom tooth pain, burning mouth syndrome as well as occlusal dysesthesia may be improved in this way.

Medicinal Herb Therapy

Medicinal herb therapy is an important supplemental modality of psychosomatic dental therapy. Proper use of medicinal herbs may be utilized for such therapeutic purposes efficiently. However, potential health hazards should be avoided. Therefore, great care should be taken especially in the case of patients with severe systemic diseases as well as during pregnancy and lactation. Similarly, great care should also be taken, when long run administration of medicinal herbs is needed. In such cases consultation with (or referral to) an internist and/or family doctor is highly recommended before starting medicinal herb therapy [Fábián and Fejérdy 2010]. It should be also considered that, medicinal herb therapy is frequently used for health enhancement by patients without any professional control; and unfortunately, they also use medicinal herbs during pregnancy and lactation or under severe systemic diseases, which may cause significant health hazards [Fábián and Fejérdy 2010]. Concurrent use of medicinal herbs and pharmaceutical drugs without any control of medical or dental professionals is relatively common and the majority of herbal medicine users are not aware of potential adverse effects [Zhang et al. 2008]. Therefore, dentist should carefully collect information about the patients' medicinal herb related usage. Besides specific contraindications, potential health hazards including possible interactions with medications [Segelman et al. 1976], risk of abuse of medicinal herbs [Siegel 1979] and risk of herbal intoxication [Siegel 1976] should also be considered very carefully before starting medicinal herb therapy.

A principled multi-target strategy of medicinal herb therapy may be advantageously used [Ginsburg et al. 2008]; however the use of an unprincipled combination of medicinal herbs should be strictly avoided. To avoid any potential adverse effects, dentist should administer medicinal herb therapy for a limited time span (few months) only. Following this period the therapeutic administration (at least two cups per day and/or use of medicinal herb extracts) of medicinal herbs should be either terminated or surrendered to the family doctor (or other professionals like internist, psychiatrist etc.). In the case of pregnancy, lactation, and any severe compromised health conditions, a consultation with the family doctor (or any other professionals responsible for the treatment of the condition at issue) is highly recommended before starting any medicinal herb therapy. For the treatment of psychogenic symptoms administration of Black Cohosh, Chastetree, Gingko, Ginseng and St John’s wort as well as Cocoa, Coffee and Tea may be considered primarily.

Black cohosh (Cimicifuga racemosa) constituents likely act on serotonin receptors and may relieve hot flashes of women and improve mood through a serotoninergic effect [Burdette et al. 2003, Geller and Studee 2005]. Improvement of sleeping, fatigue and abnormal sweating [Pockaj et al. 2004] could also be based on premised serotoninergic (antidepressant) effect. Black cohosh may also exert bone-protective effects. The combination of black cohosh with St John's wort (see below) was found efficient also in psychovegetative disorders, likely via a synergistic effect [Liske 1998]. Use of Black cohosh is contraindicated in pregnancy, lactation, failured liver function and may be breast cancer.

Chastetree (Vitex agnus-castus) is a progesterone-like substance containing [Brown 1997, Geller and Studee 2005] plant approved for the treatment of premenstrual syndrome (PMS), breast tenderness and irregularities of menstrual cycle [Geller and Studee 2005]. Similarly, chastetree may improve peri- and postmenopausal symptoms including emotional problems and hot flashes [Lucks 2003]. The use of this plant should be avoided during pregnancy and lactation [Daniele et al. 2005] and interference of chastetree with dopaminergic antagonists may also be expected [Daniele et al. 2005].

Ginkgo (Ginkgo biloba) increases blood flow especially to the brain, increases uptake of glucose by brain cells and improve transmission of nerve signals [Geller and Studee 2005]. Ginco is approved for use of cerebral insufficiency, vertigo, tinnitus and also for peripheral vascular diseases like Raynaud's syndrome [Kleinen and Knipschild 1992, Geller and Studee 2005]. Ginco may also be used to improve memory function and dementia.

Ginseng (Panax ginseng) is used as a tonic for invigoration and fortification in times of fatigue, for improvement of declining capacity for work or concentration, and for coping with psychosocial stress [Geller and Studee 2005]. It may also be used to improve depression, insomnia, well being [Tode et al. 1999, Wiklund et al. 1999] and unexplained chronic fatigue [Bentler et al. 2005]. Ginseng also enhances the anti-allergic effect of green tea [Maeda-Yamamoto et al. 2007]. However, in the case of malignancies use of ginseng could be contraindicated [Geller and Studee 2005].

St John's wort (Hypericum perforatum) seems to be effective to improve mild to moderate depressive symptoms (but not major depression) [Linde et al. 1996, 2005, Volz 2005], as well as fatigue [Volz 2005], atypical depression [Volz 2005], several somatoform disorders [Volz 2005] and likely also anxiety [Volz 2005]. A synergistic effect of St John's wort with black cohosh (see above) in the case of psychovegetative disorders is also very likely [Liske 1998, Geller and Studee 2005]. Climacteric symptoms including several psychological and psychosomatic symptoms and sexual well-being may also be improved efficiently with the use of St John's wort [Grube et al. 1999]. However, great care should be taken with herb-drug interactions because St John's wort is a potent ligand for pregnane X receptor [Moore et al. 2000, Carlson et al. 2008] and consequently increases cytochrome P450 dependent hepatic drug metabolism. Therefore St John’s wort may decrease blood concentration of several drugs including anticoagulants, oral contraceptives, cyclosporin, digoxin etc.

Cocoa contains a variety of active substances which act at the same site in the brain like cannabis [DiTomaso et al. 1996] and amphetamine [Benton and Donohoe 1999]. Cocoa also contains relatively high amount of stimulants like theobromine and caffeine as well as magnesium [Bruinsma and Taren 1999] which improves mood and may improve coping ability with stress. Certain cocoa flavonols also exert anti-inflammatory properties.

Coffee constituents exert several physiological effects including central nervous system stimulation, acute elevation of blood pressure, increase of metabolic rate and diuresis. Other constituents exert rather significant antioxidant activity [Higdon and Frei 2006]. Moderate coffee consumption (up to 3-4 cups in a day) is associated with a reduced risk of depression [Smith 2009], improved cognitive functioning [Smith 2009], improved mood [Robelin and Rogers 1998], improved psychomotor performance [Robelin and Rogers 1998] and decreased fatigue [Smith 2002] all of which are rather advantageous also for psychosomatic therapies.

Tea (Camellia sinensis) is a native plant of South Asia, which may be (black tea) or may not be (green tea) “fermented” prior drying . Black tea is rich in caffeine but, the total content of flavonoids is usually lower. Consumption of black tea is associated with a reduced risk of depression [Smith 2009], improved cognitive functioning [Smith 2009], improved mood [Robelin and Rogers 1998], improved psychomotor performance [Robelin and Rogers 1998] and decreased fatigue [Smith 2002]. Green tea is rich in flavonoids, but the caffeine content is much lower than in black tee. Tea flavonoids exert significant anxiolytic, sedative and psychological stress reducing properties [Adachi et al. 2006, Vignes et al. 2006]. Tea flavonoids also induce immunosuppressive alterations on human dendritic cells, decrease the adhesiveness and migration of mast cells and are likely to inhibit T-cell activation. They also inhibit activity and expression of matrix metalloproteinases (agents causing alveolar bone loss) and inhibits osteoclast formation [Yun et al. 2004]. Since tea flavonoids inhibit hepatic cytochrome P450-dependent enzymes [Yang et al. 2000, McKay et al. 2002], possible herb-drug interactions should also be considered especially in the case of green tea.

Acupuncture

Acupuncture is a traditional Chinese practice that attempts to regulate and restore energy balance by stimulating specific acupoints [Whittaker 2004]. Acupuncture therapy may be based on the trigger point method, in which painful trigger points are recognized and stimulated with acupuncture needles and/or with any other acupuncture modalities (i.e. electro acupuncture, laser- or PEMF acupuncture, acupressure, moxibustion etc.) [Baldry 2005, Fábián and Fejérdy 2010] Similarly, acupuncture treatment of intraoral painful points (i.e. oral acupuncture) may also be used [Schmid-Schwap et al. 2006]. In this case most painful points are selected by the "very-point method" [Gleditsch 1980] after palpation of the retromolar areas of maxilla and mandible and the vestibulum [Gleditsch 1980, Schmid-Schwap et al. 2006].

Besides trigger point (and/or intraoral "very-point") based treatment, acupuncture therapy based on the traditional Chinese conception of vital energy (called "Chi" or "Qi") may also be used [Baldry 2005, Fábián and Fejérdy 2010]. Traditional acupoint Hegu (LI-4) may be used for the treatment of oral and/or dental pain as well as for the treatment of TMD disorder. Yifeng (SJ-17) may also be used for the treatment of oral and/or dental pain. Chengjiang (REN-24) may be used for control gag reflex and also for the treatment of xerostomia. Jiache (ST-6) and Xiaguan (ST-7) may be used for the treatment of xerostomia and also for the treatment of oral and/or dental pain. Daying (ST-5) and Tinggong (SI-19) may also be used to treat xerostomia. Serious adverse effects following acupuncture are rare [Vachiramon and Wang 2005]. However acupuncture may be contraindicated in the case of patients with certain psychiatric conditions like paranoid psychosis, hypochondria (etc.). Great care should be taken for infection control. Injuries of blood vessels nerves and any other sensitive tissues should also be strictly avoided when needle type acupuncture is used. Specific cautions should also be considered when laser-, electric-, or electromagnetic (PEMF) stimulation are used.

Mind-Body Therapies

Relaxation

Relaxation belongs to the natural behavior repertoire of human, but can also be induced by several methods following a learning process [Tóth and Fábián 2006, Fábián and Fejérdy 2010, Fábián in press]. The most frequently used basic methods are simple eye-closure, standard exercises of Autogenic Training [Schultz 1932], progressive muscle relaxation [Jacobson 1938], and biofeedback assisted relaxation [Ray et al 1979]. Relaxation induces a relaxing feeling, reduced arousal level, and reduced stress. In relation with oral psychosomatic symptoms, relaxation may be used efficiently for the therapy of bruxism, myofascial pain and TMD symptoms of muscular dysfunction origin [Biondi and Picardi 1993, Sarlani et al. 2005/a]. Somatoform chronic pain may also be treated efficiently using progressive muscle relaxation [Kröner-Herwig et al. 1998, Derra 2003, Rehfisch and Basler 2004]. Dental fear and dental phobia can also be treated with relaxation based methods [Hammarstrand 1995, Moore et al. 1996]. Relaxation may also be combined advantageously with numerous psychotherapeutic approaches. Accordingly, combination of progressive muscle relaxation with cognitive behavioral therapy and abdominal/diaphragmatic breathing was highly efficient to reduce pain-activity interference, pain intensity, depression, maladaptive pain beliefs, catastrophizing and to improve masticatory jaw function in a randomized controlled trial [Turner et al. 2006].

Hypnosis

Hypnosis may be defined as an altered state of consciousness (ASC) achieved by suggestions. Numerous important theories were developed to explain hypnosis [Orne 1959; Shor 1962, Bányai and Hilgard 1976, Hilgard 1991, Bányai 1991, Crawford and Gruzelier 1992]. However, there is currently consensus only on that the real essence of hypnosis lies in the experienced subjective alteration of consciousness (ASC) [Varga et al. 2001]. In this relation, altered state of consciousness (ASC) can be defined as sudden and transient subjective experience significantly different from those of common everyday experiences. ASC may induce significant changes of most psychological functions including attention, perceptions, sense of time, body image, self image, imagination, fantasy, cognition, emotions, arousal, memory, self-control, suggestibility, identity etc. [Kihlstrom 1984, Pekala and Kumar 1989, Farthing 1992, Halsband et al. 2009]. Importantly, significant pain relieving effect also occur following induction of hypnotic state; which can be influenced (i.e. increased or decreased) significantly using specific suggestions [Meier et al. 1993; Rainville et al. 1997, 1999; Fábián and Fábián 1998; Gáspár et al. 2003]. Data indicate that, changes of attentional function during hypnosis may induce dissociation of several psychological functions [Hilgard 1991, 1994] including dissociation of sensory and affective components of pain [Meier et al. 1993] as well as other pain related functions including generation of pain at the periphery, sensitization of secondary sensory neurons, modulation of endocrine-, immune- or autonomic responses and modulation of psychological functions [Miltner et al. 1992,

Larbig 2004, Carli 2009, Vanhaudenhuyse et al. 2009]. Besides pain perception, other physiological functions such as autonomic and hormonal responses, neuromuscular function, immune surveillance and immune/inflammatory reactions may also be advantageously influenced using hypnosis [Gruzelier et al. 2001, Gruzelier 2002, Mawdsley et al. 2008]. Hypnosis may be used for the treatment of bruxism and other neuromuscular symptoms, myofascial pain, atypical facial pain, oropyrosis and other psychogenic pain [Staats and Krause 1995, Chaves 1997, Schmierer 1997,2004, Fábián and Fábián 1998] Hypnosis may be used highly efficiently also in the treatment of psychogenic denture intolerance [Ament and Ament 1970, Barsby 1997, Eli and Kleinhaus 1997, Fábián and Fábián 2000, Fábián et al. 2007].

Self-Hypnosis

Self-hypnosis may be defined as an altered state of consciousness (ASC) achieved by self-suggestions. During practicing self-hypnosis, a deep hypnoid trance state (altered state of consciousness) develops similarly to those of hypnosis (see above). Autosuggestive techniques have been widely used from the earliest time of history [Heinze 1993, Hoppál 1993/a,b] but self-suggestions stood in the limelight of scientific interest in the last century only. There are several methods may be classified as self-hypnosis including (self)imagination techniques, active-graded-(self)hypnosis [Kretschmer 1946, Langen 1969], and biofeedback coupled techniques. Photo-acoustic stimulation (see below) may also be used to induce peculiar self-hypnotic states. The prototype of self-hypnotic methods is Autogenic Training [Schultz 1932], which is based on giving suggestions toward phenomena spontaneously occurring under relaxation to amplify and control them [Schultz 1932, Krause 1994]. Self-hypnosis practice can be resulted in prolonged increase of overall mental health, including decrease of depression scores, (trait)anxiety level, perceived stress scores, increase of self-observed level of mental energy and improved sleep quality under stress conditions. Sleeplessness (light sleep, disturbed sleep, insomnia) of patients can also be improved significantly using several self-hypnotic methods. Self-hypnosis may also be used efficiently for most forms of somatoform disorders; including somatoform chronic pain, pseudoneurological symptoms, autonomic dysfunction, pruritus (itching), several motor symptoms, fatigue, and allergic symptoms [Leuner and Schroeter 1997, Bongartz and Bongartz 2000, Langewitz et al. 2005].

Meditation

Although there are several forms of meditation, and no two meditation practices are alike in all features [Ospina et al. 2007, Halsband et al. 2009] meditation can be defined as volitional self-induced altered state of consciousness (ASC), established by mental faculties, without dominant contribution of other persons, highly intense body exercises or use of drugs [Fábián in press]. Practices of meditation may be divided into two subgroups such as concentrative type and nonconcentrative type methods [Orne and Whitehouse 2000, Fábián in press]. Although concentrative and nonconcentrative approaches differ from each other, the

subjective experience of deeper stages seems to be rather similar phenomenologically. Finally both group of meditation techniques, lead to a state of "Being", a state of "Knowing" or "Experiencing" without objectification and discursive thinking [Fábián in press]. In religious form of meditation, premised deep meditative states and experiences have certain religious overtones [Fábián in press]. There is an overall improvement of psychological abilities of meditators leading to more efficient social functioning and improved stress tolerance coupled with decreased level of neuroticism, depression, (trait)anxiety, trait negative affect, stress induced emotional irritability and stress induced anger. Long-run training of meditation also shortens habituation of stressful stimuli, and decreases the level of perceived stress [Fábián and Fejérdy 2010]. Meditative states also possess highly efficient anti-nociceptive effects. Sustained increase of pain tolerance [Kingston et al. 2007], reduction of pain induced distress [Mills and Farrow 1981] and reduced reactivity to pain in the brain [Kakigi et al. 2005, Orme-Johnson et al. 2006] were also reported following meditation training.

Photo-Acoustic Stimulation

Early studies demonstrated that turning the light or sound on and off induce alpha desynchronization on EEG [Berger 1930, Walter et al. 1946], leading to powerful stimulating effect on the central nervous system for a short time. In contrast, long lasting stimulation with flash light and tone signals (5-10 Hz frequency) leads to drowsiness and mixed alpha-theta activity [Williams and West 1975] coupled with body relaxation [Brauchli 1993] and appearance of significantly altered state of consciousness [Fábián et al. 2002]. These data indicate that, photo-acoustic stimulation whereas helps to keep the body relaxed, activates psychophysiological functions conducive to meditation (ASCs) coupled with somewhat increased arousal level [Fábián et al. 2005, 2009]. Photo-acoustic stimulation also exerts anti-depressive properties [Fábián et al. 2005, 2009].

