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Oral Rehabilitation Considerations for Partially Edentulous Periodontal Patients

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Abstract

Traditional tooth-supported and implant-supported fixed/removable restorations are currently used to replace teeth lost due to periodontal disease. This article reviews the existing literature for oral rehabilitation of partially edentulous periodontal patients with various designs of removable dental prosthesis (RDP), fixed dental prosthesis (FDP) and implant-supported single crown (SC), by addressing their (a) general features, (b) survival and complication rates, along with considerations for treatment planning in periodontal patients, and (c) preference by patients. To answer these issues, relevant articles were searched and critically analyzed, and their data were extracted. Data reviewed indicated that despite many advantages, implant-supported restorations have higher complication rates than tooth-supported restorations. Systematic reviews on conventional RDPs are lacking, but existing literature reviews provide limited evidence suggesting the use of RDPs with design modifications along with strict periodontal care in periodontal patients. Numerous systematic reviews on conventional FDPs and implant-supported restorations provide a moderate level of evidence favoring their survival in periodontal patients; however, for long-term success of these restorations, the patient's periodontal condition needs to be stabilized. In terms of patient preference, no restoration is superior, as they all are governed by their cost, advantages, and disadvantages. Thus, in the wake of existing weak evidence for prosthodontic rehabilitation of periodontal patients by these restorations (especially, conventional RDPs and for FDPs and SCs in implant-supported restorations), longitudinal studies with standardized treatment protocol and methodology are needed to evaluate and compare tooth-supported and implant-supported restorations in periodontal patients with regard to survival rates, cost, maintenance, and patient-centered outcomes.

Periodontal disease is a chronic microbial infection characterized by persistent inflammation, connective tissue breakdown, and alveolar bone destruction.[1] In advanced periodontal disease, there is often severe bone loss and loss of teeth. Hopeless teeth are extracted in the emergency phase, whereas teeth with questionable prognoses that have not responded to the initial phase of periodontal therapy may have to be extracted following reexamination.[2] Subsequently, prosthodontic rehabilitation is often necessary to restore function and esthetics in a periodontally compromised dentition.[2]

Missing teeth and supporting oral tissues have been traditionally replaced with removable or fixed partial dentures. For the past 40 years, dental implants have been an alternative option. They are surgically inserted into the jaw bones to support the dental prosthesis and are retained through the intimacy of bone growth onto their surface (i.e., osseointegration).[3] Success with dental implants has led to substantial changes in treatment strategies for RDPs when extension bases can be avoided, and for FDPs with the presence of caries-free or well-restored adjacent teeth, which otherwise would have been prepared for use as abutments with a substantial loss of tooth structure. Additionally, implants are now more often used to replace teeth with a questionable prognosis.[4] Dental implants have thus been considered one of the most significant scientific breakthroughs in dentistry over the past 30 years[3] and a gold standard for the treatment of total or partial edentulism in most clinical scenarios.[5]

In a critical review of some dogmas in prosthodontics, Carlsson[6] noted that the widespread opinion that implant treatment is more secure than conventional fixed prostheses is not in accordance with the current literature. Likewise, based on numerous long-term studies and systematic reviews, Pjetursson and Lang[7] opined that the incidence of complications is substantially higher in implant-supported than in tooth-supported

reconstructions. Additionally, based on survival rates, complications, and patient-related issues, the same authors concluded that while planning prosthetic rehabilitations, conventional end-abutment tooth-supported FDPs, solely implant-supported FDPs, or implant-supported single crowns (SCs) should be the first treatment option. Only as a second option, because of financial aspects, patient-centered preferences, or anatomical structures, should cantilever tooth-supported FDPs, combined tooth-implant-supported FDPs, or resin-bonded FDPs be chosen.[7] However, these evidence-based conclusions by Pjetursson and Lang[7] are general in nature, and no such conclusions are available for oral rehabilitation of periodontally compromised partially edentulous patients (with tooth loss due to progressive periodontitis, but who had received thorough periodontal therapy), who present with a unique habitat of periodontal microorganisms and periodontally weakened abutment teeth, which may or may not affect the long-term survival and success of various prosthodontic treatment options. Recently, a review conducted in two parts by Kanno et al[8,9] on implant and conventional prosthodontic therapy treatment for periodontally compromised partially edentulous patients concluded that such patients could be treated successfully with implants, but it is difficult to evaluate RDP treatment for these patients. From the results of some long-term follow-up retrospective studies, FDPs with high-risk design showed excellent results.[8,9]

Currently, there is no defined evidence-based consensus on the use of various RDP (conventional and implant-supported) and FDP (conventional, cantilever, resin-bonded, implant-supported, and combined tooth-implant-supported) designs, as well as implant-supported SCs in the oral rehabilitation of partially edentulous periodontal patients. Evidence-based dentistry is defined as "an approach to oral health care that requires the judicious integration of systematic assessments of clinically relevant scientific evidence, relating to the patient's oral and medical condition and history, with the dentist's clinical expertise and the patient's treatment needs and preferences."[10] Thus, with these principles of evidence-based dentistry, the aim of the present review is to critically evaluate the available literature with the objective of defining the best evidence-based treatment option for the oral rehabilitation of periodontally compromised partially edentulous patients, by raising specific issues regarding the general features, long-term survival and complication rates, along with considerations for treatment planning in partially edentulous periodontal patients, and patient preferences for implant-supported and traditional tooth-supported restorations.

Methods

Using the online databases MEDLINE (PubMed), Cochrane Library, and Google Scholar, literature was searched from 1960 to, and including, September 2011. Using the keywords "dental implant," "fixed partial denture," "fixed dental prosthesis," "removable partial denture," "removable dental prosthesis," "cantilever bridges," "resin-bonded bridges," "implant-supported restorations/prosthesis," "combined tooth-implant-supported restorations/prosthesis," "single crowns," "decision making," "prognosis," "risk factors," "treatment outcome," "survival," "success," "biological complication," "technical complication," and "failure," relevant articles were identified to construct a review in the traditional style. English-language publications in peer-reviewed journals were considered, but abstracts were excluded. Articles available online in electronic form before their publication and in print ("Epub ahead of print" or "online early") were considered eligible for inclusion in this review.

A complementary manual search from 1980 to September 2011 was also carried out in the following journals: *Journal of Periodontology, Journal of Clinical Periodontology, Periodontology 2000, International Journal of Periodontics and Restorative Dentistry, Journal of Oral Rehabilitation, Clinical Oral Implants Research, Clinical Implant Dentistry and Related Research, Journal of Prosthodontics, International Journal of Prosthodontics, Journal of Prosthetic Dentistry, and International Journal of Oral and Maxillofacial Implants*. In addition, the reference lists of articles selected for inclusion in this review were screened. Bibliographies from selected articles, the proceedings of the Fourth ITI Consensus Conference (2008), and position papers of the American Academy of Periodontology were screened as well.

Of the 2439 titles obtained from the online search, 218 were selected for full-text review after reading the abstracts. From the 218 full-text articles, 110 were included for data extraction in this review. Two additional articles were included based on a manual search. Thus, a total of 112 publications[2,4,11-120] focusing on the oral rehabilitation of partially edentulous periodontal patients were included in this review, and are grouped to answer the following clinically relevant issues.

General indications, contraindications, advantages, and disadvantages of tooth- and implant-supported restorations

By using the data extracted from articles[4,11-50] of the literature search, the salient indications, contraindications, advantages, and disadvantages along with the long-term survival rates of conventional RDPs, conventional FDPs, and implant-supported restorations (implant-supported RDPs, implant-supported FDPs, combined tooth-implant-supported FDPs, and implant-supported SCs) are summarized in Table 1. The selection of tooth- or implant-supported restorations is dictated by the condition of the dentition, alveolar ridge and mucosa, patient's age, and occlusal, periodontal, and medical conditions. Due to rising concerns for the preservation of dental tissues, esthetics, and various limitations of the conventional prosthesis, implant-supported restorations have become an accepted manner of treating partial edentulism.[22] Implant-supported restorations have numerous advantages and are placed independently of potential abutment teeth. An implant-supported FDP may be indicated where the length of the edentulous span is too great for a resin-bonded or conventional FDP, or where there are no suitable abutment teeth.[51] Furthermore, implant-supported restorations may be preferable to a conventional prosthesis for patients with compromised supporting bone (severe resorption and jaw reconstruction) or mucosa (oral lichen planus, aphthous stomatitis, pemphigus vulgaris, cicatricial pemphigoid, lupus erythematosus, scleroderma, and allergy to dental plastics),

Table 1 Indications, contraindications, advantages, and disadvantages of tooth- and implant-supported restorations

Restoration	Indications	Contraindications	Advantages	Disadvantages (limitations and complications)
Conventional RDP	• Replacement of posterior teeth (i.e., Kennedy–Applegate classification Class I and II)[11–13] • Class III, IV, or V situations (Kennedy–Applegate classification) when the edentulous space is too large for fixed prosthesis or when alveolar bone loss is so extensive it is necessary to replace missing bone with a resin flange to support middle third of patient's face[11,13] • As interim restorations after recent extractions (until site heals), need for effect of bilateral bracing, i.e., RDP may act as a periodontal splint by providing cross-arch bracing, esthetics in anterior region, and economic considerations[11] • If abutment teeth need crowning, attachment-retained (e.g., precision attachment or telescopic) RDPs may be preferred[14] • If teeth are sound, resin-bonded adhesive attachment retaining the RDP can be an option[14]	• Diseases such as diabetes and dry mouth may restrict RDP treatment because of inability of mucosa to withstand mechanical trauma; esthetic considerations and aspects of comfort may also be contraindications[14] • Weak evidence of an allergy to specific metals in the casting alloy[14] • Use of precision attachments in Kennedy-Applegate classification Class I and II situations to avoid visible retentive clasp arms is contraindicated, as the firm connection between a distal extension free-end denture base and abutment increases the risk of mechanical failures[13]	• Inexpensive solution for prosthetic rehabilitation of patients with functional or esthetic need for replacement of posterior teeth[11–13] • If conventional FDP is not possible because of extensive tooth loss, and implant treatment is not realistic, clasp-retained RDP is a valid alternative[14] • Non-invasive to remaining dentition's structure[14] • In patients with diagnosed TMDs (in those reporting pain and other problems) if restoration of molar support is advisable, RDP is preferred given its advantage of reversibility[14]	• Risk of caries and periodontal disease adjacent to abutment teeth and resorption of residual ridge[13] • Wear of RDPs may be associated with complaints regarding appearance of the dentition as elements of denture framework or acrylic become visible[13] • Root caries in elderly patients where risk of inadequate oral hygiene is high[14] • Non-physiological loading of retaining teeth[15] • Patient dissatisfaction due to poor adaptation[15] • In attachment-retained RDPs, as removable reconstructions are generally designed to be firmly attached to fixed restoration, there is a risk that strain may give rise to cementation failure or abutment fracture[13] • Inflammatory tissue reactions like traumatic ulcers, denture stomatitis, irritation hyperplasia, flabby ridges, and burning mouth syndrome may occur[16] • Associated with complications such as fracture of denture and its components (occlusal rests); preparation of occlusal rest in amalgam restoration weakens restoration and leads to its fracture under masticatory force[17,18] • Ill-fitting retainers, occlusal disharmony, pain in soft tissues under the connector or denture base, rotational denture movements, and ridge resorption are frequently observed after long-term use of distal extension RDPs[19]

Continued.

Table 1 Continued.

Restoration	Indications	Contraindications	Advantages	Disadvantages (limitations and complications)
				• Survival rate of conventional metal frame RDPs on basis of replacement and not wearing is around 75% after 5 years and 50% after 10 years. Fracture of metal frame occurs in 10–20% of RDPs after 5 years and in 27–44% after 10 years[20]
FDP (conventional, cantilever, and resin-bonded)	• Replacement of single or two missing teeth by support of abutment teeth with equal or greater root surface area (Ante's law)[21] • Applicable to most situations where abutment crown-to-root ratio is less than 1:1 [21] • Considered where conditions of potential abutment (i.e., from a preexisting crown or a damaged tooth) justify their complete circumferential preparation or when modification of tooth form and volume is necessary due to erosion, abrasion, functional, or esthetic concerns[22] • Metal-ceramic FDPs are preferred in high load-bearing areas without any esthetic concerns and when many teeth are to be replaced[23] • All-ceramic FDPs should be limited to replacement of incisor teeth (as single-unit restoration) and is recommended only when interocclusal space allows for fabrication of framework with adequate thickness, when minimal or no occlusal contacts are present on framework, and when connection of sufficient dimensions can be established[22] • Cantilever FDPs are preferred: for rehabilitation of unbounded edentulous ridges; if abutment teeth needs crowning; in situations	• More than 1:1 crown-to-root ratio of abutment exists, excessive mobility of abutment(s), and cantilevered designs on incisor teeth[21] • Endodontically treated anterior teeth are predisposed to long-term failure as FDP abutments, as are pier abutments. Pulp capped teeth are at high risk for requiring endodontic treatment and make poor choices for abutment teeth because endodontic treatment would remove the tooth structure necessary for long-term stability of an FDP[21] • Prospective abutment teeth that were subject to luxation or avulsion injuries are at significant risk for resorption[21] • Young patients[22] • All-ceramic FDPs are contraindicated when there is reduced interocclusal distance (short clinical crowns, deep vertical overlap anteriorly without horizontal overlap), or an opposing supraerupted tooth, for cantilevers, periodontally involved abutment teeth, and patients with severe bruxism or parafunctional activity[26] • Replacement of a maxillary canine with a cantilever FDP is contraindicated[27] • Short clinical crown height with limited interocclusal distance, heavily restored teeth, patients with	• High patient acceptance, short treatment time, and experienced laboratory support[28] • Metal-ceramic FDPs have predictable structural performance, versatility, and cost with superior load-bearing capacity (as compared to all-ceramic FDPs)[29] • All-ceramic FDPs have improved esthetics (tooth-resembling color and enamel-like translucency) and lower allergenic potential of ceramic materials as compared to metal-ceramic FDPs[29,30] • If implants are contraindicated due to medical reasons, presence of jeopardizing anatomical structures or because of patient-centered factors such as financial concerns, cantilever FDPs are still treatment option to be considered in unbounded edentulous areas[24] • Resin-bonded FDPs offer a treatment option to patients not otherwise suitable for implant-supported restorations (lack of adequate space to place implant). Compared to conventional FDPs, they offer a more conservative preparation approach in which most abutment tooth reduction terminates within enamel (consequently, less risk of adverse pulpal reaction) and preparation finish line is placed supragingivally (simplifies impression taking and	• Significant reduction in amount of tooth structure is necessary, which may predispose to biologic (caries, loss of pulp vitality, periodontal disease progression) and technical (loss of retention, abutment tooth fracture, fractures of veneer or framework) complications[21,31] • Requires high level of operator clinical skills and complex laboratory procedures[15] • Metal-ceramic FDPs have disadvantages such as low esthetics (visible metal margin) and allergy to metal alloys, while all-ceramic FDPs have limitations of high cost, wear of opposing dentition and restorations, more tooth preparation, brittleness, crack propagation, and low tensile strength.[26,32] 5-year survival rate of metal-ceramic FDPs (94.4%) is significantly higher than all-ceramic FDPs (88.6%). Metal-ceramic FDPs fail primarily due to tooth fracture and caries. The frequency of material fractures (framework and veneering material) is significantly higher for all-ceramic FDPs. Other technical complications (loss of retention) and biological complications (caries and loss of pulp vitality) are similar for the two. FDPs made out of glass ceramics or glass-infiltrated ceramics fail primarily due to fracture of the