Besides premised effects, flash light stimuli interact with the visual imagination leading to spontaneous appearance of various aspecific colored simple forms (i.e.: line, curve, web, lattice, spiral, cloud, tunnel etc.) [Fábián et al. 2005, 2009] similar to those induced by several hallucinogens in the phase of non-complex images [Siegel and Jarvik 1975, Siegel 1977]. (Using lower light intensities real visual imaginations may also appear [Fábián et al. 2005, 2009].) Since such visual imaginations appear spontaneously, a delightful experience of altered state of consciousness can be achieved even in case of patients with low motivation such as psychogenic denture intolerance (PDI) patients [Fábián et al. 2005, 2006, 2009].

Photo-acoustic stimulation improves oral immune surveillance. Both secretory immunoglobulin A [Brauchli 1993] and salivary chaperokine HSP70/HSPA [Fábián et al. 2004/b] (a salivary defense protein, molecular chaperone and cytokine) were increased significantly under photo-acoustic stimulation induced meditative state. Similarly, other oral defense proteins such as salivary amylase [Fábián et al. 2002, 2004/b] proposed to inhibit microbial growth [Shugars and Wahl 1998] and salivary lysozyme [authors' unpublished data] being bacteriolytic for gram-positive bacteria were also increased under premised meditative state. All premised changes induced by photo-acoustic stimulation advantageously improve defense of the oral cavity leading to clinical improvement of several oral mucosal symptoms especially of psychosomatic origin [Fábián and Fábián 2000, Fábián et al. 2005; 2007, 2009].

Somatoform orofacial chronic pain can also be treated efficiently using photo-acoustic stimulation [Fábián et al. 2002, 2005, 2006, 2009, Bálint et al. 2003]. Improvement of salivary gland function including significant increase of both flow rate and protein concentration following photo-acoustic stimulation treatment was also reported [Kaán et al. 2003, Fábián et al. 2009]. Premised improvement of salivary gland function is likely because of a prolonged decrease of sympathetic activity following treatment [Kaán et al. 2003]; notwithstanding that, there is a prompt, but short-term sympathetic activation under photo-acoustic stimulation. Tinnitus was also improved using photo-acoustic stimulation [Tönnies 2006]. Photo-acoustic stimulation was also used efficiently in the treatment of PDI cases with various somatic type manifestations [Fábián et al. 2004/a, 2006, 2009]. Photo-acoustic stimulation may be used highly efficiently also as a group-therapy [Fábián et al. 2006, 2009].

Biofeedback Methods

Biofeedback methods alter patient's physiological processes using devices that amplify signs of physiological processes that are ordinarily difficult to perceive without some type of amplification [Forgione and Mehler 2006]. Patients use the provided feedback signals as a guide. Measurable parameters of body functions coupled with relaxation such as muscle tension (EMG), skin conductance level (GSR or SCL), heart rate, heart rate variability (HRV) and skin temperature may be used efficiently for biofeedback treatment of orofacial psychosomatic patients [Forgione and Mehler 2006]. Feedback of breathing with light and sound signals called respiratory feedback [Leuner 1984, 1997, Barolin 2001] may also be used efficiently, because advantageous psychophysiological effects of breathing exercises and photo-acoustic stimuli also succeed in this case. Spontaneous appearance of altered state of consciousness was reported in significant proportion of subjects learning relaxation with the assistance of biofeedback equipment [McKee 1980, Leuner 2001] indicating that, therapeutic suggestions given under biofeedback may also be used highly efficiently [Leuner 2001]. Somatoform chronic pain may be treated efficiently using several biofeedback methods [Derra 2003, Kröner-Herwig 2004]. Other somatoform symptoms including pseudoneurological symptoms, autonomic dysfunction, pruritus (itching), several motor symptoms, fatigue (etc.) may also be treated efficiently with several biofeedback methods [Winkler and Krause 1989, Martin and Rief 2006]. Sleeplessness (light sleep, disturbed sleep, insomnia) of patients can also be improved with biofeedback [Krause 1983, Niepoth and Korn 2006].

Contraindication of Mind-Body Therapies

Contraindication of mind-body therapies includes several prepsychotic- and psychotic conditions, dementia and other deficiency of intelligence and also narcolepsy. Mind-body therapies may also be contraindicated under acute psychic trauma (crisis) because of increased liability toward regression of the patient. Treatment of borderline and narcissistic patients, strongly depressive or hysteric patients, introverted patients and also hypochondria patients may also be contraindicated [Fábián et al 2009, Fábián and Fejérdy 2010, Fábián in

press]. Great care should be taken with somatic diseases of unknown origin, because palliation of symptoms via mind-body techniques may impede definitive diagnosis of dangerous diseases (if any) [Leuner and Schroeter 1997]. A possible disadvantageous parasympathetic "rebound" effect (parasympathetic "overshoot") induced by generalized relaxation of asthmatic patients was also expected in a study [Lehrer et al. 1997]. For the sake of completeness it can be noted that, increased epilepsy risk of meditation was also expected, but these expectations are likely exaggerated [Barnes 2005, Orme-Johnson 2005]. Photo-acoustic stimulation induced ASCs should be avoided in case of epileptic patients (danger of visually induced seizure), in several eye disorders (especially glaucoma) and also in case of blepharospasm [Fábián et al. 2005, 2009]. Photo-acoustic stimulation should also be used carefully in case of pregnancy, cardiac problems, pacemaker patients and other strongly compromised health conditions because of its strong influence on the central and autonomic nervous system [Fábián et al. 2005, 2009].

Complementary and Alternative Medicine

Prayer

Prayer is an active process of religious communicating with and/or appealing to God or other supernatural being belonging to God. The importance of religious methods is derived from that, they possess spiritual (sacral, transcendent) surplus, which improves efficiency of these kinds of methods [Fábián and Müller 2008, Fábián and Fejérdy 2010]. Evidently, religious techniques also improve religiosity, which is known to be associated with health promoting attitude and decreased frequency of medical symptoms and diseases. For psychosomatic therapy of religious patients at least prayer (the most frequently used religious CAM practice [Krause 2004, Tindle et al. 2005, Wahner-Roedler et al. 2005]) should be considered and utilized. Besides intercessory prayer (petitions on behalf of others) there are three major forms of prayer [Jantos and Kiat 2007] including conversational prayer (informal conversation with God), ritual prayer (reciting or reading well known prayers) and meditative prayer (i.e. repetition of short formulas, contemplation, imagery of religious themes etc.). A prolonged increase of overall mental health frequently occurs following regular practice of prayer [Meisenhelder and Chandler 2000] including positive mood [Wachholtz and Pargament 2005], decreased level of illness-related depression [Coleman et al. 2006], decreased anxiety [Harris et al. 2005, Wachholtz and Pargament 2005], higher level of perceived control over emotional reactions [Harris et al. 2005] and existential well being [Wachholtz and Pargament 2005]. Long-run practice of prayer also decreases psychophysiological stress reactions including salivary cortisol stress response [Tartaro et al. 2005]. It is also likely that, prayer improves immunological functions, and defense against infectious disorders [Fitzpatrick et al. 2007]. In general there is no contraindication of prayer, however practice of meditative forms may have contraindications similar to those of mind-body methods (see above).

Breathing Exercises

Breathing exercises can be classified primarily by frequency (low ≈6/min; high ≈60-140/min and very low frequency ≤3-4/min) [Fábián in press] but also by tidal volume (shallow or deep breathing), by location (abdominal, thoracic) and by specifically modified phases during breathing (shortening or lengthening inhalation, retention, exhalation and apnea) [Fábián in press]. Breathing exercises are primarily used to preserve healthiness, however they may also be used efficiently for therapeutic purposes. Breathing techniques can be utilized for mind-body therapies as a self-focus skill or anchor [Ospina et al. 2007, Fábián in press]. Similarly, combination of abdominal/diaphragmatic breathing with cognitive-behavioral therapy and progressive muscle relaxation was highly efficient to reduce pain-activity interference, pain intensity, depression, maladaptive pain beliefs, and catastrophizing as well as to improve masticatory jaw function in a randomized controlled trial [Turner et al. 2006]. Breathing exercises may be contraindicated in case of pregnancy, cardiac problems, pacemaker patients and other conditions with strongly compromised health. Breathing coupled meditation may have contraindications similar to those of mind-body methods (see above).

Tai-Chi and Qigong

Tai-Chi (Tai Chi Chuan) and Qigong (Chi Kung) are traditional Chinese practices of meditation designed to control expected vital energy (called "Chi" or "Qi") of the body to promote health and spiritual development. Thai-Chi (but not Qigong) may also be considered as a Chinese martial art based on suppleness and evasion [Cheng 2007] coupled with control of premised expected vital energy ("Chi"/"Qi"). Besides some static body postures and voice training, there are three major components of Tai-Chi and Qigong training including slow moving exercises, breathing exercises and meditation [Lewis 2000; Jones 2001; McCaffre and Flower 2003].

Movement in Qigong usually involve meditative visualizing of internal consequences of flow of the expected vital energy, although in some cases vital energy is expected to be transferred into other persons (patients) on purpose to cure. Movement in Tai-Chi (although usually practiced slowly) may be sped up and might involve meditative visualizing the external consequences of a motion as well (i.e. to provide a self-defense) which is not the case in Qigong. Tai-Chi and Qigong practice can be advantageously utilized for the treatment of psychosomatic patients especially when practiced repeatedly for longer-run. Prolonged increase of overall mental health can be achieved with long-run practicing regularly, including decrease of perceived stress and (trait)anxiety; as well as improve of mood, vitality, sleep quality and general social functioning [Fábián and Fejérdy 2010]. Tai-Chi and Qigong practices may be contraindicated in case of pregnancy, cardiac problems, pacemaker patients and other conditions with strongly compromised health [Vígh 1972, Fábián in press]. Meditative forms may have contraindications similar to those of mind-body methods (see above).

Yoga

Yoga is a collective noun of traditional practices developed in India to improve health, and to prepare body and mind for meditation and spiritual development. Classical yoga incorporates moral and ethical observances (yama, niyama), body postures and exercises (i.e. hatha yoga), breathing techniques (pranayama) and meditative techniques (i.e. dhyana, samadhi) [Joshi 1967; Ospina et al. 2007, Fábián in press]. There are several major subdivisions of yogic tradition such as hatha yoga, pranajama, kundalini yoga, and raja yoga [Fábián in press]. There are also some modern schools of yoga such as Iyengar yoga and Vivekananda yoga [Fábián in press]. Hatha yoga includes some dynamic body exercises, but most typically several breathing exercises (pranayama, see below) and body postures like sittings, standing poses, inverted poses, muscle and spine stretching poses, trunk rotating poses, symbolic hand/body gestures, and relaxing poses. Pranayama is a collective noun of all breathing exercises of yoga tradition including breathing exercises of hatha yoga and kundalini yoga. Kundalini yoga is a yogic practice aimed at control of expected vital-energy of the body (called "prana") via meditation coupled with certain body postures and breathing exercises. Raja yoga is a pure meditative form of yogic exercises aimed at self-absorption experience (called "samadhi") [Fábián in press]. Iyengar yoga is based on hatha yoga traditions (including pranayama and meditation) but employs props that allow to practice body postures despite limited experience and flexibility. Vivekananda yoga is also based on hatha yoga traditions (including pranayama and meditation) but aimed at therapeutic utilization of yoga tradition. Long-run practice of yoga induce prolonged increase of overall mental health including increased level of optimism and decreased level of perceived stress, neuroticism, depression, (trait)anxiety and anger under chronic illness-stress [Shapiro et al. 2007, Smith et al. 2007, Kjellgren et al. 2007]. Yoga was found highly efficient also in the treatment of unexplained chronic fatigue as well [Bentler et al. 2005]. Yoga may be contraindicated in case of pregnancy, cardiac problems, pacemaker patients and other conditions with strongly compromised health [Vígh 1972, Fábián in press]. Meditative forms may have contraindications similar to those of mind-body methods (see above).

Other Therapies

Some other forms of CAM therapies like sleep deprivation, keeping fast and light therapy may also be used. Sleep deprivation (vigil) positively influences mood having prompt and significant antidepressive effect [Benedetti et al. 2003/a,b, Wirz-Justice et al. 2005]. Vigil decreases anterior cingulate cortex metabolism likely due to an increase in the activity of brain serotonergic [Benedetti et al. 2003/a] and dopaminergic [Benedetti et al. 2003/b] pathways as well. Sleep deprivation coupled increase of the serotonergic neural activity in dorsal raphe nucleus was also demonstrated in an animal study [Gardner et al. 1997]. Keeping fast is frequently used as a practice to preserve healthiness. Fasting therapy may also improve chronic pain [Michalsen et al. 2002] as well as syndromes of stress and exhaustion [Michalsen et al. 2002]. Fasting activates hypothalamic-pituitary-adrenocortical axis (HPA axis) leading to increased serum cortisol level and sympathetic activity [Fichter and Pirke 1986]. Altered function of hypothalamic and hippocampal septal systems was also assumed

[Winkelman 1986; Heinze 1993]. Fasting also activates the immune system (NK cell activity) and alleviates fatigue [Masuda et al. 2001], however a complete food restriction for two-three days (or more) may lead to immune suppression [Chiapelli and Hodgson 2000]. Light therapy (taking delight in the sunrise, sunset, candlelight, glittering surfaces of water and snow as well as sun-bathing) is frequently practiced by many people. Besides the rewarding and symbolic meaning of such practices, also neurophysiologic effects of the light should be counted in these cases. Light stimuli influences the function of pineal gland, epithalamus and supraoptic region of hypothalamic medial zone [Clark et al 2006]. Further, significant effect of light exposure on mood (i.e. antidepressive effect [Benedetti et al 2003/a, Wirz-Justice et al. 2005]) likely based on brain serotonergic pathways and phase changes of biological rhythms [Benedetti et al 2003/a] was also reported.

Conclusion

Even though prosthesis is fabricated conscientiously and properly, there is no assurance that the patient will be comfortable while wearing it or satisfied with the therapy [Mazurat and Mazurat 2003]. A normative evaluation by a dentist and a subjective evaluation by the patient related to the denture or to the dental treatment may be rather different [Lechner and Roessler 2001]. There are various psychogenic symptoms, which may occur in relation with making denture [Fábián and Fábián 2000, Fábián et al. 2006, 2007]. Although these symptoms are primarily of psychogenic origin, their pathomechanisms may include both somatic and psychogenic mechanisms. Therefore, both somatic and psychogenic pathways of pathomechanism should be considered carefully for a proper choice of methods used for palliative dental care, mind-body therapy as well as prevention of relapse using certain CAM therapies. Since lacking a religious sensitivity, medical science will always be woefully incomplete, no matter how great its discoveries [Pollack 1999] the importance of religious methods of complementary and alternative medicine should also not be underestimated.

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Chapter XII

Psychogenic Complications of Making Dentures. Theoretical Background, Prevention and Treatment Possibilities

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Abstract

Psychogenic complications of making dentures as well as consequently appearing psychogenic denture intolerance is a complex and rising problem of dentistry and presents many intricate problems, which are being tackled by various disciplines of both basic and clinical research. Estimations based on the available data and clinical experience indicate that, at least 3-4% of denture wearers suffer from psychogenic symptoms caused by the treatment procedure, insertion or wearing of fixed or removable dentures. No wonder that, there is a high amount of scientific information gathered so far, however data are rather divergent, sometimes even contradictory and there are numerous questions without any available data to answer. Present chapter is primarily dedicated to the clinical aspects of these phenomena, including clinical manifestations, diagnosis, prevention and treatment possibilities. Other relevant subject areas of this chapter include theoretical background and peculiarities of denture-related psychological and psycho-physiological phenomena, background and pathomechanisms of denture induced psychosomatic manifestations, basic principles of communication and patient-nurse-dentist interrelationships. This collection of information helps the reader to be at home in scientific field of denture related psychogenic manifestations.

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Introduction

The problem of psychogenic denture intolerance (PDI) stood in the limelight of scientific interest in the second half of the last century. Although early complete denture related studies sometimes missed the point that psychogenic denture intolerance may also develop in relation to other kind of dentures; later on psychogenic problems related to other kinds of dentures (i.e. removable partial dentures and/or fixed dentures) were also analyzed, and lastly a "holistic view" of psychogenic denture intolerance emerged. In this approach, denture intolerance is recognized as a member of the "large family" of orofacial psychosomatic manifestations [Ross et al. 1953, Schweitzer 1964, Marxkors and Müller-Fahlbusch 1981, Müller-Fahlbusch and Marxkors 1981, Müller-Fahlbusch and Sone 1982, Newton 1984, Demmel and Lamprecht 1996, Wolowski 2000].