Continued.

Table 1 Continued.

Restoration	Indications	Contraindications	Advantages	Disadvantages (limitations and complications)
	thought to be less demanding regarding occlusal load or where extensions may mainly serve esthetic aspects[24] • Resin-bonded FDPs are preferred for single-tooth replacement and when teeth are sound[25]	parafunctional habits (like bruxism) are relative contraindications for resin-bonded FDPs[25]	reduces possibility of adverse gingival/periodontal reaction to cemented prosthesis). Moreover, fabrication of an interim prosthesis is seldom required. Reduced chairside time for preparation of abutments and impression taking, as retraction cord placement is usually not necessary, and lower laboratory fees result in lower cost of resin-bonded FDPs as compared to conventional FDPs[25]	reconstruction (framework and veneering ceramic), while in FDPs made from zirconia, reasons for failure are primarily biological (secondary caries) and technical complications (cohesive fracture of veneering porcelain)[33] • 10-year survival and success rates of cantilever FDPs (81.8% and 63%, respectively) are lower than those of conventional FDPs (89.1% and 71.1%, respectively), and biological and technical complications are frequent[24] • Use of resin-bonded FDPs is not an easy clinical procedure; careful treatment planning and clinical skills are required. Tooth preparation must be designed to minimize tensile forces. Case selection also plays a great role in longevity of prostheses. Various retainer and tooth surface treatments together with cement (bonding) used also have some bearing on success. Despite the high 5-year survival rate (87.7%) of resin-bonded FDPs, technical complications like debonding are frequent. This implies that a substantial amount of extra chair time may be needed following their incorporation. Besides this, resin-bonded FDPs may suffer from biological complications like caries and tooth discoloration[34,35]
Implant-supported restorations	• Abutment teeth without restoration or need for restoration, abutment teeth with large pulp chambers[21] • Non-vital abutment teeth, abutment teeth with a history of avulsion or luxation, and abutment teeth that are prospective pier abutments for either FDPs or RDPs[21]	• Developing patients (particularly in maxilla, where vertical growth continues after permanent teeth are fully erupted), uncontrolled periodontal disease, esthetic areas with thin, highly scalloped gingiva, adjacent periapical pathology, and non-motivated patients[21]	• Firm bone anchorage, referred to as osseointegration, or functional ankylosis (defined as a direct structural connection at the light microscopic level between bone and surface of a load-carrying implant). No soft connective tissue or periodontal ligament-like	• Patient's fear of surgery and cost[42] • Surgical complications include neurosensory disturbances, hematoma, mandibular fracture, hemorrhage, and tooth devitalization. Initial and long-term marginal bone loss as well as peri-implant soft tissue

Continued.

Table 1 Continued.

Restoration	Indications	Contraindications	Advantages	Disadvantages (limitations and complications)
	• Prospective implant site should possess a full complement of bone and soft tissue or the potential to create it, minimum restorative and surgical mesiodistal dimension of 6 mm, minimum vertical surgical dimension of 10–12 mm of bone, and available restorative dimension to provide prosthetic material for esthetics and occlusal function[21] • Secondary indications for implant restorations are patients who desire a restoration similar to natural tooth esthetics that facilitate regular hygiene procedures[21] • Implant-supported RDPs may be preferred for replacement of teeth (Kennedy–Applegate classification Class I, II, III, IV, and V situations) in patients in whom treatment with an implant-supported FDP is not feasible for economic or technical reasons[13] • Splinting teeth to implants in case of combined tooth–implant-supported FDPs is preferred in the following situations: when anatomic limitations restrict insertion of additional implants (e.g., maxillary sinus, mental foramen); lack of bone for implant placement; patient refusal to undergo a bone augmentation procedure; desire to splint a mobile tooth to an implant; to preserve the papilla adjacent to tooth for esthetic or functional concerns (e.g., phonetics)[36] • Implant-supported SCs: for replacement of single strategically important, but missing tooth abutments to restore short edentulous segment of dentition[37]	• Post head and neck radiation therapy (absolute, but provisional restrictions; reduced bone remodeling, risk of osteoradionecrosis, implant placement 6–8 weeks before or ≥1 year after radiotherapy)[4] • Severe psychosis[4] • Pregnancy (absolute, but provisional; to avoid additional stress and radiation exposure)[4] • Immunosuppressants or long-term steroid medication, uncontrolled HIV infection (absolute, but provisional restrictions)[4] • Relative contraindications are where adjacent root flaring precludes placement (correction needed with orthodontics), smokers (increased failure rate, especially in type IV bone), connective tissue diseases, diabetes, and autoimmune diseases[21]	interface is detectable between bone and implant, and osseointegrated implant functions without mobility[38] • Preservation of tooth structure and bone, improved masticatory performance, and resistance to caries[39] • Criteria that favor implant-supported restorations in esthetic zone are normal wound healing capacity, intact neighboring teeth, unfavorable potential abutment teeth, extended edentulous spaces, missing strategic abutment teeth, and presence of diastemata[40] • Implants are used to improve the RDP support, enhance retention and stability, preserve residual ridge underneath the denture base, reduce the stress applied on abutment teeth, eliminate the need for unesthetic clasp assemblies, and modify unfavorable arch configurations. Implant-supported RDP serves as a cost-effective, prosthetic solution for partially edentulous patients who are not immediate candidates for extensive, fixed implant-supported restorations. In implant-supported RDP, connection between clasps and abutment teeth, and connection between denture base and implant, is more flexible than that of cement- or screw-retained fixed prostheses (combined tooth–implant-supported FDPs). Thus, implant-supported RDP would be quite safe even if there were rigid connections between implant and natural teeth from the denture base and clasps[19,41]	complications are identified. Mechanical complications include screw loosening/fracture; implant fracture; framework, resin base, and veneering material fractures; as well as esthetic and phonetic complications.[43] Most common technical complications of cement-retained, implant-supported fixed restorations are loss of retention, chipping, and abutment screw loosening[44] • At present, implant-supported RDP designs have not been verified by sufficient scientific and clinical experience to establish their long-term success[13] • Implant-supported FDPs do not provide significant improvement in masticatory performance compared to conventional RDPs for Kennedy Class I and II partially edentulous mandibles.[45] Despite high survival of implant-supported FDPs (95% after 5 years and 86.7% after 10 years), biological and technical complications are frequent (38.7% after 5 years). This implies that substantial amounts of chair time must be accepted by the patient, dental service, and society at large following the incorporation of implant-supported FDPs.[46] For implant-supported cantilever FDPs, 5-year event-free survival rate varies between 66.7 and 79.2% and between 83.1 and 96.3% for non-cantilever FDPs. No significant differences exist with regard to peri-implant bone level change between 2 prosthetic groups, either at prosthesis or at implant level. The incorporation of cantilevers into implant-supported prostheses may be associated with higher incidence