In general, roughly 10 percent of the dental patients may be counted as a risk patient for any psychosomatic manifestations [Doering and Wolowski 2007], from which more than a third (roughly 3-4 % of all patients with dentures) suffer from psychogenic denture intolerance [Fábián and Fejérdy 2007, 2010]. This is a not too large but still significant proportion, and the incidence may increase [Fábián and Fejérdy 2007,2010, Sugawara et al. 1998]. It should be also considered that, even two or three of such patients may unbalance dentist's entire schedule [Schweitzer 1964] and can occupy a large percentage of the dentist's time [Swoope 1973]. Moreover, it also gives rise to legal proceedings in certain cases [Figgener 1996]. Thus, the importance of psychogenic denture intolerance should not be underestimated, but considered as a rather important and difficult problem of dentistry.

Concept of Psychogenic Denture Intolerance

Emergence of the Concept

The problem of psychogenic denture intolerance stood in the limelight of scientific interest because of comparatively frequent unsuccess during making complete dentures (full dentures). Although complete denture related studies sometimes missed the point that psychogenic denture intolerance may develop in relation to other kind of dentures as well (i.e. partial removable and/or fixed dentures); huge knowledge of the psychological and psychopathological mechanisms behind psychogenic denture intolerance were collected based on this approach. Importance of patient's personality structure [Seifert et al. 1962, Ismail et al. 1974] and affective state [Golebiewska et al. 1998] as well as patient’s level of psychosocial stress [Swoope 1973] level of anxiety [Swoope 1973] and level of fear of death [Dolder 1956, Kranz 1956] were recognized. Similarly, the importance of various unconscious psychological processes [Dolder 1956, Kranz 1956] and several mental disorders [Levin and Landesman 1976, Drost 1978/a,b] were documented. Further, significance of dentist's personality [Langer et al. 1961, Seifert et al. 1962] and communication skills [Guckes et al. 1978, Reeve et al. 1984] and quality of patient management [Hirsch et al. 1972, Reeve et al. 1984] were acknowledged. The importance of several transference and counter-transference processes [Drost 1978/a,b] were also recognized based on such studies.

Similarly, patient's persistence and motivation [Michman and Langer 1975] as well as patient's expectations [Levin and Landesman 1976] and emotional involvement in the development of a symptom [Holland-Moritz 1980] were documented. The importance of socio-cultural factors [Lowental and Tau 1980], self-image [Silverman et al. 1976, Tau and Lowental 1980], body-image [Ament and Ament 1970, Silverman et al. 1976] and gender differences [Massler 1951, Kotkin 1985] were also recognized. The significant influence of menopausal processes [Niedermeier et al. 1979] and the importance of quantitative and qualitative parameters of saliva secretion [Niedermeier 1991] were also recognized. The significance of neuromuscular coordination and adaptation [Michman and Langer 1975, Landt 1978], multifold sensory functions of mouth and teeth [Balters 1956/a,b], several masticatory learning processes [Michman and Langer 1975] and localization of the denture (i.e. upper or lower jaw) [Seifert et al. 1962] was also acknowledged. Finally, the important correlation between the satisfaction with dentures and the patient's ability to adjust to general health [Emerson and Giddon 1955] as well as the importance of written documentation (including the mutual agreement of objectives before treatment is begun) [Swoope 1972] was also documented based on complete denture related studies primarily.

On the base of premised findings (and collaterally), psychogenic problems related to other kinds of dentures (i.e. removable partial dentures and/or fixed dentures) were also analyzed, and lastly a "holistic view" of psychogenic denture intolerance emerged. In this approach, denture intolerance is recognized as a member of the "large family" of orofacial psychosomatic manifestations. Studies based on this concept investigate both peculiarities and general aspects of denture related psychogenic symptoms from the viewpoint of orofacial psychosomatics as a whole and more general problem [Ross et al. 1953, Schweitzer 1964, Marxkors and Müller-Fahlbusch 1981, Müller-Fahlbusch and Marxkors 1981, Müller-Fahlbusch and Sone 1982, Newton 1984, Demmel and Lamprecht 1996, Wolowski 2000].

Major role of provocative life events like traumas and object loss and the consequent appearance of depression were primarily documented based on this "holistic" approach [Müller-Fahlbusch 1972, 1975, 1976, Hach et al. 1978, Holland-Moritz 1979, Fassbind 1985]. Accordingly, the significance of traumatizing dental events (frequently causing traumas and object loss) and their role as a significant provocative life event was also acknowledged [Schweitzer 1964, Miller 1970, Marxkors 1975]. The importance of learning processes (including classic/operant conditioning or model learning) [Ross et al. 1953, Newton 1984] was emphasized as well. The meaning of symptom chronification processes induced by repeated unsuccessful somatic dental treatments [Müller-Fahlbusch 1975, Wolowski 2000, Fábián et al. 2004, Fábián and Fejérdy 2007, 2010] as well as the significance of primary and secondary gain from illness [Ross et al. 1953] were also recognized mainly on the base of this approach.

Similarly, importance of the rather complex patient-nurse-dentist interrelationships [Miller 1970, Fábián and Fábián 2000, Fejérdy et al. 2004, Fábián et al. 2007/a, 2010], meaning of the dental team's mental health [Gerbert et al 1992, Fábián and Fejérdy 2010], as well as the significance of proper timing of the prosthodontic treatment [Müller-Fahlbusch 1992] were documented. Meaning of the impact of oral health on quality of life [Giddon and Hittelman 1980, Leao and Sheiham 1996, McGrath and Bedi 1998, 1999, Watanabe 1998], patient's oral health behavior [Weinstein et al. 1979, Kiyak 1996] and patient's oral health-

related beliefs [MacEntee 1996, McGuire et al. 2007] were recognized as well. The importance of social [Nakaminami et al. 1989], existential [Graham 2005, Fábián et al. 2006/b] and spiritual/religious [Fábián et al. 2005/b, Fábián 2007/a] aspects of psychogenic denture intolerance were also emphasized based on the latter "holistic" approach primarily.

Definition of Psychogenic Denture Intolerance (PDI)

Considering above described emergence of its concept no wonder if yet there is currently no consensus on the etiology and pathogenesis of psychogenic denture intolerance. Similarly, there is neither a prevalent definition nor a current abbreviation for convenient use in the scientific literature of psychogenic denture intolerance. Thus, a consensus definition of psychogenic denture intolerance is still keeping us waiting. Therefore, psychogenic denture intolerance will be defined in the present work as follows: Patient's refusal accepting or wearing truly prepared (standard, properly made) fixed and/or removable denture(s) because of appearing any kind of psychogenic symptom(s) in relation to the denture or to the treatment procedure [Fábián and Fábián 2000, Fábián et al. 2004, 2007/a, Fábián and Fejérdy 2010]. Further, an abbreviation derived from the first letters of psychogenic denture intolerance (namely "PDI") will also be used in the text.

Psychological Peculiarities of Mouth and Teeth

The orofacial region is an area of human privacy of special personality relevance with overproportional cortical representation, which appears to be particularly predisposed for a large number of different functional and somatoform psychosomatic disorders [Kreyer 2000]. There are several deep-seated psychological reasons for this sensitivity. The oral psychogenic manifestations (including PDI) are based on the unique psychological and dept-psychological function of the mouth, and teeth during infancy (breasting), sexuality, aggressiveness and communication [Fábián and Fábián 2000, Fábián et al. 2000, 2007/a, Fábián and Fejérdy 2010]. There is also a great importance of the symbolic values of the mouth, teeth, tongue, and face [Fábián and Fábián 2000, Fábián et al. 2000, 2007/a]. The mouth (including the teeth and tongue) also serves as a primary zone of interaction with the environment, and as such can have far-reaching emotional significance [Ament and Ament 1970, Benson 2000]. It is surely tremendously important already in the baby's life as an organ through which to receive nourishment, as an organ of pleasure, as an organ of contact with the mother, as an organ of testing, learning and understanding and as an organ of social signal [Ament and Ament 1970]. The mouth should be considered also as a highly charged erotogenic region already from the childhood [Ament and Ament 1970, Benson 2000]. The mouth (including the teeth and tongue) is also a source of contention, and when speech comes, the mouth becomes a seat of power in a new sense as well [Ament and Ament 1970].

Psychoemotional consequences of certain traumas like the experience of forced feeding by parents in the childhood, as well as the forced manipulation of the tongue blade by the physician, or a forced (or even painful) approach by the dentist (already in the early

childhood) should also be considered [Ament and Ament 1970]. The early traumatizing experience of the infant related to losing somebody (the baby must be taken off the breast) and destroying something (intake of food with the use of the teeth) is strongly coupled to the oral region and the teeth too. (Premised coupling may be especially important during the so-called oral stage and oral-sadistic stage of the psychological development [Fábián et al. 2000, Fábián et al. 2006].) Loss of milk teeth (deciduous teeth) is usually the first loss of any part of the body and the first significant injury of body image [Ament and Ament 1970]. Next, wearing orthodontic appliances may lead to shame and body image disturbances. In many cases the dental treatment may also be traumatic for adults, and the dental experience may be perceived as an "assault" which recapitulates the old feelings (i.e. from the childhood) of helplessness, aggression, defenselessness etc. [Ament and Ament 1970]. Tooth loss may profoundly affect the psychosocial well-being of patients, even those who are apparently coping well with dentures [Fiske et al. 1998, Allen and McMillan 2003]. Complete edentulousness is a serious life event which can be perceived as more stressful than retirement [Bergendal 1989, Trullson et al. 2002], because tooth loss (especially edentulousness) also symbolizes the loss of living force, and evokes a symbolic meaning of growing old, evanescence and death [Fábián and Fábián 2000, Fábián et al. 2000, 2006, 2007/a].

The importance of dental appearance to overall appearance is also rated high [Hassel et al. 2008], and tooth loss can have tremendous patient impact and social implication [Roumanas 2009]. Therefore, significant alteration of the patient's self image may occur with an increasingly worsened dental status [Fiske et al. 1998, Trullson et al. 2002, Allen and McMillan 2003]; which may lead (in the absence of dental restorations and/or dentures) to a self-image can be labeled as "becoming a deviating person" [Trullson et al. 2002]. Bed dental status also may lead to feeling of guilt and shame [Trullson et al. 2002]. Notwithstanding that, removable dentures may significantly improve oral health-related quality of life [Adam et al. 2007, Ellis et al. 2007]; living and coping with removable dentures (especially with full dentures) may lead to a self-image can be labeled as "becoming an uncertain person" [Trullson et al. 2002]. (Premised self-image may appear because of the uncertainty and insecurity when having to cope with a removable denture.) In order to manage premised uncertainty and being in control, patient often develops avoiding strategies to ensure that no-one would notice his/her removable denture [Trullson et al. 2002]. Such patient frequently keeps the hand in front of the mouth when talking or laughing, and avoids social interactions, especially when eating. These avoiding strategies contribute to restricted social participation and a further change (worsening) of self-image [Trullson et al. 2002].

Besides premised psychological and psychosocial aspects (see above), certain neurobiological aspects of the orofacial region should also be considered. Importantly, those tissues, which are of mesodermic origin in most part of the body, are of ectodermic (ectomesodermic) origin in the orofacial region indicating a strong coupling of orofacial and nervous structures. Accordingly, stem cells present in the human dental pulp has a tendency to differentiate into functionally active neurons under certain experimental circumstances [Király et al. 2009]; which may be another indication of the above mentioned relatively strong coupling of several orofacial and nervous tissues. Further, innervation of the orofacial region is originated from the brain stem (instead of spinal cord); which may also be a base of a strong influence of psycho-emotional functions on the orofacial tissues and function.

Premised peculiarities may also be responsible for the finding that, facial and masticatory muscles are highly sensitive to psycho-emotional processes, reacting earlier, stronger and longer lasting with muscle spasm to psychoemotional stress comparing to other muscles of the body [Heggendorn et al. 1979]. It is also likely that, increased activity of facial and masticatory muscles have a special extraordinary role in the attenuation (elimination due to motor activity) of psychoemotional stress [Sato et al. in press]. A similar extraordinary role in the attenuation of psychoemotional stress due to autonomic activity (i.e. similar to that of shedding tears) may also be expected in relation with the psychoemotional stress induced alterations of saliva secretion [Fábián and Fejérdy 2010]. In addition, mouth, teeth and tongue act as organs of sense of touch temperature and taste, leading to a reach representation of these organs in the central nervous system [Fábián et al. 2007/a]. Taking together all above data it is no wonder that, the orofacial region is affected by psychosomatic manifestations much more frequently comparing to most other parts of the body [Böning 1990].

Psychogenic Pain Manifestations

Concept and Features of Pain

Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage [Merskey 1979]. Pain is a multifaceted and multilevel phenomenon including a specific sensation, a variable emotional state, an aspect of interoception and a specific behavioral motivation [Carli 2009]; all of which are strongly influenced by personality, cultural background, as well as social and economic factors [Dworkin and Sherman 2006, Vanhaudenhuyse et al. 2009]. Previous pain experiences [Vanhaudenhuyse et al. 2009], the significance of the organ involved [Vanhaudenhuyse et al. 2009], local pain threshold of tissues [Ogawa et al. 2004] as well as individual's current pain tolerance, mood (depression) and level of anxiety also influence pain experience significantly [Dworkin and Sherman 2006]. There are three major components of pain such as psychogenic-, neuropathic- and nociceptive pain components [Burton 1969, Gerbershagen 1995, Baldry 2005]. Importantly, pain of vascular and muscular origin also belong to nociceptive pain, because nociceptors of blood vessels or muscles (or other related tissues) are the primary sources of pain impulses in these cases [Baldry 2005] In some cases pain symptom is solely due to a single pain component; in other cases two or three components may be present concomitantly [Burton 1969, Gerbershagen 1995, Baldry 2005].

Radiation of Pain

Local radiation of pain leading to local (near) referred pain is a frequent concomitant phenomenon of pain, especially when deep-seated pain appears (i.e. painful teeth radiating pain into other teeth or the ear). Distant radiation of pain may also occur, according to the location of dermatomes which are skin areas having sensory innervations from the same central nervous segment. Radiating visceral pain usually does not cover the whole dermatome

surface, but specific smaller areas of the dermatome, which are referred to as Head-zones [Hansen and Schliack 1962, Gerbershagen 1995]. Although the "classical" dermatomes typically belong to the spinal cord segments; brainstem is also considered as a "segment" of the central nervous system in this relation, and skin innervations areas of the branches of trigeminal nerve are considered as dermatomes of the facial region [Gerbershagen 1995]. There are also smaller facial skin areas located roughly concentric around the mouth called „trigeminal projection fields" [Gerbershagen 1995] which are considered as facial Head zones.

Pain Chronification Processes

Pain chronification processes are also highly important in relation with orofacial pain. Whenever increased activity of pain related afferent fibers and other neurons of pain related centers appears, profound intracellular changes occur in few hours (but latest in few days). Premised profound changes are referred to as activity dependent neuronal plasticity which includes activation of immediate early genes and several transcription factors as well as altered synthesis of neurotransmitters, receptor precursors, or secondary messengers like kinases or phosphatases (etc.) [Hunt et al. 1987, Besson 1999, Zimmermann 2004]. Although premised changes are reversible at the beginning, they may become irreversible in the course of time (roughly in months). Whenever irreversible changes appeared, the pain sensation may become independent from the primary cause and may become chronic, because at this stage neurons may fire spontaneously in an irreversible manner.

Atypical Facial Pain

Atypical facial pain is an idiopathic symptom. It is a diagnosis of exclusion, after other conditions have been considered and eliminated. Although any area of the face can be involved, the most commonly affected areas are the maxillary region [Sarlani et al. 2005/b] and other non-muscular non-joint orofacial areas [Köling 1998]. Atypical facial pain may also appear in relation with PDI [Fábián 1999, Fábián et al. 2006/a, Fábián and Fejérdy 2010]. Although atypical facial pain is considered as idiopathic [Sarlani et al. 2005/a,b], psychological distress, anxiety and depression are prevalent among PDI related atypical facial pain patients.