Continued.

Table 1 Continued.

Restoration	Indications	Contraindications	Advantages	Disadvantages (limitations and complications)
			• Advantages of combined tooth–implant-supported FDPs include: reduced cost for tooth replacement; teeth provide proprioception; additional support for total load on dentition; reduction of number of implant abutments needed for a restoration; possibly avoid the need for a cantilever[36] • Implant-supported SCs help avoid preparation of intact or previously successfully crowned neighboring teeth[37]	of minor technical complications (porcelain fractures and bridge-screw loosening).[47] The 5- and 10-year survival rate of short span implant-supported cantilever FDPs is 94.3 and 88.9%, respectively, with some biological (peri-implantitis) and technical complications (veneer fracture, screw loosening, loss of retention, and abutment/screw fracture)[48] • Survival rates of both implants (90.1% after 5 years; 82.1% after 10 years) and reconstructions (94.1% after 5 years; 77.8% after 10 years) in combined tooth-implant-supported FDPs are lower than those for implant-supported FDPs. The incidence of biological (peri-implantitis, loss of abutment teeth and implant) and technical (fractures of veneer material, loss of retention, intrusion of abutment teeth, abutment/screw loosening, abutment and screw fractures and implant fracture) complications after 5 years of function for implants in combined tooth-implant-supported FDPs is 11.7% and 0.7–9.8%, respectively[49] • Implant-supported SCs have a high 5-year survival rate (94.5%), but biological (peri-implantitis, soft tissue complications and bone loss exceeding 2 mm) and particularly technical (implant fractures, screw or abutment loosening, screw or abutment fracture, ceramic or veneer fractures) complications are frequent[50]

RDP - removable dental prosthesis; FDP - fixed dental prosthesis; SC - single crown.

xerostomia, severe gag reflex elicited by a removable prosthesis, high susceptibility to candidiasis (in immunosuppressive therapy, HIV, anemia), diseases affecting orofacial motor function (Parkinson's disease), or a psychological inability to wear removable prostheses.[43] Additionally, patients who demand improved chewing comfort, phonetics, and confidence and self-esteem, or patients with one or more missing teeth adjacent to sound healthy teeth, are better served with implant-supported restorations.[43]

In contrast, conventional tooth-supported RDPs or FDPs may be preferable to implant-supported restorations in the following situations: severe systemic diseases (uncontrolled diabetes, hypertension, severe bronchitis or emphysema, severe anemia, cirrhosis, nephritis, severe hemorrhage risk, malignant disease); risk of oral carcinoma (tobacco smoking/chewing, alcohol abuse, oral premalignant lesions such as oral lichen planus, verrucous leukoplakia, actinic cheilitis, chronic hyperplastic candidiasis, submucous fibrosis, discoid lupus erythematosus, dyskeratosis congenita, and epithelial dysplasia); risk of anaphylaxis (titanium allergy); for demanding esthetics; risk of endocarditis, myocardial infarction, osteoradionecrosis or compromised healing (smoking, diabetes, HIV, immunosuppressive therapy); intake of systemic medication (cyclosporin, antiepileptics, cytotoxic chemotherapy, corticosteroids, anticoagulants, and channel blockers); anorexia or bulimia; growing and pregnant patients; patients with severe fear of surgery; patients suffering from severe psychiatric disorders and alcohol or drug abuse; and patients with unrealistic demands.[43] Smoking, poor bone quality, atrophic maxillae, pre-irradiation and bone-grafting procedures of the atrophic maxilla, and post-irradiation therapy are considered as high risks for implant failure.[43]

Based on certain clinical studies and case series, Levin[52] and Grossmann et al[41] concluded that implant-supported RDPs may alleviate some of the problems associated with conventional RDPs. Implants can improve RDP support, enhance retention and stability, preserve the residual ridge underneath the denture base, reduce the stress applied on the abutment teeth, eliminate the need for unesthetic clasp assemblies, and modify unfavorable arch configurations; however, Levin[52] also noted that RDPs are still needed in cases of un-replaced failed implants, or where economic, systemic, or local anatomic conditions preclude the use of extensive rehabilitation with fixed implant-supported restorations.

Survival refers to the presence of a restoration with or without complications. With regard to the survival rate of conventional RDPs, when abutment retreatment is used as a measure of failure, the 5- and 10-year survival rate is 40% and >20%, respectively.[20] Using *replacement* and *not wearing the RDP* as failure criteria, the survival rate is around 75% after 5 years and 50% after 10 years. Metal frame fracture occurs in 10% to 20% of RDPs after 5 years and in 27% to 44% after 10 years. Cases of distal extension require more adjustments of the denture base as compared to tooth-supported base RDPs.[20] Contrary to conventional RDPs, implant-supported RDPs have not been evaluated in any longitudinal study to establish their survival and success rate.