Myofascial Pain

Myofascial pain is characterized by the presence of focal, exquisitely tender muscle areas called trigger points typically found in the taut muscle band and producing a characteristic pain referral pattern on palpation. Besides trigger points, myofascial pain may also lead to the appearance of heterotopic orofacial pain as well as to the pain of the temporomandibular joint and to denture soreness. Major cause of PDI related myofascial pain is the overload (spasm and muscle fatigue) of masticatory muscles because of neuromuscular dysfunction induced by

complex psychogenic processes [Schwartz 1955, Laskin 1969, Dahlström 1989, Sieber et al. 2003]. Disturbed relationships of the teeth and/or occlusal surfaces, altered occlusal guidance as well as poorly occluding and/or ill fitting dentures also may trigger neuromuscular malfunctions.

Glossodynia and Oropyrosis (Burning Mouth Sy.)

Burning mouth syndrome (BMS) is a distinct clinical entity characterized by a chief complaint of unremitting oral burning concomitant with no oral mucosal clinically observable lesions, or other relevant apparent organic basis. It is usually milder upon awakening and progressively increases in the curse of the day [Sarlani et al. 2005/b]. Insertion of the denture increases the pain intensity in many cases. Although PDI related burning mouth syndrome can be induced via psychogenic pathways; data suggest a complex interaction between several general health factors, psychosocial stressors and denture dysfunction in order to explain burning mouth syndrome in most cases [Swensson and Kaaber 1995, Aneksuk 1989, Grushka and Sessle 1991].

Toot-Located Psychogenic Pain

Tooth-located pain of primarily psychogenic origin is called atypical odontalgia [Sarlani et al. 2005/b, Dworkin and Sherman 2006, Baad-Hansen 2008]. The pathomechanism of atypical odontalgia is far not clear yet; however, alteration of catecholamine (epinephrine and norepinephrine) [Nagy et al. 2000] and HSP70/HSPA type stress protein [Fábián et al. 2009/a] levels in the dental pulp may play an important role. Although there are only few published cases in the literature, tooth located pain of psychogenic origin is a rather frequent symptom of PDI patients [Müller-Fahlbusch 1991, Fábián 1999, Fábián and Fejérdy 2010]. The pain can be centered on apparently normal teeth, endodontically treated teeth, abutment teeth [Sarlani et al. 2005/b] and on dental implants [Kromminga et al. 1991]. Extraction site (alveolar bone) of a previously extracted tooth (or removed implant) is also frequently targeted and referred to as phantom tooth pain [Fábián 1999, Sarlani et al. 2005/b].

Psychogenic Neuromuscular Symptoms

Specificities of Orofacial Muscles

Masticatory and facial muscles are highly sensitive muscles having a rather extended representation in the motor cortices comparing to other muscles [Sergl 1996]. Besides motor cortices, other brain centers including limbic system, thalamus, cerebellum, as well as the basal ganglia and brainstem reticular formation are also involved in the neuromuscular regulation of facial and masticatory muscles [Harris and Griffin 1975]. In contrast to most other muscles, which are supplied via the spinal cord, motor nervous supplies of masticatory

and facial muscles are directly from the brainstem via several cranial nerves. Brainstem is a structure mediating numerous important psychoemotional processes such as pain, arousal, attention, mood (i.e. depression), anxiety as well as defensive and reproductive behaviors [Clark et al. 2006]. Therefore, brainstem seems to be an ideal structure to regulate muscles having unique functions strongly interrelated with emotions including speech (chewing muscles, tongue-, lip-, and facial muscles), expressing emotions nonverbally (facial muscles), fighting and aggressiveness (chewing muscles) or sexuality (lips, tongue). Thus, it is no wonder that, facial and masticatory muscles are highly sensitive to psycho-emotional processes [Heggendorn et al. 1979, Graber 1995, Fuhr and Reiber 1995], and increase of their tone (muscle tension) occurs rather frequently [Heggendorn et al. 1979, Graber 1995, Fuhr and Reiber 1995]. Accordingly, their reaction (increase of tension) to stress is stronger and longer lasting comparing to other muscles of the body, which is expected to be a basis of the high frequency of occurrence of myofascial pain [Heggendorn et al. 1979]. Since stress induced increase of muscle tension is usually higher in elevators comparing to depressors [Heggendorn et al. 1979, Graber 1995, Fuhr and Reiber 1995], increased muscular tone may also lead to the decrease of free way space; which may trigger parafunction due to the increasing frequency of occurrence of spontaneous contact between antagonist teeth [Troest 1995].

Occlusal Discomfort and Dysesthesia

Occlusal discomfort may be induced by occlusal interferences especially in sensitive patients with increased vulnerability [Le Bell et al. 2006]. Oral parafunctions and/or increased muscle tension leading to fatigue in masticatory muscles can also result in occlusal discomfort [Mew 2004, Litter 2005] because of the failure of proper proprioceptive feedback [Litter 2005]. In more severe forms occlusal complaint may appear as an occlusal dysesthesia (OD) [Baba et al. 2005, Clark et al. 2005], which is a collective noon of several uncomfortable feelings of occlusion despite the absence of any observable occlusal anomaly or discrepancy [Fábián et al. 2005, Baba et al. 2005]. These patients are preoccupied with their dental occlusion, believing that, it is abnormal [Jagger and Korszun 2004], therefore occlusal dysesthesia is frequently also referred to as "phantom bite" or "occlusal neurosis" in the literature. The condition is remarkable for the nature of the involved explanations and interpretations that the patients give and for their persistence in trying to find a "dental" or "occlusal" solution [Jagger and Korszun 2004] or a "bite correction" [Toyofuku and Kikuta 2006]. However, available evidence suggests that, the symptoms cannot be improved by occlusal treatments; therefore, it is essential to avoid irreversible restorative treatment [Jagger and Korszun 2004, Toyofuku and Kikuta 2006].

Instability of Removable Denture

Stability of dentures is highly important for patient satisfaction with removable dentures. Increased vertical dimension and improper determination of the horizontal dimension of

occlusion as well as occlusal interferences and unfavorable denture bearing tissues may frequently lead to instability of removable dentures (especially of complete dentures) [Griffin and Harris 1975, Gonzalez and Desjardins 1983]. Inadequate border seal [Kivovics et al. 2007], overextension or underextension of the denture base as well as the improper relation of teeth to the ridge and inadequate contour of the artificial gingiva may also lead to denture instability [Gonzalez and Desjardins 1983]. Use of canine guidance instead of bilateral balanced occlusion may also trigger instability of complete dentures [Rehmann et al. 2008]. Certain patients, especially edentulous patients also complain of lack of adequate space of tongue movement and consequent instability of denture [Griffin and Harris 1975]. Changes of saliva secretion [Niedermeier et al. 2000, Wolff et al. 2003] and alterations of neuromuscular function may also be a cause of instability of removable (especially complete) dentures. Since psychogenic factors including psychosocial stress and other psychoemotional conditions may significantly alter both neuromuscular function and saliva secretion, an appearance of instability of dentures as a symptom of psychogenic origin of PDI also frequently occur.

Bruxism

Bruxism can be defined as a nonfunctional contact of the teeth during grinding, gnashing, tapping or clenching. Malocclusions including occlusal early contacts and other occlusal disharmonies as well as improper determination of the vertical dimension and/or other alterations of the maxillomandibular relationship [Biondi and Picardi 1993, Le Bell et al. 2006] may induce bruxism. Ill-fitting removable dentures also frequently induce clenching [Sandler et al. 1995]. Malocclusions and denture related discrepancies are likely to trigger ancient mechanisms similar to those being responsible for the elimination of impacted occlusal foreign bodies in animals (i.e. impacted pieces of bones, or small pebbles) via biting on it with strong biting forces (to crush by pressing) and/or via intermittent isometric grinding movements (to grind, to „erode" it). Importantly, psychosocial factors [Biondi and Picardi 1993, Kampe et al. 1997] and psycho-emotional conflicts [Somer 1991, Biondi and Picardi 1993] may also be responsible for the appearance of bruxism. Increased level of anxiety and lower level of socialization also increases the incidence of bruxing behavior [Kampe et al. 1997]. Premised psychogenic factors are likely to be responsible for PDI coupled bruxism cases.

Accidental Biting on Soft Tissues

Inadequacies of dentures including instability, decreased vertical dimension, insufficient horizontal overlap and shaping of teeth, improper position of teeth, and poor location of plane of occlusion may frequently lead to biting of tongue, cheek and lip [Gonzalez and Desjardins 1983, Piquero et al. 1999] and mucosa ridging [Piquero et al. 1999]. Accidental biting on tongue (and other soft tissues) also may occur as soft tissue parafunction of neuromuscular origin. Therefore, in PDI related psychogenic cases psychosocial stress effects and consequent neuromuscular dysfunction rather than denture mistakes and organic diseases are

the major cause of such manifestations. In such cases stress induced malfunction of preventive reflex mechanisms such as the inhibitory influence of jaw muscle proprioceptors on genioglossus activity (which may lead to accidental bite on tongue) [Sauerland and Mizuno 1970] as well as a decreased (or absence of) inhibitory effect of the mechanical stimulation of tooth on tongue protrusion [Schmitt et al 1973] can be expected as a concrete cause [Griffin and Harris 1975].

Overactive Gag Reflex ("Gagging")

The term gagging refers to a defense reflex, which attempts to eject unwanted, irritating, or toxic materials from the upper gastrointestinal tract. Although gag reflex is a normal defense function of human, overactive gag reflex ("gagging") may be rather disadvantageous for denture wearers, especially for those wearing removable dentures. Gagging may also lead to failure to tolerate making impression and/or other routine dental procedures. There can be numerous mechanisms behind gagging including several gastrointestinal and central nervous defense pathways; but denture related gagging are primarily induced by several conditioning processes, or several neurotic psychological pathways [Savage and McGregor 1970, Newton 1984, Gáspár et al. 2002]. Conditioning processes are typical of gagging caused by learned avoidance reactions originating from former aversive encounters with dental treatment [Eli and Kleinhauz 1997]; whereas neurotic psychological pathways are typical of gagging caused by deep-seated defense mechanisms, which serve as inadequate solutions to several psychodynamic conflicts [Eli and Kleinhauz 1997, Gáspár et al. 2002].

Other Psychogenic Symptoms

Mucosal Allergic Reactions

Allergic and/or irritative reactions of the oral mucosa primarily occur due to wearing fixed- and/or removable dentures prepared from dental cast alloys and/or acrylate resins. Other dental materials like amalgam and rarely composites may also induce such reactions. These reactions usually belong to delayed type (type IV) allergic reactions which develop in three major phases as follows: (1) metal ions or other small molecule allergens (referred to as haptens) bind to proteins and hapten-protein-complexes develop [De Rossi and Greenberg 1998, Büdinger and Hertl 2000, Martin 2004]; (2) hapten-protein-complexes are presented by antigen presenting cells inducing T-lymphocyte activation and consequent proliferation/accumulation of a specific T-lymphocyte population in lymph nodes [De Rossi and Greenberg 1998, Büdinger and Hertl 2000, Martin 2004]. Premised T-lymphocyte population is specifically sensitized and possess hapten-protein-complex-specific antigenreceptors on their surfaces [De Rossi and Greenberg 1998, Büdinger and Hertl 2000, Martin 2004]; therefore, this phase is referred to as sensitization phase; (3) if hapten-protein-complexes at issue appear again, trafficking (recirculating) sensitized T-lymphocytes become reactivated and start to release proinflammatory cytokines and chemokines which lead to cellular immune-inflammatory reactions in the tissue [De Rossi and Greenberg 1998,

Büdinger and Hertl 2000, Martin 2004]. Accordingly, this phase is referred to as effector phase [Borelli et al. 1988]. The occurrence of premised effector phase is the primary cause of most denture related mucosal allergic reactions, as well as for various allergic reactions including contact eczemas, allergic dermatitis and certain granulomatous reactions [De Rossi and Greenberg 1998, Büdinger and Hertl 2000, Borelli et al. 1988, Martin 2004]. Since higher cortical-, limbic- and neurosensory systems (receiving and integrating a great diversity of signals arising from inside and outside the body) significantly influence immunity [Chrousos 1998, Ligier and Sternberg 2000]; influence of personality, cognitions and certain psychoemotional stress states on immune responses frequently occur. Primary effector arms of the psychoemotional nervous reactions are the hypothalamus, anterior pituitary gland and adrenal cortex (referred to as hypothalamic-pituitary adrenocortical axis, HPA axis) [Chrousos 1998, Ligier and Sternberg 2000]. Other key elements are located in the brain stem, which elements influence the immune reactions primarily due to the activation of the sympathetic nervous system [Chrousos 1998, Ligier and Sternberg 2000]. Despite the expected role of HSP70/HSPA in the oral tolerance data in the literature suggest that stress induced overexpression of HSP70/HSPA may also play an important role in the appearance of stress related mucosal allergic reactions, because HSP70/HSPA proteins are likely to play a role in haptenation and consequent sensitization [Fábián et al. 2009/a].Although allergic reactions are primarily of somatic origin, in PDI related cases psycho-emotional stress induced central nervous processes may play a major role in the maintenance of symptoms.

Chronic Inflammations

There is a high number of several inflammatory processes, which may occur in the oral cavity in relation with preparing or wearing dentures. Some of them may be stress induced and frequently appear also as a major symptom of PDI patients. Psychosocial stress induced chronic inflammations of the oral mucosa, dental pulp, periapical tissues and periodontal tissues belong to this group primarily. Stress induced activation of HSP70/HSPA type stress proteins are likely to play pivotal role in premised stress induced oral inflammatory processes [Fábián et al. 2007/b, 2008,b,c, 2009/a,b]; notwithstanding that HSP70/HSPA proteins also play a highly important role in the maintenance of orofacial tissues' health [Fábián et al., 2007/b, 2008,b,c, 2009/a,b]. Oral mucosal inflammation may occur because of cross reactivity of specific antibodies against microbial HSP70 type stress proteins with human HSP70/HSPA proteins and/or because of autoantibodies against HSP70/HSPA proteins. Inflammatory processes of the dental pulp can also be triggered or worsened due to the overexpression of HSP70/HSPA proteins under stress. Disadvantageous amplification of inflammatory response to bacteria (i.e. carious dentine) and/or to several dental materials as well as to tooth preparation due to the immune enhancing effect of HSP70/HSPA proteins could be expected as a possible pathway [Fábián et al. 2009/a]. Flare up or formation of periapical lesions may also be triggered and or worsened due to stress induced overexpression of HSP70/HSPA molecules in lymphocytes and endothelial cells of inflammatory granulation tissues, as well as in lining epithelium of radicular and residual cysts [Fábián et al. 2009/a, Fábián and Fejérdy 2010].

Exacerbations of periodontal inflammations are also likely to occur due to a bone resorptive effect of HSP70/HSPA proteins [Fábián et al. 2009/a,b]; after the turning of gingivitis into a more severe inflammation (i.e. periodontitis) with pocket formation and irreversible destruction of the periodontal bone.

Cognitive-Behavioral Symptoms

Besides various cognitive-behavioral symptoms caused by any psychiatric conditions of PDI patients, the most important behavioral symptom of PDI patient is overcriticism. It frequently appears as esthetical complaints of overcritical patients [Ma et al. 2008]. Overcritical patients usually demands extraordinary efforts (and/or previous guarantees of treatment outcome) at no additional cost [Ma et al. 2008], and expect treatment goals, which are very difficult or impossible to achieve [Ma et al. 2008]. Although appearance of esthetic complaints may be the most frequent, overcriticism may also occur in relation with any other aspect of denture and dental treatment certainly. Importantly, failure to recognize psychogenic factors in such cases, together with prolonged unsuccessful somatic/operative dental therapy may induce profound behavioral changes, and incite certain patients to seek relief through litigation [Harris et al. 1993].

Salivation Problems

Saliva is a major determinant of the oral environment and oral comfort. Salivary components can originate from several sources (i.e. major and minor salivary glands, blood, oral mucosal cells and oral microbes) leading to a rather complex collection of molecules [Fábián et al. 2008/a,d]. Saliva constituents play major role in several oral processes, including formation of acquired pellicle on tooth surfaces, bacterial adhesion and biofilm (plaque) formation, crystal growth homeostasis of teeth, mucosal surface protection, hard tissue surface protection and antimicrobial defense [Guggenheimer and Moore 2003, Fábián et al. 2008/a,d].

Saliva also play important role in the oral wound healing, dental caries formation, calculus formation and gingival inflammation [Fábián et al. 2008/a,d]. Quantitative and/or qualitative changes of saliva are also major cause of both subjective dry mouth sensation (xerostomia) and ptyallorhea (ptyalismus) [Fábián et al. 2008/a,d].