Despite high success rates, implant fixture failure may occur and is defined as "the inadequacy of the host tissue to establish or maintain osseointegration."[53] Implant failures are further categorized as early or late. When implants fail early, it is usually during the first weeks or months after implant placement. Early failures are frequently related to surgical trauma, complicated wound healing, insufficient primary stability, and/or initial overload. On the other hand, late implant losses occur after an initially successful osseointegration, and can be caused by microbial infection, overload, or toxic reactions from the contamination of the implant surface, such as that from acid remnants.[4] Occlusal overload of an osseointegrated implant occurs when the load-bearing threshold set by the biological phenomenon of osseointegration is exceeded. Overload results in a sudden loss of osseointegration with implant mobility (a hopeless prognosis). Microbial infection initiates peri-implant mucositis, which corresponds to gingivitis and may progress into peri-implantitis, which corresponds to periodontitis. While peri-implant mucositis is a reversible inflammatory reaction in the soft tissues surrounding an implant, peri-implantitis is an inflammatory reaction associated with the loss of supporting bone around an implant in function.[4]

The survival and complication rates of fixed implant-supported restorations have been evaluated in several systematic reviews. In a systematic review, Pjetursson et al[54] reported 5-year survival rates for conventional tooth-supported FDPs (93.8%), cantilever FDPs (91.4%), implant-supported FDPs (95.2%), combined tooth-implant-supported FDPs (95.5%), and implant-supported SCs (94.5%). After 10 years of function, however, the estimated survival rates decreased for conventional FDPs (89.2%), cantilever FDPs (80.3%), implant-supported FDPs (86.7%), combined tooth-implant-supported FDPs (77.8%), and implant-supported SCs (89.4%). Even though 5-year survival rates were high, more than one-third (38.7%) of patients with implant-supported FDPs had some complications (ceramic fractures or chipping, abutment or screw loosening and loss of retention) as compared to 15.7% of patients for conventional FDPs (caries and loss of pulp vitality) and 20.6% of patients for cantilever FDPs.[54] Additionally, among the tooth-supported FDPs, the 5-year survival rates of metal-ceramic FDPs (94.4%) is significantly higher than that of all-ceramic FDPs (88.6%), with the frequency of material fractures (framework and veneering material) being significantly higher for all-ceramic FDPs (6.5% and 13.6%) compared with those of metal-ceramic FDPs (1.6% and 2.9%).[33] Similarly, despite the high 5-year survival rate (87.7%) of resin-bonded FDPs, technical complications like debonding (19.2%) are frequent.[35]

Similar conclusions of frequent biologic and technical complications despite the high survival rate are drawn in recent systematic reviews of implant-supported SCs[50] and implant-supported cantilever FDPs.[47,48] Thus, from the literature, it can be concluded that compared with tooth-supported FDPs, the incidence of technical complications is significantly higher for implant-supported restorations. The possible reason for this is that after the placement of implants, the bone as well as the soft tissue response is controlled by wound-healing factors, biomechanics, and mineral metabolism. Because of this tissue response, the healing process as well as the maintenance of implants may be influenced by many factors such as diet, drug use and smoking, age, and systemic and oral diseases.[43] Through examining the above data, it can be interpreted that

conventional tooth-supported and implant-supported RDPs and FDPs have their own indications, contraindications, advantages, and disadvantages (in terms of limitations and survival and complication rates), which may vary according to the oral anatomy and systemic condition of the patient, and thus influence the clinician's decision for rehabilitation of the patient with these treatment options.

Long-term survival and complication rates along with considerations for oral rehabilitation with tooth- and implant-supported restorations in periodontally compromised partially edentulous patients

Conventional RDP

Currently, no systematic review exists concerning the survival and complication rates of RDPs in periodontitis patients. The impact of RDP wearing on periodontal health has been regularly reported to be unfavorable,[17,55-67] with gingivitis being more frequently found in Kennedy's class I than in class II RDP wearers, and more frequent in the mandibular than in the maxillary arch.[58] The three main factors responsible for periodontal breakdown related to RDPs are (1) plaque and oral hygiene, (2) coverage of the marginal gingiva by parts of an RDP, and (3) occlusal forces transmitted to the remaining teeth and their periodontal tissues by the prosthesis.[68] Moreover, a 2009 study[69] on the relationship between periodontal diagnosis and prognosis and the survival of prosthodontic abutments revealed a 3.05-fold increased risk for tooth loss with RDP abutments than with FDP abutments. The study thus concluded that teeth with a periodontal prognosis other than good and those used as RDP abutments had an increased risk of tooth loss.[69] Additionally, the microbiological risk for periodontitis of abutment teeth is greater than that for non-abutment teeth in RDP wearers.[70] Contrary to this, some studies show no such unfavorable periodontal outcomes.[71-74] Better oral hygiene is generally associated with less-detrimental periodontal effects of RDP wearing,[57,65,71,73,75,76] and regular recall for RDP-wearing patients has mostly been shown to reduce the periodontal consequences.[65,74,77]

Recent reviews[78,79] have also concluded that well-constructed RDPs used with regular periodontal maintenance may not pose a risk to existing periodontal health; however, additional research in the form of longitudinal studies is needed to further investigate the effects of RDPs in the progression of periodontal disease. Periodontal health of teeth can be maintained if basic principles of RDP design are followed, that is, factors such as rigid major connectors, simple design, and proper base adaptation; however, improper RDP design may lead to changes in tooth mobility and increased probing depth due to an increase in plaque bacteria accumulation.[78,79] Prior to RDP treatment, periodontal screening of a patient in terms of oral hygiene, the presence of plaque and gingival inflammation, attachment loss, remaining osseous support, and mobility should be accomplished.[78] This should be followed by definitive periodontal treatment to eliminate periodontal disease, treat any defects that hinder plaque control, and create a better environment for cleaning. Strategic extractions of periodontally weakened teeth with hopeless prognoses should be performed, especially in cases where the treatment plan does not change. Periodontal pockets should be treated via surgical or non-surgical therapy. Crown lengthening is indicated for altered passive eruption of the abutment teeth to establish better crown contours and to create the minimal space required for the different RDP components. Gingival augmentation may be considered in instances of lack of attached gingiva around the abutment teeth.[78]

Hansen et al[80] also suggested certain design modifications during restoration of a periodontally compromised dental arch with a conventional RDP. These modifications include the following:

(a) multiple rests (to ensure that adequate vertical support remains in the event that primary abutment teeth are lost);
(b) open or closed base strategically placed in the maxillary major connector (to facilitate the replacement of subsequently lost teeth);
(c) location of finish lines modified to provide a smoother resin-to-metal transition when posterior teeth are lost; and
(d) wire direct retainers that provide more physiologically acceptable clasping of compromised teeth and that are easily adjusted and added to the prosthesis.[80]

The concept of splinting periodontally involved abutment teeth with adjacent healthy teeth prior to rehabilitation with RDP has been evaluated only in a few in vitro studies.[81-85] The first of these studies using a photoelastic model concluded that splinted abutments are indicated when using the attachment retainers for RDPs.[81] Another in vitro study[82] showed that a significant decrease in the magnitude of movement resulted when the abutment teeth were splinted. Further, an in vitro study[83] using an in vitro model with strain gauges concluded that at least two teeth on each side should be splinted when extracoronal distal extension attachment prostheses are used. By using a photoelastic model, another in vitro study[84] evaluated the effects of periodontal support and fixed splinting on load transfer by RDPs. Results showed that the more severe the osseous defect, the greater the assistance provided by splinting to periodontally sound teeth.