Salivary changes may also lead to halitosis, alteration of taste perception and alteration of phonation. Based on above data it is obvious that, salivary changes are major determinant of the oral milieu; and qualitative or quantitative alterations of saliva secretion may lead to general Oral. Dis.comfort as well as specific oral symptoms. There can be several causes behind alterations of salivary secretion including several systemic diseases and/or their medication as well as insertion of new dentures. Importantly, occurrence of psychosocial and/or psychoemotional stress including anxiety [Somer et al. 1993] and depression [Bushfield et al. 1961, Gottlieb et al. 1961] also strongly influence salivary secretion, therefore may lead to the appearance of several saliva related manifestations including saliva related symptoms of PDI.

Halitosis (Oral Malodor, Foetor Ex Ore)

The most plausible causes of oral malodor (halitosis) are insufficient oral hygiene, periodontal disease, carious lesions [Yaegaki and Coil 1999/a,b, 2000/b, Lang and Filippi 2004, Nalcaci and Baran 2008] or non-oral causes like nose-throat disorders, several medical conditions, several drugs, or nutritional habits [Yaegaki and Coil 2000/a,b, Lang and Filippi 2004]. However, in some cases there are several psychological or psychopathological causes behind the appearance of oral malodor [Yaegaki and Coil 1999/a,b Lang and Filippi 2004]. It may occur that patients expect but do not exhibit own oral malodor (also referred to as "pseudohalitosis" or "halitofobia") [Yaegaki and Coil 1999/b, 2000/a,b, Giddon and Anderson 2006], which may also appear as a symptom of PDI. Since the bacterial decomposition processes and resulted volatile sulfur compounds are decisively responsible for the appearance of malodor in most cases [Lang and Filippi 2004], stress induced deterioration of salivary defense functions (and consequent changes of oral microbiota) may also lead to oral malodor of psychogenic origin [Fábián et al. 2008/a,d]. Elimination of gingival bleeding, periodontal pockets or carious lesions, and also professional dental hygiene and proper individual dental hygiene including tongue brushing are crucial to control oral malodor (halitosis) [Sanz et al. 2001] also in cases of psychogenic origin certainly. However, in cases of psychogenic origin psychosomatic therapy of patients is also needed [Yaegaki and Coil 1999/a, 2000, Lang and Filippi 2004].

Alteration of Taste Sensation

Denture induced oral inflammations, bacterial biofilm accumulation because of wearing dentures or release of chemical components from dentures (i.e. acrylate monomer [Har-Zion et al. 2004], nickel [Pfeiffer and Schwickerath 1991]) may appear as real taste stimuli. However, dentures may induce a “real” alteration of taste sensation as well. Such denture induced alterations of taste sensation may occur primarily due to six major pathways as follows: (1) prevention of contact between receptor sites and food [Har-Zion et al. 2004, Nalcaci and Baran 2008]; (2) prevention of contact of the tongue with the palatal rugae, which is considered as highly important for dispersing the food and bringing it into more intimate contact with the taste buds [Har-Zion et al. 2004]; (3) entrapment of a part of the food between the mucosa and the baseplate [Har-Zion et al. 2004]; (4) interference with chewing and usual mobility of the tongue and cheeks and consequently decreased release of taste and smell flavor stimuli [Har-Zion et al. 2004]; (5) interference with the free movement of humid and warm air in the oral and nasal cavities and consequent affection of retronasal olfaction; (6) appearance of pain and pressure or alteration of mucosal touch experience, which also may lead to taste alterations [Har-Zion et al. 2004]. Importantly, psychological stress factors may also lead to the alteration of taste sensation in PDI cases [Fábián and Fejérdy 2010]. There can be numerous central nervous mechanisms considered behind psychological alteration of taste sensation including conditioned learning processes [Chang and Scott 1984] and modulation of glutamate-, GABA- or substance-P related orosensory

(taste related) synaptic transmission of the rostral nucleus of the solitary tract (rNST) in brainstem [Smith et al. 1998, Grabauskas and Bradley 1998].

Alteration of Speech

Speech may be altered in some patients after insertion of a new prosthesis, especially (but not exclusively) in the case of complete denture patients. Obviously, it is more difficult to adapt pronunciation of consonants to a new oral situation than vocals; because of the crucial impact of morphology and position of lips, teeth, palatal gingiva, palate and tongue during pronunciation of consonants [Molly et al. 2008]. Artificial teeth (of any dentures) primarily disturb the production of plosives and fricatives [Molly et al. 2008], whereas removable dentures (including RPDs and especially full dentures) frequently make the pronunciation of labio-dental and apico-alveolar consonants difficult [Lundqvist 1993, Molly et al. 2008]. However any other consonants [Kaán et al. 1993] (i.e. bilabial-, palatal- velar- and glottal-consonants [Molly et al. 2008]) or vocals [Seifert et al. 1999/a,b] may also be distorted following insertion of a new denture. Moreover the voice itself, and the range of the voice may also be changed because of insertion of new dentures [Seifert et al. 1999/a,b]. Importantly, stress and other psychoemotional factors strongly influence both saliva secretion and psychomotor function both of which play major role in phonation. Therefore, alteration of speech may also appear as a primarily psychogenic symptom of PDI.

Pseudoneurological and General Health Symptoms

Pseudoneurological symptoms are symptoms appearing as if they would be caused by any neurological disorder; however without any detectable somatic/neurological background. Several sensory disturbances such as hypoaesthesia, hyperaesthesia, anaesthesia, paraesthesia and dysaesthesia as well as facial palsy are the most important such symptoms in the orofacial region. Certain pain symptoms, taste related phenomena and tinnitus as well as certain autonomic and motor symptoms (i.e. facial tic, oral parafunctions) may also be classified as a member of this group. Some general symptoms including fatigue, weakness, headache, dizziness, nausea, emotional tension and irritability may occur in relation with denture intolerance as well. Psychogenic fever a common psychosomatic disease with acute or persistent body temperature above normal range under psychosocial stress may also appear as symptom of orofacial psychosomatic manifestations [Oka and Oka 2007] including PDI. Complaints by patients who attribute their symptoms to dental alloys or other dental materials are also often general in nature [Garhammer et al. 2001]; and may include various symptoms like headache, weakness, paraesthesia as well as appearance of blisters and intestinal problems [Garhammer et al. 2001]. Although pseudoneurological and general health symptoms of PDI patients are of psychogenic origin in many cases [Di Felice et al. 1991, Hampf 1987]; any possible somatic causes including both local (peripheral) and central nervous causes should also be considered and ruled out very carefully.

"Amalgam Illness"

Possible adverse health effects due to mercury released by amalgam fillings have been discussed in several studies of patients who attribute various symptoms to the effects of amalgam fillings [Lindberg et al. 1994, Malt et al. 1997, Bailer 2001, Vamnes et al. 2004]. Although the frequency of occurrence of amalgam related symptoms is not rare, in general, no systematic relation of specific symptoms to increased mercury levels could be established in such cases [Lindberg et al. 1994, Malt et al. 1997, Bailer 2001]. Although in certain cases the toxic/irritative effects may not be excluded [Scott et al. 2004, McCullough and Tyas 2008], there are primarily psychological and/or pathopsychological causes behind the "amalgam illness" [Lindberg et al. 1994, Malt et al. 1997, Bailer 2001]. In the absence of any clear toxicological and/or allergological evidence, "amalgam illness" may be seen as a label for a general tendency toward somatization [Lindberg et al. 1994, Malt et al. 1997, Bailer 2001].

Diagnosis and Differential Diagnosis

Cornerstones of Diagnostic Process

One of the most important goals of the diagnosis of psychogenic denture intolerance (PDI) is the early recognition of the disorder and the avoidance of further useless invasive dental treatment, especially because aggravation or spread of symptoms following invasive dental interventions is not uncommon. Early diagnosis (or assumption) of PDI is also crucial for the prevention of symptom chronification which frequently render pain and other symptoms intractable.

The most important diagnostic tool for such purposes is collecting detailed patient's history and careful evaluation of all relevant psychosocial, medical and dental anamnestic data including their understanding in a context of a biopsychosocial model of orofacial disorders [Ross et al. 1953, Engel 1977, Barsby 1994, Pertes 1998, Green and Laskin 2000, Dworkin and Sherman 2006, Fábián and Fejérdy 2010]. Careful clinical examination of the oral and orofacial region and general health status as well as X-ray, MRI and other specific examinations are also cornerstones of a proper diagnostic process certainly. Referral to other professionals may also be needed, and especially recommended in the case of pain and other (pseudo)neurological symptoms. Since psychogenic symptoms may mimic a great variety of somatic symptoms, a clear-cut diagnosis and proper differential diagnosis of PDI could be rather difficult.

Therefore, it should be emphasized that, the diagnosis of PDI is a presumptive one in many cases. The diagnosis may change later in the course of the disease as the clinical findings change and/or stabilize, therefore continuous monitoring and evaluation of the patient over time is essential.

A detailed differential diagnosis considering possible disorders of the teeth, and/or oral- and maxillofacial tissues should also be carried out, and any other possible somatic causes behind the symptoms should also be excluded.

Patient's History (Anamnesis)

As previously mentioned, one of the most important (if not the most important) diagnostic tool for making diagnosis of PDI is collecting detailed patient's history [Ross et al. 1953, Barsby 1994, Pertes 1998] including a careful evaluation of all relevant psychosocial, medical and dental anamnestic data [Ross et al. 1953, Pertes 1998, Dworkin and Sherman 2006]. History taking is an art in the subtle direction of conversation with the patient. As the interview develops and the data accumulate, insight into the patient's problems becomes more apparent to the dentist, further enabling him to direct the interview along the most useful lines. History-taking is a process usually extending over a number of patient's visit to reach adequate amount of data related to the dental-, medical-, and psychosocial life events [Fábián and Fábián 2000, Fábián et al. 2007/a]. Correlation may exist between the degree of satisfaction with dentures and the patient's ability to adjust to general health problems [Emerson and Giddon 1955, Tickle et al. 1997] and/or psychosocial problems. Therefore, interrelations between psychosocial- medical- and dental history should be evaluated carefully, and the data should be understand in a context of a biopsychosocial model of disorders [Ross et al. 1953, Engel 1977, Barsby 1994, Pertes 1998, Green and Laskin 2000, Dworkin and Sherman 2006, Fábián and Fejérdy 2010].

History of symptoms that are inconsistent with physical findings and history of a precipitating life event after which the symptom began [Müller-Fahlbusch and Sone 1982, Brodine and Hartshorn 2004, Dworkin and Sherman 2006] are hallmarks of PDI cases [Müller-Fahlbusch and Sone 1982, Brodine and Hartshorn 2004]. Moreover, as a result of apparent shortcomings in primary care and preliminary diagnostics, many PDI patients typically look back on long and complicated case histories with numerous negative examinations and futile attempts at somatic therapies and/or somatic interventions [Marxkors and Müller-Fahlbusch 1981, Dworkin and Sherman 2006]. Increased number of dental clinics and hospitals visited by the patient in the previous time also refers to an increased risk of PDI. History of any dental or facial trauma may also be a sign of increased risk of appearance of psychogenic orofacial symptoms [Müller-Fahlbusch and Sone 1982, Brodine and Hartshorn 2004]. Similarly, head and neck traumas as well as survived head and/or neck cancer may also increase the risk of such manifestations significantly. History of symptom substitutions (turning of a symptom into an other one) also frequently appear in the history of PDI patients; however the role of possible environmental or other psychosocial changes should also be considered carefully before assuming an underlying pathopsychological background [Gale and Carlsson 1976].

Evaluation of Medical and Psychosocial Status

Besides orofacial status (including intraoral and dental status, see below), there are two other major facets of patients' status namely the medical- and the psychosocial status. Medical status may strongly influence both diagnostic and treatment procedures as well as the prognosis of PDI. Importantly, there is a strong association between self-reported general health status and the subjectively evaluated oral health status [Emerson and Giddon 1955,

Tickle et al. 1997] indicating that, lower level of self reported general health may predispose to Oral. Dis.comfort and consequent oral psychosomatic manifestations [Emerson and Giddon 1955, Tickle et al. 1997]. Depression, anxiety disorder, somatization and other psychiatric disorders as well as any other diseases leading to significant suffering and/or limitations of psychosocial functioning may lead to significant treatment difficulties and poor prognosis [Dworkin and Sherman 2006].

Psychosocial status also strongly influences both treatment possibilities and the prognosis of the offered treatment. Psychosocial conditions may trigger the appearance and/or may lead to the fixation of orofacial psychosomatic problems [Ross et al. 1953, Dworkin and Sherman 2006]. Fixation of a sick role of the patients may also be rooted in several psychosocial causes [Dworkin and Sherman 2006]. Accordingly, both treatment possibilities and their prognosis are more guarded when self reported activity limitations are high. The prognosis is especially poor, if the medical and/or dental symptoms interfere appreciable with ability to discharge responsibilities (i.e. at home, in school, at work), or limit socializing activities [Dworkin and Sherman 2006]. Moreover, if there are strong extraneous social and/or health influences or any other object loss like bereavement, unemployment, placing on the retired list, diagnosis of life-threatening illness (etc.), the individual's ability to accept dentures may also be seriously compromised [Fábián and Fejérdy 2010]. The psychoemotional "strength" and supportive potential of family members, friends and other members of the social networks of patients also of high diagnostic and prognostic importance.

Diagnosis Based on Definition

The essence of diagnosis based on definition is that, the symptom(s) should fit in the definition of denture intolerance, which was defined in the present work as: patient’s refusal accepting or wearing truly prepared (standard, properly made) fixed and/or removable denture(s) because of appearing any kind of psychogenic symptom(s) in relation to the denture or to the treatment procedure [Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010]. Since psychogenic symptoms may mimic a great variety of (most of) somatic symptoms; to assess that whether a symptom is of psychogenic origin or not, the next five characteristics of psychogenic symptoms [Marxkors and Müller-Fahlbusch 1981] can be considered as follows: (1) well-marked divergence between the symptoms and the clinical findings; (2) unsuccessful previous somatic treatments; (3) fluctuation of the symptoms; (4) conspicuous emotional involvement of the patient into the dental problem; (5) presumable relationship of the symptoms and the psychosocial history [Marxkors and Müller-Fahlbusch 1981]. Symptoms which meet at least four from the above five criteria are very likely to be of psychogenic origin.

Diagnosis of Exclusion

It should be emphasized that, the diagnosis of PDI is also a diagnosis of exclusion [Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010], therefore a careful and accurate dental examination is crucial. A detailed differential diagnosis considering

possible disorders of the teeth, or oral- and maxillofacial tissues should also be carried out. PDI may be expected only at those cases without any significant dental finding. Following the careful dental examination, any other possible somatic causes behind the symptoms should also be excluded. For such purposes, exclusion of systemic diseases that may cause orofacial symptoms should also be carried out and medication induced symptoms should also be considered. Further, referral to other professionals like maxillofacial surgeon, neurologist, psychiatrist, otorhinolaringologist, ophthalmologist, internist, rheumatologist (etc.) may also be needed, and especially recommended in the case of pain and other (pseudo)neurological symptoms [Sarlani et al. 2005/a.b]. It should be also considered that, the diagnosis may change later in the course of the disease as the clinical findings change and/or stabilize, therefore continuous monitoring and evaluation of the patient over time is essential [Sarlani et al. 2005/a.b].

Prevention of Psychogenic Denture Intolerance

Cornerstones of Prevention

Besides high quality preparative dental skills and technical background, cornerstones of prevention are screening of risk patients, proper treatment planning, proper communication with the patient, screening of the patient-nurse-dentist interrelationships, as well as prevention of dental fear, prevention of treatment-induced pain and prevention of relapse. It is also crucial for the prevention that patients must be made aware of their responsibilities in achieving a satisfactory outcome. It is also a matter of considerable significance that the clinician carefully weighs the option of nontreatment in certain cases. Moreover, dental team members should also be able to accept a patient from the bottom of hart as well as to understand and accept own emotions for a proper and successful treatment and for the avoidance of treatment failure. Therefore, dentists and other team members should become a mature, well-disposed and good person on behalf of the patients as well as on behalf of their own interest. Maintenance of the mental health of dental team is also crucial for the prevention of PDI. Lack of attention to all above aspects may invite treatment failure and may lead to the occurrence of PDI.