In contrast to these earlier studies, a recent in vitro study[85] using 3D finite element models concluded that (a) splinting a tooth with reduced bone height to an adjacent healthy tooth redirects the stress from the bone crest to the apical areas of both teeth; (b) even after fixed splinting of two abutments, gradual loss of bone support increases the stress in the alveolar crest area; (c) fixed splinting of a very weak abutment to an adjacent healthy tooth might not be beneficial (the maximum acceptable crown-to-root ratio for fixed splinting of a weak abutment to the adjacent normal tooth was shown to be 1.65–2); and (d) splinted teeth can tolerate non-axial loads.

Conventional FDP

As early as in 1991, in a comprehensive literature review based on numerous clinical studies, Lundgren[86] concluded that adequately treated and controlled dentitions can carry fixed, cross-arch bridges on an extremely reduced amount of

periodontium, with a good long-range prognosis. Furthermore, FDPs are generally considered preferable in periodontally compromised individuals because FDPs splint mobile teeth, which leads to a more favorable distribution of functional load to the remaining periodontium.[2]

As stated by Kourkouta et al,[2] the indications for extensive tooth-supported fixed prosthodontic treatment in periodontally compromised patients include the mobility of the remaining periodontally treated teeth affecting patient comfort and/or chewing ability, a jaw relationship permitting establishment of anterior occlusal contacts, favorable distribution of potential abutment teeth, existing restorations requiring replacement, adverse conditions for implant treatment (medical reasons; lack of appropriate bone dimensions; proximity of anatomical structures such as the inferior alveolar nerve and maxillary sinus; financial considerations), and patients' desire to maintain their own teeth.[2] Contraindications include lack of patient motivation/compliance, unrealistic esthetic demands, a jaw relationship that does not permit establishment of anterior occlusal contacts (e.g., excessive overjet in Class II division 1 cases), unfavorable abutment distribution resulting in excessive load over long pontic spans or unbounded cantilever segments, inadequate dental laboratory support, and financial considerations.[2]

Focusing on cantilever FDPs, Stockton[87] noted that these might inadvertently contribute to the initiation and progression of periodontal destruction. Contrary to these views, Himmel et al,[88] in an earlier review, commented that a cantilever FDP with adequate periodontal support can replace any tooth in the dental arch, and is especially useful as an alternative to an RDP. Moreover, teeth with poor periodontal support survive better than those with good support when used as abutments for cantilevered prostheses, because patients with reduced periodontal support produce substantially less biting force.[89]

The above positive statements on the suitability of FDPs in the rehabilitation of partially edentulous periodontal patients have been reinforced in a recent systematic review[90] that explored the impact of severely reduced, but healthy, periodontal tissue support on the survival rate and complications of FDPs after a mean follow-up time of at least 5 years. The results showed an estimated FDP survival rate of 96.4% and 92.9% after 5 and 10 years, respectively, and it was concluded that (a) masticatory function could be established and maintained in subjects receiving FDPs on abutment teeth having severely reduced but healthy periodontal tissue support and (b) FDP survival rates compared favorably with those of FDPs incorporated in patients without severely periodontally compromised dentitions. The authors, however, cautioned against the generalization of these favorable outcomes of FDP placement in periodontitis in the six included studies, as in these studies, all periodontal and prosthetic treatment was provided in specialist clinics of Swedish universities. This may partly explain the favorable long-term outcomes of FDPs in these studies compared with those obtained by FDPs placed by general practitioners in excluded studies.[90]

Implant-supported restorations

Among the systematic reviews[91-99] (Table 2) dealing with long-term survival rates of implant-supported restorations in periodontally compromised patients, only two systematic reviews[91,94] commented on the survival rates of suprastructures supported by implants, wherein, the 3- to 5-year survival rate for the FDPs supported by implants was reported to be 92% to 100%, and the 5-year survival rate of these suprastructures was not significantly different in individuals with periodontitis-associated and non-periodontitis-associated tooth loss. Other systematic reviews[92,93,95-99] have reported only the survival rates of the implants in implant-supported restorations. The results of these systematic reviews have shown that there is no significant difference in the survival of the implants after 5 and 10 years between individuals with previous tooth loss due to periodontitis and individuals with previous tooth loss due to reasons other than periodontitis. Additionally, there are no significant differences in both short-term and long-term implant survival between patients with a history of chronic periodontitis and periodontally healthy individuals.[93] However, limited evidence suggests that patients with a history of periodontitis receiving implants might have greater risk of peri-implantitis.[91,92,94,96-99]

According to Al-Zahrani,[95] although the available evidence is weak, it suggests good short-term survival of implants placed in periodontally well-maintained aggressive periodontitis patients; however, Karoussis et al[93] commented that although the short-term implant prognosis for patients treated for aggressive periodontitis is acceptable, on a long-term basis, the matter is open to question. As pointed out by Van der Weijden et al[100] and in various other systematic reviews,[91-94,96-99] the results from longitudinal studies of implant treatment outcomes in periodontitis patients need to be interpreted with caution due to their various methodological deficiencies such as the varied definition of the type and extent of periodontal disease, heterogeneity in the study design and clinical outcomes assessed, infection control performed, number of extracted teeth, and lack of accounting for confounding factors, such as smoking status of the patients.

Besides a direct link between tooth loss and implant loss (i.e., microbial load and oral hygiene), several mutual confounding factors for periodontitis and peri-implantitis have been identified, including smoking, uncontrolled diabetes, and genetic predisposition.[101] Among these, periodontal status and smoking are significant risk factors for late implant failures, as identified in a recent longitudinal study.[102] Additionally, local factors such as accessibility at the implant sites for oral hygiene appear to be related to the presence or absence of peri-implantitis.[103] Thus, the maintenance of periodontal health rather than a previous history of periodontitis is the critical determinant of increased risk of peri-implantitis.[104]

In two extensive literature reviews, Quirynen et al[101,105] noted that although slightly higher failure rates have been reported, implants in periodontally compromised partially edentulous patients can function successfully for longer periods of time in the presence of a strict supportive periodontal therapy program. Patients with aggressive periodontitis and/or with very rough implants (S_a values of $\geq$3 mm) appear to be more susceptible to peri-implantitis/late implant loss; however, longer-term studies, with follow-up periods of 10 years or more, are needed to validate these statements. For restoring partially edentulous patients by means of implants, it is

Table 2 Systematic reviews of implant-supported restorations in periodontitis patients