Screening of Risk Patients

Screening of risk patient is primarily based on the collection of a detailed patient's history as well as on careful evaluation of medical- psychosocial and orofacial status. Dissatisfaction with the existing denture may also indicate a risk of PDI. Patients with high dental fear and high fear of pain as well as with previous disturbances of patient-dentist relationship may also be considered as risk patients, because dental fear, pain and disturbances of patient-dentist relationship may lead to significant psychological stress that may turn into PDI symptoms. Accordingly, patients with high level of perceived stress may also be considered as risk patients. Besides semi-structured interview [Levin and Landesman 1976, Kaban and Belfer 1981] certain psychological and pathopsychological questionnaires may also be used for

screening purposes efficiently. Patients with increased dental fear could be recognized using the Dental Anxiety Scale (DAS) [Corah 1969], the Dental Fear Survey (DFS) [Kleinknecht et al. 1973, 1984] or the single-item Dental Anxiety Question (DAQ) [Neverlien 1990]. Risk patients in relation with dental fear may also be recognized using the "Expectation Scale" [Fábián G. et al. 2007]. Fear of pain may be measured using the Short form of Fear of Pain Questionnaire (FPQ-SF) measuring four factors such as fear of severe-, minor-, injection- and dental-pain [Asmundson et al. 2008]. Previous disturbances of the patient-dentist relationship may be recognized using the Getz's Dental Beliefs Survey (DBS) [Milgrom et al. 1985]. Exposure to stressful life events during the preceding period may be measured using the Social Readjustment Rating Scale (SRRS) [Holmes and Rahe 1967]. Similarly, patients' perception of stress may be measured using the Perceived Stress Scale (PSS) [Cohen et al. 1983]. Shortest form (Form C) of Cattell's 16 PF questionnaire may also be used to predict the appearance of PDI [Cattell et al. 1970, Reeve et al. 1984].

Proper Treatment Planning

Lack of attention to all facets of treatment planning may invite treatment failure; therefore, assessment of both mental (psychosocial) as well as physical (biomedical) conditions should be evaluated carefully [Bensing 2000, Green and Laskin 2000]. Accordingly, patient's subjective need as well as the normatively determined need for replacement of missing teeth should also be evaluated carefully before any prosthodontic treatment [Mazurat and Mazurat 2003/a,b, Graham et al. 2006]; and it should always be considered that the success of a prosthetic treatment strongly depends on the patients' perception of the value of such replacement [Mazurat and Mazurat 2003/a,b]. It should be also considered that, patients are rather focused on social meaning of the mouth than to physical (physiological) function of the teeth when defining subjective need for replacement of missing teeth [Graham et al. 2006]. Although occlusion of a complete dental arch is preferable normatively in most cases, many people are really satisfied with less than 28 natural (± wisdom) teeth. In fact, there is a discrepancy between the normative need and perceived need even for complete denture services in edentulous. Therefore, prompt replacement of absent teeth without a subjective need of patients may lead to an overtreatment and discomfort [Mazurat and Mazurat 2003/a,b] especially when RPDs are used because of financial (or other) reasons [Mazurat and Mazurat 2003/a,b, Bae et al. 2006].

It should be also considered that aesthetics seems to be more important than other functions for a great majority of individuals [Elias and Sheiham 1998]; therefore there can be a lack of subjective need for replacement of missing posterior (particularly molar) teeth [Elias and Sheiham 1998, Mazurat and Mazurat 2003/a,b] especially if only a few teeth are absent. Although aesthetics seems to be more important than other functions for a great majority of individuals, expectations and wishes of patient related to chewing must also not be underestimated [Fábián and Fábián 2000, Mazurat and Mazurat 2003/a,b, Fábián et al. 2007/a]. Although chewing ability can be acceptable for patients functioning from second premolar to second premolar (i.e. when all molars missing) [Mazurat and Mazurat 2003/a,b]; more advanced loss of teeth may induce strong difficulties of chewing. In such cases

improvement of mastication may be a highly important wish of patients certainly [Mazurat and Mazurat 2003/a,b]. Patients' expectations related to speech may also influence satisfaction with dentures strongly. Similarly, numerous other expectations and wishes of patients related to the denture and/or dental treatment may also appear. Importantly, executable and acceptable wishes and expectations of patient should be fulfilled. If inexecutable and/or unacceptable wishes and expectations also appear, the clinician should carefully weigh the option of nontreatment [Levin and Landesman 1976, Stein 1983, Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010].

Besides premised subjective need and conscious wishes related to denture function, unconscious wishes of patients related to both dental treatment and denture (as well as to dentist) should also be considered [Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010]. In contrast to conscious wishes, understanding unconscious wishes (e.g. to look younger, to stop the appearance of aging, to be loved by the dentist etc.) may be more challenging but is similarly important for preventing the manifestation of PDI symptoms [Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010]. It may occur that, the patient's conscious and/or unconscious wishes related to the dental treatment and/or dentures and/or dentist may not harmonize with the reality and possibilities of a prosthetic treatment.

It is a matter of considerable significance that the clinician carefully weighs the option of nontreatment in such cases [Stein 1983, Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010].

It should be also considered that, fixed dentures are usually preferable to a removable one for most patient [Szentpétery et al. 2005]. Therefore properly planned fixed dentures supported either by natural abutment teeth or by properly inserted dental implants may decrease the risk of triggering psychogenic symptoms (comparing to the estimated risk of similar cases treated with RPDs).

However, financial means and compliance of the patient as well as the amount of stress and possible complications induced by preparation of teeth and/or implant-surgical interventions should also be considered very carefully. Because of the high success rate of endosseus dental implants, strategic extraction of compromised tooth/teeth and their replacement with implant supported fixed dentures should also be considered.

Importantly, planning of a time-schedule ensuring enough time to carry out a high quality, precise, "lege artis" dental treatment is one of the most important points to prevent triggering psychogenic symptoms. Timing of the start of prosthetic treatment and the insertion of dentures may also be of particular importance [Müller-Fahlbusch and Sone 1982], because heavy psychosocial and/or psychoemotional stress conditions as well as the active phases of psychiatric disorders significantly increase the risk of PDI [Müller-Fahlbusch and Sone 1982].

Therefore, starting of prosthetic treatment or insertion of dentures under any heavy psychological stress conditions and/or active phases of psychiatric disorders should be avoided [Müller-Fahlbusch and Sone 1982]; and the prosthetic treatment or insertion of denture should be delayed [Müller-Fahlbusch and Sone 1982].

Communication with the Patient

Communication with patient is a key factor of the prevention of PDI. There are three major facets of proper and efficient patient-dentist communication including (1) good interpersonal relationship and mutual trust, (2) exchange of information, and (3) making treatment related decisions [Fábián and Fejérdy 2010]. A good interpersonal relationship and mutual trust can be created due to friendliness, genuineness, readiness to help, empathy, respect, warmth, as well as eliciting feelings, paraphrasing and reflecting. Silence as well as humor may also be very useful in certain cases. Genuineness and congruence of any nonverbal communication is also highly important for creating a good interpersonal relationship and mutual trust. Simple basic techniques such as verbal following (to show he/she is listening to what the other say) [Deneen et al. 1973] and verbal reflection (to restate the essential feelings and contents of the message) [Deneen et al. 1973] as well as greeting the patient and using the patient's name should also not be forgotten. Exchange of information consists of information giving and information seeking, and to meet their needs, both dentists and patients alternate between information giving and information seeking. Patients need to know that what is the cause of their disorder as well as what are the treatment possibilities and possible treatment outcomes. Clear information about treatment procedures and their conditions should also be presented for patients; and patients' level of understanding should be raised until they clearly understand how the proposed treatment will meet their needs [Shigli et al. 2008]. Patients also need to know if the dentist accepts them and takes them seriously. Dentist needs information to establish the right diagnosis and treatment plan. For such purposes, listening to what the patient saying but also to what he/she is unable to say is crucial [Fábián and Fejérdy 2010]. Treatment related decisions-making should be based on mutuality, because not only the dentist but also the patient is responsible for his/her own health. The dentist should give up to hiding behind the facade of a professional authority and should share the problem and problem solving with the patient [Freeman 1999/a,b, Lechner and Roessler 2001]. However, if the dentist has unresolved issues regarding power and control, dependency and insecurity, self-esteem, prejudice, or other similar issues [Cohen 1994] such a "shared" decision-making could be rather untoward. Therefore, dentist’s skills should include both an understanding of the patient as well as an understanding of oneself [Fábián and Fejérdy 2010].

Prevention of Dental Fear

Prevention (or at least a reduction) of dental fear should be integrated into dental treatment of every patients regularly, and especially into the treatment of patients with increased dental fear values [Kreyer 1989, Benson 2000, Hermes et al. 2006]. Especially because traumatizing dental events may trigger PDI symptoms [Müller-Fahlbusch and Sone 1982]. The most common reasons of dental fear are bad (painful or fearful) dental experiences [Moore and Birn 1990], lack of control over the social situation in the dental chair [Moore and Birn 1990], lack of control over personal emotional reactions [Moore and Birn 1990], feeling of powerlessness during treatment [Moore and Birn 1990] and social

learning processes with a negative image of dentists [Moore and Birn 1990]. The most important method for reduction of dental fear is communication. Great care should be taken to avoid fear producing terms or phrases describing the dental treatment or the dental instruments. It is also highly important that, to make only those promises that can be backed [Botto 2006]. It is also important that, to give the perception of being in control to the patient [Botto 2006]. For such purposes, the "tell-show-do" technique [Addelston 1959] may be used efficiently. This method includes describing in simple terms what is about to occur ("tell"); than allowing the patient to see, feel, explore and manipulate the tools or instruments ("show"); and than the starting of the procedure ("do") [Addelston 1959, Allen 2006]. Methods for distraction to refocus patient's attention away from the potentially painful/fearful stimulus or procedure may also be used, advantageously [Allen 2006, Botto 2006]. Offering of brief brakes during treatment is the simplest method for such purposes [Allen 2006]. Another simple forms of distraction include jiggling of the patients' cheek or asking them to hold their legs up in the air during a critical procedure (i.e. administrating of local anesthesia, or making impression) [Botto 2006]. Music expressing positive emotions [Suda et al. 2008] may also be used for distraction during the dental treatment [Vinard and Ravier-rosenblaum 1989, Botto 2006]. Audiovisual methods like video games [Allen 2006], two-dimensional DVD-glasses and three-dimensional virtual reality technology [Askay et al. 2009] may also be used. Mind-body therapies including hypnosis, self-hypnosis, photo-acoustic stimulation, relaxation and several biofeedback methods are also suitable for distraction during the dental treatment. In some cases pharmacological methods including premedication with anxiolytics relative analgesia (inhalation of nitrous oxide - oxygen mixture), conscious sedation (intravenously administered benzodiazepines) and occasionally general anaesthesia as well as psychotherapeutic approaches may also be used to reduce dental fear.

Prevention of Treatment Induced Pain

Painful dental treatment may also trigger PDI, especially when patient was emotionally traumatized [Müller-Fahlbusch and Sone 1982]. Therefore, pain catastrophizing behavior of patients (if any) should be recognized and considered. The use of highly efficient anaesthesia (including postoperative anaesthesia) and the use of psychological stress reducing interventions before treatment (i.e. cognitive or behavior therapy), during treatment (i.e. relaxation, hypnosis etc.) and after treatment (i.e. post hypnotic suggestions, self-hypnosis etc.) is also crucial for such patients. Despite local anaesthesia that have made painless dentistry a reality, psychological methods for alleviation of pain (and/or fear of pain) are still needed for sensitive patients [Benson 2000].

Patient-Nurse-Dentist Interrelationships

Psychological factors in patient-nurse-dentist interrelationships are major determinants of treatment outcome. Four major facets of patient-nurse-dentist relationships should be considered, such as the real relationship and the boundaries of relationship as well as the regression and the transference phenomena. The real relationship is an equal and unique

relationship between persons [Freeman 1999/b]. This is a genuine and realistic interaction in which the uniqueness of the dentist is complemented by the uniqueness of the patient and the uniqueness of the nurse [Freeman 1999/b]. The real relationship between the patient and the dentist (and/or nurse) should be protected by boundaries [Reid et al. 2007]. Acceptance of gifts, dinner invitations or unconventional payments for treatment (i.e. exchanging dental services for housepainting service, or for a discount on an automobile purchase etc.) put the dentist and/or the nurse at high risk of violating boundaries with patients [Reid et al. 2007]. Consequently, conflicts of interest may appear, which may erode their ability to make objective decisions on behalf of the patient [Reid et al. 2007]. Importantly, relation between the dentist and the nurse should also be protected by similar boundaries [Fábián and Fejérdy 2010]. Regression simply describes the psychological state of the patients (and/or nurse and/or dentist) as they change from being in an emotionally controlled to a less well-controlled emotional state, which is associated with a change in relationship status [Freeman 1999/b]. Because of regression, the relationship may show a typical pattern of interaction between a parent and child [Freeman 1999/b] or any other pattern of emotionally deep-rooted relationships. Regression is frequently coupled with transference phenomena. Within the transference patients (and/or nurse, and/or dentist) will re-experience emotions and psycho-emotional patterns of previous relations (primarily from the childhood) [Freeman 1999/b]. The transference is particularly important because the dentist (as a "major target" of transference) may, therefore, be perceived emotionally as a "caring parent" or as a "powerful" or "threatening" person (or "any other" important person) [Freeman 1999/b, Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010]; which may lead to patient's (and/or nurse's) behavior appearing as inadequate and disturbing from the viewpoint of the dentist.

Prevention of Relapse

Prevention of relapse is primarily based on inducing and maintenance of long run changes of patients' health related behavior in respect of somatic (dental and medical) as well as mental health. It should be considered that, a structural plan for patient education has a better chance for success than one based only on intuition. Therefore, a clear identification and establishment of the educational needs of patients is crucial [Wentz 1972]. Subsequently, identification of possible/available motivation stimuli and concrete goal setting should be carried out [Wentz 1972]. Next goals of education plan should be achieved due to motivation and learning reinforcement [Wentz 1972]. Finally, results should be evaluated and controlled regularly [Wentz 1972]. Importantly, whatever structural plane is to be used, it must incorporate some means of providing information other than in an advice-giving format [Freeman 1999,a]. Information must be presented in such a way that patients feel its importance, and in a way that they can "take ownership" of it [Freeman 1999,a]. Depending on their personality, somatic condition, family/social background and symptoms, various methods may be offered for the patients. Most preferable home practice of several mind-body methods, diet- and medicinal herb therapy as well as CAM methods may be offered. Online support groups as well as patients' clubs could be another promising possibility for prevention

of relapse of PDI patients. Although prevention of relapse is primarily based on the patients' self-reliance, patient should be told to return for care if symptoms recur and cannot be quickly controlled by the previously used (home practice) procedures [Laskin and Block 1986].

Mental Health of Dental Team

It should be emphasized that, many dentists (and other members of the dental team) have a working situation with rather hard work conditions and occupational stress. Further, dentists' profession is coupled with a difficult psychoemotional challenge as well [Kreyer 1992]. The active inhibition of dentist's emotional expression (especially when dealing with problem patients) may also lead to increased working stress and risk for a variety of health problems [Berry and Pennebaker 1993]. To reduce psychoemotional stress during working with patients, dental team members should be able to accept a patient from the bottom of hart as well as to understand and accept own emotions. Thus, dentists and other team members should become a mature, well-disposed and good person on behalf of the patients as well as on behalf of their own interest. For such purposes several psychotherapeutic approaches as well as several mind-body methods are available and may be useful for dentists as well. Besides intrapersonal problems, interpersonal problems of team members should also be managed [Kreyer 1992]. In this respect, the most important is to recognize, verbalize and discuss the appearing problem. Verbalization and discussion can be facilitated due to organizing regular formal team meetings as well as informal team meetings.

Treatment Possibilities

Strategy of Psychosomatic Dental Therapy

Majority of psychogenic denture intolerance patients refuse to accept psychological background of their symptoms [Ross et al 1953, Schwichtenberg and Doering 2008], and instead of psychiatrists or psychotherapists, first they visit dentist and insist on the somatic origin of their symptoms [Ross et al. 1953]. Therefore, a simple referral to psychiatrist and/or psychotherapist would not solve the problem in most cases. Consequently, an initial psychosomatic therapy is needed prior to definitive therapy, which is a scope of dental profession's duty [Moulton et al. 1957, Pomp 1974]. The most important goals of initial psychosomatic therapy are avoidance of further useless invasive dental treatment [Brodine and Hartshorn 2004, Reewes and Merrill 2007, Baad-Hansen 2008] as well as obtaining decrease (recovery) of symptoms and motivation of patients to participate in a definitive psychosomatic therapy (which is the highest level care of psychogenic denture intolerance patients).

Gradual escalation of therapy and avoidance of irreversible forms of treatment are "cornerstones" of the initial psychosomatic therapy [Laskin and Block 1986]; which utilizes several placebo and/or palliative methods (i.e. physiotherapies, medication, medicinal herb therapy, diet therapy, complementary and alternative medicine /CAM/ therapy etc.) combined

with certain psychotherapeutic approaches and administration of any mind-body therapies (which are the "basic therapeutics" for psychosomatic disorders [Iversen 1989, Binder and Bider 1989, Krause 1983, 1994, 2000, Fábián in press]). In contrast to initial therapy, definitive psychosomatic therapy should be carried out by specialized dental professionals as members of a specialized psychosomatic team including experienced dentists and other medical and psychotherapeutical professionals. Definitive psychosomatic therapy should be offered for patients being refractory to the initial psychosomatic therapy, and for patients responding to it but without a stable treatment outcome in a long run (i.e. patients with frequent relapses). Fundamentals of the complex process of dental psychosomatic therapy will be discussed in details below.

Initial Psychosomatic Therapy

As already indicated above, most of oral psychosomatic patients (especially PDI patients) refuse to accept psychological background of their symptoms [Ross et al 1953, Schwichtenberg and Doering 2008]. Instead of psychiatrists or psychotherapists, first they visit dentist and insist on the somatic origin of their symptoms [Ross et al. 1953, Fábián et al. 2005/a]. In a dental psychosomatic unit, at least three-fourth (76,1 %) of the patients would surely need psychotherapy [Schwichtenberg and Doering 2008] but only 37,8 % of the patients would really begin a psychotherapeutic treatment [Schwichtenberg and Doering 2008]. Those, who do not begin definitive psychotherapy (the majority of such patients), are apt to continue doing "dentist shopping" (i.e. frequent and useless change of dentist) [Schwichtenberg and Doering 2008], with futile attempts at somatic therapies and/or surgical interventions [Kreyer 2000].

These data clearly indicate that, a simple referral to psychiatrist and/or psychotherapist would not solve the problem of the majority of PDI patients. Therefore, an initial psychosomatic therapy (IPT) is needed prior to definitive therapy, which is a scope of dental profession's duty [Moulton et al. 1957, Pomp 1974]. Initial psychosomatic therapy (IPT) is a scope of every dentist's duties currently, because of the absence of an extended network of specialized dental professionals. However, management of oral psychosomatic patients in specialized dental groups appears to be a meaningful perspective for the future [Dahlström et al. 1997, Green and Laskin 2000, Schwichtenberg and Doering 2008]. It may also be considered that, the network of prosthodontists may fulfill this task, but in this case, post-graduate education of prosthodontists should be completed with proper psychological and psychotherapeutical knowledge in a suitable manner.

In acute cases, the most important goal of initial psychosomatic therapy (IPT) is the avoidance of further useless invasive dental treatment [Brodine and Hartshorn 2004, Reewes and Merrill 2007, Baad-Hansen 2008], especially because aggravation or spread of symptoms following invasive dental interventions may occur frequently [Lesse 1956, Köling 1988, Toyofuku and Kikuta 2006]. The prevention of symptom chronification is also crucial, because chronification (especially with prolonged unsuccessful somatic/operative dental therapy in the history) frequently render pain and other symptoms intractable [Harris et al. 1993, Wöstmann 1996, Toyofuku and Kikuta 2006]. Prevention of symptom chronification

can be carried out efficiently with the simple avoidance of repeating unsuccessful dental treatments in many cases, in other cases symptom-centered palliative methods, certain psychotherapeutic approaches and any mind-body therapies should also be used.

Administration of premised symptom-centered palliative methods combined with certain psychotherapeutic approaches and with any mind-body therapies may lead to recovery in many cases, and solve the problem finally (definitively) [Pomp 1974, Harris et al. 1993, Wöstmann 1996, Fábián and Fejérdy 2010]. In other acute cases, there is some significant improvement, but there is no recovery of the symptoms during IPT. In such cases another important aim of initial psychosomatic therapy (IPT) is to keep these patients in a psychosomatic therapeutic relationship and motivate them to participate in a definitive psychosomatic therapy.

In chronic cases the prognosis of IPT is rather poor [Harris et al. 1993, Dahlström et al. 1997, Fábián and Fejérdy 2010]. There is no significant improvement during IPT in roughly half of chronic oral symptoms [Dahlström et al. 1997; Fábián et al. 2004, Schwichtenberg and Doering 2008]. Therefore, majority of chronic patients would need proper definitive psychosomatic therapy. Consequently, besides reaching some improvement of the symptoms (if any), major goal of IPT in chronic case is avoidance of repetition of unsuccessful futile somatic/operative dental treatment [Brodine and Hartshorn 2004] and obtaining motivation of patients to participate in a definitive psychosomatic therapy [Brodine and Hartshorn 2004, Demmel 2007].

As mentioned above, gradual escalation of therapy and avoidance of irreversible forms of treatment [Laskin and Block 1986] are "cornerstones" of the initial psychosomatic therapy. Therefore, the first goal of IPT in the management of psychogenic denture intolerance patients is to provide them with some understanding of their problem [Laskin and Block 1986], even if these patients often have difficulty accepting a psychophysiologic explanation for their disease [Laskin and Block 1986]. During this phase of IPT use of placebo and/or palliative methods (physiotherapies, medication, medicinal herb therapy, diet therapy, CAM therapy etc.) combined with certain psychotherapeutic approaches may be an appropriate way [Green and Laskin 1974, Laskin and Block 1986] to decrease the symptoms, and to develop a good patient-dentist relationship. At this phase of IPT some of the cases may be solved, others may be improved and at least an increase of patients' understanding related to their symptoms may be reached [Fábián and Fejérdy 2010].

Based on patients' improved understanding, second goal of IPT is to administer any mind-body therapies, which are "basic therapeutics" for psychosomatic disorders [Iversen 1989, Binder and Bider 1989, Krause 1994, Fábián et al. 2009/d]. Mind-body therapies (i.e. hypnosis, self-hypnosis, meditation, photo-acoustic stimulation, biofeedback methods etc.) advantageously improve psychogenic symptoms in most of the cases leading either to a recovery or to a significant improvement, coupled with increased motivation of patients to take part in a definitive psychosomatic therapy (see below) [Fábián and Fábián 1998; Fábián et al. 2002, 2005/a, 2009/c,d]. Accordingly, third goal of IPT is to refer patients being refractory to IPT to definitive psychosomatic therapy (see below) and to make sure that these patients enter and participate in the definitive psychosomatic therapy [Fábián and Fejérdy 2010, Demmel 2007].

Although the efficiency of initial psychosomatic therapy (IPT) is strongly depends on the improvement of symptoms; using efficient symptom-centered treatments it should be always

considered that, any psychogenic symptom may represent a defense against psychiatric decompensation [Lesse 1956, Delaney 1976, Marbach 1978, Violon 1980, Kaban and Belfer 1981]. Therefore, symptom-centered interventions should be administered carefully, resulting in slow-going, gradual decrease of the symptoms to prevent decompensation of the patient during IPT.

Definitive Psychosomatic Therapy

Definitive psychosomatic therapy (DPT) is a highest level care of PDI patients utilizing any available dental, medical and psychotherapeutical treatment possibilities in an evidence based manner. Definitive psychosomatic therapy should be offered for patients being refractory to IPT [Laskin and Block 1986], and for patients responding to IPT but without a stable treatment outcome in a long run (i.e. patients with frequent relapses). Definitive psychosomatic therapy (DPT) is clearly not a scope of every dentist's duties. Definitive psychosomatic therapy should be carried out by specialized dental professionals [Dahlström et al. 1997, Hertrich and Joraschky 1996, Dworkin et al. 2002, Fábián and Fejérdy 2010] as members of a specialized psychosomatic team including experienced dentists and other medical and psychotherapeutical professionals.

Although clinical experiences clearly indicate that there is a major role of specialized dental professionals also in definitive psychosomatic therapy (DPT) in most cases; close collaboration with medical professionals (especially with psychiatrists and neurologists) and with psychotherapists is clearly needed for DPT [Dahlström et al. 1997, Hertrich and Joraschky 1996, Von Korff 2005, Turner et al. 2006, Schwichtenberg and Doering 2008]. Dentists having full-qualification in psychotherapy and/or psychosomatic dentistry seem to be the most adequate professionals to organize definitive psychosomatic therapy for PDI patients, especially because continuation of a psychosomatic supportive dental care is needed in most of the cases [Laskin and Block 1986, Fábián and Fejérdy 2010].

It should be also considered that, PDI patients usually display a lower level of psychopathology comparing to psychiatric patients [Meldolesi et al. 2000]; but in some cases severe psychopathologies including psychoses may also appear as a background of PDI symptoms [Lesse 1956, Delaney 1976, Marbach 1978, Violon 1980, Kaban and Belfer 1981, Fábián 1999]. In such cases referral to psychiatrist and definitive psychiatric therapy (instead of psychosomatic therapy) is crucial; although a supportive type psychosomatic dental care is usually also needed for proper definitive treatment and for stabilizing oral functions and oral health.

After-Care

All patients including PDI patients who wear any fixed or removable dentures should have annual examinations [Woelfel 1983]. These examinations should include evaluation of the health of oral/orofacial tissues (with special respect of the supporting teeth and other supporting tissues) as well as evaluation of the condition, retention, stability and other

relevant properties of dentures [Woelfel 1983]. PDI related psychogenic symptoms of patients should also be examined.

Although there are rather few studies about the efficiency of treatment of oral psychosomatic patients, it is likely that at least 50-60% of such patients significantly improve in their complaints [Schwichtenberg and Doering 2008]. Sometimes, especially in not yet chronic cases the success rate may be even higher. However, there is still a relatively large amount of patients without any success or with suffering from several residual symptoms.

Therefore, patients should be made aware that it may not be possible to provide a permanent cure for their problem, but that they can learn to manage in a satisfactory manner [Laskin and Block 1986]. Home practice of most mind-body therapies, diet- and medicinal herb therapy as well as complementary and alternative medicine (CAM) therapies regularly supervised by the dentist (and/or other professionals) are good tools to manage such residual symptoms as well as to maintain clinical results and to prevent relapse [Laskin and Block 1986, Fábián and Fejérdy 2010]. In the case of relapse (or exacerbation) of the PDI symptoms, patients should be treated as described in respect of initial psychosomatic therapy (IPT).

Conclusion

Even though a prosthesis is fabricated conscientiously and properly, there is no assurance that the patient will be comfortable while wearing it or satisfied with the therapy [Mazurat and Mazurat 2003/a,b]. A normative evaluation by a dentist and a subjective evaluation by the patient related to the denture or to the dental treatment may be rather different [Lechner and Roessler 2001]. The factors not related to operative/technological dental skills that contribute to the success of prosthodontic treatments are becoming more and more important.

PDI related symptoms are usually multifactorial (multicausal) notwithstanding that there is always a major psychogenic component behind the symptoms too [Fábián and Fábián 2000, Fábián et al. 2006, 2007/a]. Therefore, both somatic and psychogenic pathways of pathomechanism should be considered carefully for both diagnosis and treatment. Since psychogenic symptoms may mimic a great variety of somatic symptoms; a clear cut diagnosis and proper differential diagnosis of PDI could be rather difficult. Therefore it should be emphasized that, the diagnosis of PDI is a presumptive one in many cases. The diagnosis may change later in the course of the disease as the clinical findings change and/or stabilize, therefore continuous monitoring and evaluation of the patient over time is essential [Sarlani et al. 2005/a.b]. A detailed differential diagnosis considering possible disorders of the teeth, and/or oral- and maxillofacial tissues should also be carried out, and any other possible somatic causes behind the symptoms should also be excluded.

Prevention is likely to be the most important tool for the management of psychogenic denture intolerance related problems at a social level. Cornerstones of prevention are screening of risk patients, proper treatment planning, proper communication with the patient, screening of the patient-nurse-dentist interrelationships, as well as prevention of dental fear, prevention of treatment induced pain and prevention of relapse [Fábián and Fábián 2000, Fábián et al. 2007/a, Fábián and Fejérdy 2010]. It is also crucial for the prevention that,

patients must be made aware of their responsibilities in achieving a satisfactory outcome. It is also a matter of considerable significance that the clinician carefully weighs the option of nontreatment in certain cases [Levin and Landesman 1976, Stein 1983, Fábián and Fábián 2000, Fábián et al. 2007/a].

Majority of psychogenic denture intolerance patients refuse to accept psychological background of their symptoms [Ross et al 1953, Fábián et al. 2005/a, Schwichtenberg and Doering 2008]; and instead of psychiatrists or psychotherapists, first they visit dentist and insist on the somatic origin of their symptoms [Ross et al. 1953, Fábián et al. 2005/a]. Therefore a simple referral to psychiatrist and/or psychotherapist would not solve the problem in most cases. Consequently an initial psychosomatic therapy is needed prior to definitive therapy, which is a scope of dental profession's duty [Moulton et al. 1957, Pomp 1974, Fábián and Fejérdy 2010]. Avoidance of irreversible forms of treatment is crucial for a proper initial psychosomatic therapy certainly. Initial psychosomatic therapy may utilize several placebo and/or palliative methods (i.e. physiotherapies, medication, medicinal herb therapy, diet therapy, CAM therapy etc.) combined with certain psychotherapeutic approaches and administration of any mind-body therapies, which are "basis therapeutics" for psychosomatic disorders.

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Chapter XIII

Pulsed Electromagnetic Field (PEMF) Therapy for Peri-Implant Healing and Bone Remodeling

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Abstract

Data in the literature revealed that bone formation around dental implants can be promoted due to PEMF treatment significantly. Since PEMF decreases the rate of residual ridge resorption following tooth extraction, PEMF is likely to improve healing of implants inserted into extraction sites as well. PEMF may also be used advantageously for accelerating bone healing following advanced implant surgery. Although PEMF stimulation during the first two weeks after surgery seems to be the most efficient; late phase bone healing (even four weeks after surgery) may also be accelerated with PEMF administration. Moreover, PEMF stimulation speeds up bone remodeling processes which effect is likely to be a crucial factor of the phenomenon that PEMF accelerates tooth movement (and coupled periodontal processes). PEMF also influence the function of periodontal ligament fibroblasts, which also may play a significant role in the acceleration of bone remodeling around orthodontically moved teeth as well as around teeth subjected to high mechanical load during mastication (i.e. abutment teeth) or because of parafunction. Although PEMF was found to be beneficial to a wide variety of therapeutic processes also in dentistry; the exact mechanisms by which PEMF affects alveolar bone and other periodontal tissues is far not fully understood yet. However,

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certain mechanisms are already recognized and the increased amount of knowledge may be utilized also for the clinical practice. In this chapter scientific data of clinical relevance are collected and discussed.

Introduction

How a cell detects a PEMF signal is unknown currently, although some mechanisms have been proposed to account for the interaction of PEMF with cells. PEMF may interact with moving charges and change their velocities as in the classic interaction of magnetic fields with any moving charge [Blank 1995, Goodman and Blank 1998]. Resonance-interaction of PEMF fields with Earth's magnetic field [Goodman and Blank 1998] as well as the phenomenon of ion-cyclotron resonance [Liboff et al. 1987, Lednev 1991, Blanchard and Blackman 1994] may also be responsible for several biological responses. Since PEMF penetrate the cell (unlike electric fields) interaction can occur anywhere inside (or outside) the cell [Goodman and Blank 1998]. It is very likely that PEMF signal exhibit sufficient energy to elicit a transient activation/alteration of membrane bound receptors or their inner associated proteins [Luben 1982, Varani et al. 2003, Schnoke and Midura 2007] and may also alter density of certain receptors of the cells [Varani et al. 2003]. Therefore, PEMF is believed to influence the function of receptor coupled signal transduction pathways [Luben 1982, Goodman and Blank 1998, Varani et al. 2003, Schnoke and Midura 2007]. A wide variety of cell-membrane structural and functional properties are also altered by PEMF including binding of Ca^{2+} to anionic fixed charges in the cell membrane [Lednev 1991], conformational changes of ion channels [Balcavage et al. 1996] and trans membrane ion transport [Lednev 1991]. PEMF significantly increases intracellular free Ca^{2+} level and decreases Ca^{2+} dependent signal transduction responses to receptor ligands present in the serum as well [Satake et al. 1990]. Alteration of cell communication via alteration of local factor production and gap junction signaling is also very likely [Lohmann et al. 2003]. Further, PEMF is likely to induce phosphorilation of several proteins of intracellular signal transduction pathways [Schnoke and Midura 2007]. PEMF induced changes of the activity of several ATPases and enzymes is also very likely [Blank 1995, Goodman and Blank 1998]. PEMF is also likely to influence gene activation [McClellan et al. 1990, Blank and Goodman 1997], transcription [Blank and Goodman 1997, Tuinstra et al. 1997, Solazzo et al. 2010] as well as translation and protein synthesis [Goodman et al 1993, Goodman and Blank 1998] pathways of the cell.