Author and year	Objectives	Results	Conclusions
Schou et al (2006)[91]	To assess whether individuals with previous tooth loss due to periodontitis have an increased risk of loss of suprastructures, loss of implants, peri-implantitis, and peri-implant marginal bone loss as compared with individuals with previous tooth loss due to reasons other than periodontitis	• Two studies with a 5- and 10-year follow-up, respectively, were identified including a total of 33 patients with tooth loss due to periodontitis and 70 patients with non-periodontitis-associated tooth loss • No significant difference in survival of the suprastructures after 5 years • No significant differences in survival of the implants after 5 and 10 years • Significantly more patients affected by peri-implantitis in group with periodontitis-associated tooth loss during the 10-year follow-up period, with risk ratio of 9 • Significantly increased peri-implant marginal bone loss observed in patients with periodontitis-associated tooth loss after 5 years, with mean difference of 0.5 mm	• Survival of the suprastructures and the implants was not significantly different in individuals with periodontitis-associated and non-periodontitis-associated tooth loss • However, significantly increased incidence of peri-implantitis and significantly increased peri-implant marginal bone loss were revealed in individuals with periodontitis-associated tooth loss • Small sample size and the methodological quality assessment of studies suggest that results should be interpreted with caution • Further long-term studies focusing particularly on outcome of implant treatment in young adults with aggressive periodontitis are needed before final conclusions can be drawn about outcome of implant treatment in patients with history of periodontitis
Klokkevold and Han (2007)[92]	To evaluate the available literature to assess whether smoking, diabetes, and periodontitis have an adverse effect on the outcomes of implants placed in patients with these conditions	• 13 articles identified for periodontitis • Periodontitis type (ranged from chronic to aggressive periodontitis) and severity (mentioned as 'advanced' to simply 'patients with periodontitis') varied widely in included studies • Pooled estimate of 95.0% implant survival for patients with a history of treated periodontitis compared to a pooled estimate of 97.1% implant survival for patients with periodontal health over a period of 36 to 120 months. Implant survival rate for patients with history of treated periodontitis compared favorably to implant survival rate observed in patients without a history of periodontitis. The difference in implant survival rate (3.14% better for periodontally healthy patients) was not statistically significant	History of treated periodontitis does not appear to adversely affect implant survival rates, but it may have a negative influence on implant success rates, particularly over longer periods

Continued.

Table 2 Continued.

Author and year	Objectives	Results	Conclusions
		• Pooled estimate for implant success of all patients with a history of treated periodontitis was 89.0% over a period of 12 to 120 months. Although this compares favorably to 89.2% pooled estimate for implant success in patients without a history of periodontitis, the difference in implant success rates (11.05% better for periodontally healthy patients) was statistically significant	
Karoussis et al (2007)[93]	To perform, applying a systematic methodology, a comprehensive and critical review of prospective studies regarding the short- (<5 years) and long-term (≥ 5 years) prognoses of osseointegrated implants placed in periodontally compromised partially edentulous patients	• Seven short-term and eight long-term prospective studies were identified addressing the prognosis of osseointegrated implants in partially edentulous patients with a history of treated periodontitis • Only three studies comprising patients treated for aggressive periodontitis were selected • Because of considerable discrepancies among these studies, meta-analysis was not performed	• No statistically significant differences in both short- and long-term implant survival exist between patients with a history of chronic periodontitis and periodontally healthy individuals. Patients with a history of chronic periodontitis may exhibit significantly greater long-term probing pocket depth, peri-implant marginal bone loss, and incidence of peri-implantitis compared with periodontally healthy patients • Even though the short-term implant prognosis for patients treated for aggressive periodontitis is acceptable, on a long-term basis the matter is open to question. Alterations in clinical parameters around implants and teeth in aggressive periodontitis patients may not follow the same pattern, in contrast to what has been reported for chronic periodontitis patients
Schou (2008)[94]	To assess the principles and outcome of implant treatment in periodontitis-susceptible patients	• 23 prospective and retrospective cohort studies were identified assessing Ti implant treatment (follow-up period >1 year and more than five patients in the study) in partially and totally edentulous individuals with a history of periodontitis-associated tooth loss • The survival rates of suprastructures and implants were high in individuals with a history of periodontitis-associated tooth loss • In most studies, the infection control performed, including the number of extracted teeth, was not reported in detail. Moreover, the health status of the periodontal tissues before implant treatment was also described infrequently. Finally, the smoking habits were not reported in most studies	• Implant treatment in periodontitis-susceptible patients is not contraindicated, provided adequate infection control and an individualized maintenance program • The higher incidence of peri-implantitis may jeopardize the longevity of the implant treatment

Continued.

Table 2 Continued.

Author and year	Objectives	Results	Conclusions
Al-Zahrani (2008)[95]	To critically review the available research on the survival of implants in patients with aggressive periodontitis	• Nine studies were found, four of which were clinical reports • In these studies, more than 158 implants were placed; only 12 failed • Collectively, the results of these studies support the use of implants in patients treated for aggressive periodontitis • Most patients in these studies were treated for several years before implants were placed	• Although available evidence is weak, it suggests good short-term survival of implants placed in periodontally well-maintained aggressive periodontitis patients • Bone loss around implants in aggressive periodontitis patients, however, appears to occur more frequently than it does in chronic periodontitis patients or periodontally healthy individuals
Ong et al (2008)[96]	To determine implant outcomes in partially edentulous patients who have been treated for periodontitis compared with periodontally healthy patients	• Nine studies were included • Non-periodontitis patients demonstrated better outcomes than treated periodontitis patients • Strength of evidence showed that included studies were at a medium to high risk of bias, with lack of appropriate reporting and analysis of outcomes plus lack of accounting for confounders, especially smoking • Studies showed variability in the definitions of *treated* and *non-periodontitis*, outcome criteria, and quality of supportive periodontal therapy • Meta-analysis could not be performed due to heterogeneity of the chief study characteristics	• There is some evidence that patients treated for periodontitis may experience more implant loss and complications around implants than non-periodontitis patients • Evidence is stronger for implant survival than implant success • Methodological issues limit the potential to draw robust conclusions
Renvert and Persson (2009)[97]	To review the literature regarding the possible association between a previous history of periodontitis and peri-implantitis	• Of 951 papers retrieved, only three were selected for inclusion. In these studies, total number of patients with and without previous history of periodontitis was 38 and 75, respectively • Combining data through a meta-analysis was not possible because studies were substantially heterogeneous. These studies had a limited number of patients, considerable variations in study design, different definitions of periodontitis, and no accounting of confounding variables like smoking • Implant patients with the history of periodontitis showed lower implant survival rates (91%–94%) compared to implant patients without this history (97%–100%)	Patients with the history of periodontitis might be at a greater risk for peri-implantitis, but the supporting data is not robust

Continued.

Table 2 Continued.