Effect of PEMF on Osteoclasts

Osteoclasts are responsible for both bone demineralization and collagen degradation in the bone [Chang et al. 2005, Fábián et. al. 2009/a, Barnaba et al. in press]. Osteoclasts are bone resorptive large multinucleated cells derived from bone marrow hematopoietic stem cells of monocyte-macrophage lineage [Chang et al. 2005, Fábián et. al. 2009/a, Barnaba et al. in press]. The fact that immune cells and osteoclast precursor cells are derived from the same hematopoietic precursor cells may be responsible for the phenomenon that osteoclastogenesis is promoted by macrophage colony-stimulating factor (M-CSF) [Chang et

al. 2005] and also that pro-inflammatory cytokine network responsible for the activation of immune cells exert an activating effect also on osteoclast precursor cells [Fábián et. al. 2009/a]. Production of proinflammatory cytokines is an important factor also for the maturation of osteoclasts in the bone, because tumor necrosis factor alpha (TNF-α) interleukin 1β (IL-1β) and interleukin 6 (IL-6) induce the expression of RANKL (receptor activator of nuclear factor-κβ ligand; a member of tumor necrosis factor superfamily) in osteoblasts which is essential for final differentiation steps of osteoclasts (as well as for their bone resorbing capacity) [Fábián et. al. 2009/a]. Osteoblasts have RANKL on their surfaces and via contact dependent signaling they activate RANK /receptor activator of nuclear factor-κβ/ on the surface of osteoclast progenitors, resulting in osteoclast maturation and bone resorption [Chang et al. 2005, Schwartz et al. 2009]. In addition, osteoblasts also secrete soluble RANKL [Chang et al. 2005, Schwartz et al. 2009]. Provided that macrophage colony-stimulating factor (M-CSF) is present, RANKL is both necessary and sufficient for osteoclastogenesis [Chang et al. 2005]. Osteoblasts however also produce osteoprotegerin /OPG/ which acts as a decoy (scavenger) receptor binding RANKL, thereby preventing it from binding RANK on the surface of osteoclasts resulting in decreased osteoclast maturation and bone resorption [Chang et al. 2005, Schwartz et al. 2009].

PEMF is likely to cause a delay of osteoclast differentiation [Chang et al. 2004/a, 2005, Barnaba et al. in press] coupled with decreased proinflammatory cytokine (TNF-α, IL-1β, IL-6) production [Chang et al. 2004/a] and decreased RANKL and MC-SF production [Chang et al. 2005] of differentiating cells in the first week (7-9 days) of daily PEMF exposure. PEMF also increases the production of osteoprotegerin (OPG) in osteoblasts without any change of secretion of RANKL [Schwartz et al. 2009], leading to the increase of OPG/RANKL ratio resulting in decreased osteoclast maturation and decreased bone resorption [Schwartz et al. 2009]. However, the effect may be transitory in nature and may disappear thereafter [Barnaba et al. in press]; and the effect seems to be coupled with PEMF stimulation of lower energy [Chang et al. 2003, 2005]. (In contrast, stimulation with PEMF of higher energy may lead to increased osteoclast differentiation [Chang et al. 2003, 2005] coupled with increased proinflammatory cytokine (TNF-α, IL-1β) production [Chang et al. 2003] and decreased secretion of OPG and decrease of OPG/RANKL ratio [Chang et al. 2005].) Besides premised effects of PEMF on osteoclast differentiation, PEMF may also increase the apoptotic rate of osteoclasts which may also lead to decrease of bone degradation under certain circumstances [Chang et al. 2006].

Effect of PEMF on Osteoblasts

Osteoblasts produce bone matrix during development, after bone injury, and during normal bone remodeling [Chang et al 2005, Fábián et. al. 2009/a]. In contrast to osteoclasts derived from bone marrow hematopoietic stem cells of monocyte-macrophage lineage [Chang et al. 2005, Fábián et. al. 2009/a, Barnaba et al. in press], osteoblasts arise from multipotential mesenchimal (stromal) cells in bone marrow [Chang et al 2005, Fábián et. al. 2009/a]. PEMF exposure of bone marrow-derived mesenchimal stem cells (cultured in osteogenic medium) likely decreases the rate of their proliferation [Tsai et al. 2009, Jansen et al. 2010] and speeds up their osteogenic differentiation [Tsai et al. 2009, Jansen et al. 2010] in the first week (7-9

days) of daily exposure [Tsai et al. 2009, Jansen et al. 2010]. Expressed OPG/RANKL ratio also increases during this period significantly [Schwartz et al. 2009, Jansen et al. 2010]. Importantly, these effects may be transitory in nature and may disappear thereafter [Tsai et al. 2009, Jansen et al. 2010] in good accordance with the effect of PEMF on osteoclast maturation (see above). Notwithstanding that premised effects maybe be transitory, the shift towards earlier maturation is resulting in a significantly enhanced calcium deposition in the extracellular matrix also thereafter (i.e. after the 7-9-th days of stimulation as well) [Jansen et al. 2010].

There is also a stimulatory effect of PEMF on matured cell cultured osteoblasts. Daily exposure with PEMF increases proliferation of osteoblasts in vitro during the first week (2-7 days) of active proliferation stage of cell culture [Diniz et al. 2002, Chang et al. 2004/b], but importantly this effect disappears thereafter [Diniz et al. 2002, Chang et al. 2004/b]. PEMF also increases the expression of OPG and decreases the expression of RANKL (with a consequent increase of OPG/RANKL ratio) in the first 5 days of daily stimulation but not thereafter [Chang et al. 2004/b]. PEMF also enhances mineralized extracellular matrix formation of cultured osteoblasts in the first 15 days but not thereafter [Diniz et al. 2002]. Increase of extracellular matrix formation is likely to be based on upregulation of important genes related to bone formation (including genes responsible for the synthesis of both collagenous and noncollagenous matrix components) and downregulation of genes responsible for the degradation of extracellular matrix [Solazzo et al. 2010]. Besides above, daily PEMF stimulation also enhances cell proliferation and viability of osteoblasts co-cultured with macrophage cells stimulated with lipopolysacharide (to release high level of reactive oxygen species as a model of inflammatory environment) during the first 7 days of culture [Lin and Lin in press]. PEMF stimulation also induces release of a soluble factor from osteoblasts, which significantly increase vascular endothelial proliferation (a major factor of angiogenesis) in a paracrine manner [Hopper et al. 2009]. PEMF also likely to inhibit parathyroid hormone (PTH) induced release of osteoclast activating factor [Luben et al 1982, Spadaro and Bergstrom 2002], which prevent PTH induced Ca^{2+} mobilization via inhibiting resorption of the bone by osteoclasts [Spadaro and Bergstrom 2002]. (Please consider that the response of osteoclasts to PTH primarily depends on the activating factor generated by osteoblasts which have PTH receptors lacking in osteoclasts [Spadaro and Bergstrom 2002].)

PEMF Therapy and Peri-Implant Healing

Data in the literature revealed that bone formation around dental implants (i.e. bone coverage and osteointegration of implants) can be promoted due to PEMF treatment significantly [Matsumoto et al. 2000, Chan and Bergman 2008, Grana et al. 2008]. Since PEMF decreases the rate of residual ridge resorption following tooth extraction [Ortman et al. 1992], PEMF is likely to improve periimplant healing of implants inserted into extraction sites as well. In general, daily PEMF exposure of 1 to 2 hours may be recommended based on the scientific literature (2 x 30 min [Grana et al. 2008]; 1 hour [Friedricks et al. 2000, Inoue et al. 2002]; 2 hours [Chan and Bergman 2008]). However, authors experience indicated that PEMF stimulation of 10-15 minutes three times a week also appears to be promising for clinical use. Although stimulations during the first two weeks after surgery seems to be the

most efficient [Matsumoto et al. 2000]; late phase bone healing (even four weeks after surgery) may also be accelerated with PEMF administration [Inoue et al. 2002, Chan and Bergman 2008]. PEMF stimulation of late phase bone healing (1 hour per day for 8 weeks [Inoue et al. 2002]) very likely leads to somewhat greater new bone formation, increased mineral apposition rate and decreased porosity of the cortex adjacent to the healing area [Inoue et al. 2002].

It is likely that, energy value of PEMF stimulation as well as pattern of waveform characteristics including shape and amplitude of the bursts, pulse frequency of the bursts, duration of the bursts, and length of burst on-off periods (burst on-off frequency) are rather important factors of PEMF induced promotion of bone healing [Leisner et al. 2002, Miruda et al. 2005]. It is also likely that high-amplitude narrow-pulse portions of PEMF stimulation are especially advantageous to produce a beneficial bone response [Pienkowski et al. 1992]; whereas symmetry/asymmetry relations of the stimulus pulse waveform may be of less importance [Pienkowski et al. 1992]. Further, low energy fields (0.2 – 0.3 mT [Matsumoto et al. 2000]) seems to be more efficient than high energy fields (0.8 mT [Matsumoto et al. 2000]) to promote bone healing procedures [Rubin et al. 1993, Matsumoto et al. 2000]. Authors experience indicated that PEMF stimulation with very low energy fields (0.05 – 0.1 mT) also appears to be promising for clinical use. It is also very likely that low values (15 Hz) of burst on-off frequencies seems to be more efficient than high values (50 – 150 Hz) of burst on-off frequencies [Rubin et al. 1993]; although higher burst on-off frequencies also promote bone healing significantly [Rubin et al. 1993, Matsumoto et al. 2000]).

PEMF may also be used advantageously for accelerating bone healing following advanced implant surgery. PEMF enhances healing of osteotomy gaps [Pienkowski et al. 1992, Darendelier et al. 1997, Friedricks et al. 2000, Inoue et al. 2002, Grana et al. 2008]. PEMF can also accelerate bone formation (and total recovery of bone tissue) in bone defects filled with hydroxyapatite (HA) [Ottani et al. 2002] or with demineralized bone-matrix [Takano-Yamamoto et al. 1992]. Similarly, PEMF can also accelerate bone graft incorporation [Kold et al. 1987]. Further, PEMF accelerate consolidation of regenerate bone during distraction osteogenesis [Fredericks et al. 2003] and accelerate healing of both fresh [Grace et al. 1998] and ununited bone fractures [Gossling et al. 1992]. PEMF also alleviate postoperative pain [Hedén and Pilla 2008, Strauch et al. 2009] and decreases postoperative edema [Strauch et al. 2009] which could also be rather advantageous following implant surgery.

Besides above, PEMF also improves wound healing of the gastrointestinal mucosa [Mentes et al. 1996] and the skin [Patino et al. 1996, Scardino et al. 1998], therefore it may be hypothesized that PEMF improves healing of the oral mucosa around osseointegrated implants. PEMF also improves regeneration of injured nerves [Raji and Bowden 1983, Raji 1984, Zienowicz et al. 1991, Kanje et al. 1993] and increases angiogenesis [Tepper et al. 2004, Hopper et al. 2009] which could be important additional factors of periimplant bone and soft tissue healing as well. Further, PEMF reverses the proliferative defects of lymphocytes from aged subjects [Cossarizza et al. 1989/a,b], and induces the expression (and consequent release) of immune activator/modulator HSP70/HSPA type stress proteins [Goodman and Blank 1998, Heredia-Rojas et al. 2010] which are also likely to improve proper bone [Fábián et al. 2009/a,b] and mucosal healing [Fábián et al. 2003, 2007, 2009/b, 2011] around the implants.

PEMF Therapy and Bone Remodeling

Bone is remodeled continuously throughout life through the resorption of old bone by osteoclasts and the subsequent formation of new bone by osteoblasts [Chang et al. 2004/a, Fábián et. al. 2009]. These two events are tightly coupled to each other and are responsible for the renewal of bone while maintaining its anatomical and structural integrity [Chang et al. 2004/a, Fábián et. al. 2009]. As mentioned above, PEMF stimulation with low energy fields usually leads to the depression of osteoclast function [Chang et al. 2003, 2005] which may slow down bone remodeling processes. However stimulation with PEMF of higher energy [Chang et al. 2003, 2005] and/or with certain specific patterns of PEMF waveform characteristics [Leisner et al. 2002, Miruda et al. 2005] can lead to increased osteoclast differentiation [Stark and Sinclair 1987, Chang et al. 2003, 2005] coupled with increased proinflammatory cytokine (TNF-α, IL-1β) production [Chang et al. 2003] and decreased secretion of OPG and decrease of OPG/RANKL ratio [Chang et al. 2005]. Moreover, PEMF stimulation induced moderate increase of osteoclast function coupled with a somewhat more increased osteoblast function likely speeds up bone remodeling processes [Fábián and Sőti 2007].

Speed up of bone remodeling is likely to be crucial factor of the phenomenon that PEMF accelerates tooth movement and coupled periodontal processes [Stark and Sinclair 1987, Chen 1991, Darendeliler et al. 1995, 2007, Showkatbakhsh et al 2010]. Under normal conditions of orthodontic tooth movement (without use of PEMF) osteoclasts proliferate and initial resorption of superficial bone occurs in the area of periodontal ligament compression [Darendelier et al. 2007]. Accordingly, in the area of periodontal ligament tension, the periodontal fibers unwind, fibroblasts appear and osteoblasts form a non-mineralized collagenous matrix (osteoid) which is mineralized later, trapping some osteocytes in lacunae within the newly formed bone [Darendelier et al. 2007]. PEMF induced speed up of tooth movement is likely to be primarily due to a further increase of the number of osteoclasts [Stark and Sinclair 1987, Chen 1991] and other active cells [Kim 1990, Chen 1991] without induction of any unfavorable ultrastructural changes of the stimulated cells at issue [Chen 1991].

PEMF is also likely to influence the function of periodontal ligament fibroblasts [Kim 1990, Satake et al. 1990], which may play a significant role in the acceleration of bone remodeling around orthodontically moved teeth [Satake et al. 1990, Darendelier et al. 2007] as well as around teeth subjected to high mechanical load during mastication (i.e. abutment teeth) and/or because of parafunction [Kim 1990]. PEMF stimulation of periodontal ligament fibroblasts significantly increases their intracellular free Ca^{2+} level and decreases their Ca^{2+} dependent signal transduction responses to receptor ligands present in the serum [Satake et al. 1990], with a duration of roughly a day following stimulation [Satake et al. 1990]. PEMF also induce release of local factors from periodontal ligament fibroblasts, including those influencing cell attachment and (in vitro) spreading of both periodontal ligament fibroblasts and osteoblasts [Kim 1990]. Although meaning of premised effects of PEMF on periodontal ligament fibroblast is far not clear yet, premised data may indicate that PEMF significantly influences function of periodontal ligament fibroblast playing significant role in periodontal bone remodeling processes.

Contraindication of PEMF Therapy

In general, PEMF is contraindicated in the case of patients with any severe systemic diseases and with strongly compromised health [Fábián and Sőti 2007, Fábián and Fejérdy 2010]. In the case of such patients, use of PEMF should be avoided in the absence of a clear agreement of the medical professional(s) responsible for the treatment of the systemic disease(s) at issue [Fábián and Sőti 2007, Fábián and Fejérdy 2010]. Similarly, PEMF is usually contraindicated in the cases of patients with any hemorrhagic diathesis, precancerosis, and malignancy as well as in the case of patients having any oncological treatment in the anamnesis (at least in the absence of a clear agreement of the oncologist or other responsible medical professional) [Fábián and Sőti 2007, Fábián and Fejérdy 2010]. Importantly, use of PEMF should be strictly avoided near to a nevus [Fábián and Sőti 2007, Fábián and Fejérdy 2010]. Use of PEMF should also be avoided in the condylar area during the growth period [Wilmot et al. 1993]. In the absence of clear evidences about the innocuity, PEMF may be contraindicated for patients with pacemaker (especially in the case of unipolar electrode configuration [Gwechenberger et al. 2006]) or with any another implanted electric instruments [Gwechenberger et al. 2006, Fábián and Sőti 2007, Fábián and Fejérdy 2010]. Although application of physiotherapy should be avoided near to the ear, eye, brain or spinal cord (i.e. temporal or paravertebral use) in the absence of clear evidence about the innocuity of the chosen treatment modality [Fábián and Sőti 2007, Fábián and Fejérdy 2010], PEMF seems to be a rather safe treatment modality from these points of view.

Conclusion

PEMF was found to be beneficial to a wide variety of therapeutic processes in the last few decades. Although exact mechanisms by which PEMF affects alveolar bone and other periodontal tissues is far not fully understood yet; certain important mechanisms were recognized recently. Therefore a significantly increased amount of knowledge may be utilized to improve clinical efficiency of PEMF in dentistry. Although PEMF stimulation can be seen as a noninvasive tool, the few contraindications of PEMF should be considered carefully for a safe and successful use.

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Index

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z