Author and year	Objectives	Results	Conclusions
Heitz-Mayfield and Huynh-Ba (2009)[98]	To evaluate a history of treated periodontitis and smoking, both alone and combined, as risk factors for adverse dental implant outcomes	• Considerable heterogeneity in study design was found, and few studies accounted for confounding variables • For patients with a history of treated periodontitis, majority of studies reported implant survival rates > 90% • Three cohort studies showed higher risk of peri-implantitis in patients with history of treated periodontitis compared with those without a history of periodontitis (reported OR from 3.1 to 4.7) • While the majority of studies reported implant survival rates ranging from 80% to 96% in smokers, most studies found statistically significantly lower survival rates than for non-smokers	• There is an increased risk of peri-implantitis in smokers compared with non-smokers (reported OR from 3.6 to 4.6). • The combination of a history of treated periodontitis and smoking increases the risk of implant failure and peri-implant bone loss
Safii et al (2010)[99]	To evaluate the risk for marginal bone loss around implants and implant failure in patients with a history of periodontitis compared with periodontally healthy patients in studies with a minimum 3-year follow-up	• Prospective and retrospective longitudinal observational clinical studies comparing periodontal/peri-implant variables among patients with periodontitis and periodontally healthy patients were included • Five studies were eligible for meta-analysis of implant survival, and four studies were eligible for meta-analysis of bone loss around implants • The OR (3.02) for implant survival was significantly in favor of periodontally healthy patients. • A random effects model showed more marginal bone loss in periodontitis patients compared with periodontally healthy patients (standard mean difference 0.61, 95% confidence interval 0.14–1.09).	Within the limitations of the heterogenous studies available, a moderate level of evidence indicates that periodontitis patients were at significantly higher risk for implant failure and greater marginal bone loss than periodontally healthy patients were

OR - odds ratio.

important to be aware of the relevance of (a) the periodontal health of the remaining dentition, which can interfere with osseointegration; (b) the intraoral translocation of periodontopathogens, which can jeopardize the long-term success of implants because of the similarity in microflora between periodontitis and peri-implantitis (in partially edentulous patients, microbes in periodontal pockets may act as a reservoir for colonization of the subgingival area around implants. Additionally, implants with peri-implantitis in partially edentulous patients have been demonstrated to more frequently harbor *Actinobacillus actinomycetemcomitans* [now *Aggregatibacter actinomycetemcomitans*], *Porphyromonas gingivalis*, and *Prevotella intermedia* as compared to successful implants[106]); and (c) implant surface roughness.[101]

Furthermore, longevity of dental implants hinges on the success of periodontal therapy and commitment to long-term supportive care by both the dentist and the patient.[103] Periodontal surgery should be considered as a means of eliminating or reducing residual probable pocket depths in patients who have unstable and progressing periodontal sites. A period of at least 3 to 6 months should elapse after active periodontal therapy before implant installation, depending on the specific circumstances of the patient in question.[107] After implant installation, a customized recall program (3–6 months interval), monitoring of peri-implant health, followed by Cumulative Interceptive Supportive Therapy (CIST) consisting of mechanical treatment (oral hygiene instructions and mechanical debridement), antiseptic treatment (chemical plaque control using 0.1–0.2% chlorhexidine digluconate mouthrinse, local application of 0.2% chlorhexidine gel, and/or local irrigation with 0.2% chlorhexidine), antibiotic treatment (systemic metronidazole, or a combination of amoxicillin and metronidazole and local application of antibiotics using a controlled-release device), and surgical treatment, for the prevention and treatment of peri-implantitis should be instituted.[107]

From the above discussion of tooth- and implant-supported restorations, it can be summarized that well-designed RDPs, used with meticulous periodontal care, are not likely to be detrimental to existing periodontal health. FDPs can be placed and successfully maintained on a minimal number of abutment teeth with greatly reduced periodontal support, if the prosthodontic treatment is

(a) preceded by adequate periodontal therapy and
(b) followed by a plaque control program that can prevent the recurrence of periodontal disease.[2]

If presumptive abutments are well-distributed and periodontal infection is under control, as little as 20% to 30% of the original periodontal tissue support can carry fixed cross-arch partial dentures.[2] Additionally, a systematic review by Lulic et al[90] has shown that proper control of periodontal disease, strict adherence to a maintenance care program, and rigid splinting of mobile abutment teeth yielded an estimated 10-year survival rate of 92.9% for FDPs incorporated in patients treated for generalized severe periodontitis, and hence substantially reduced periodontal tissue support. Moreover, in a 6-year report on the periodontal health of FDP and RDP abutment teeth, Rissin et al[108] concluded that there were minimal differences in longitudinal periodontal effects when FDPs and RDPs were compared with both treatment alternatives providing long-term periodontal health and thus should be considered for the restoration of a partially edentulous arch. Likewise, 5-year randomized controlled trials investigating the treatment outcomes between RDPs and FDPs (conventional and combined tooth-implant-supported) for mandibular Kennedy Class I and II patients showed similar periodontal conditions between the groups.[109-111]

In the case of implants, results from various literature and systematic reviews have shown that (a) implant treatment in periodontitis-susceptible patients is not contraindicated when there is adequate infection control and an individualized maintenance program,[94] (b) the periodontal status of patients who will receive the implant should first be stable,[107,112] and (c) treated periodontitis patients receiving periodontal supportive therapy can receive dental implants if there are no systemic contraindications for therapy. In these individuals, implants can be placed in native bone, grafted bone, or in a sinus that has been augmented with bone.[113] However, data on the survival rates of SCs and FDPs supported by implants in implant-supported restorations used for oral rehabilitation of partially edentulous periodontal patients are scarcely reported in literature and systematic reviews. In this regard, the literature search for the present review yielded a retrospective study[114] conducted to evaluate the biological and technical complication rates of FDPs with end abutments or cantilever extensions on (a) teeth, (b) implants, and (c) combined tooth-implant-supported, in patients treated for chronic periodontitis. The results showed that the probability of no complications and/or failure was 70.3%, 88.9%, and 74.7% in FDPs with end abutments, but only 49.8% to 25% in FDPs with extensions at 10 years. Additionally, incidence rates of any negative events were drastically increased in the three groups with cantilever extensions. Thus, the study concluded that in patients treated for chronic periodontitis and provided with metal-ceramic FDPs, high survival rates, especially for FDPs with end abutments, can be expected. If possible, extensions on tooth abutments should be avoided or used only after a cautious clinical evaluation of all options.[114]

Patient's preferences among tooth- and implant-supported restorations

Apart from deriving the evidence-based conclusions for oral rehabilitation of partially edentulous periodontal patients with tooth- and implant-supported restorations, another aspect addressed in the present review was the consideration of patient preferences (to discern tangible benefits) for these restorations. Addressing this issue, a study by Bassi et al[115] evaluated the possibility of replacing RDPs with FDPs on osseointegrated implants in a selective group of 40 patients with partially edentulous lower jaws. Of these 40 patients, 23 showed precarious oral hygiene, five refused the treatment (being satisfied with their RDP), six refused for economic reasons, three refused for fear and skepticism, one patient refused due to the long duration of therapy, and one patient was not treated because of a very marked atrophy of the alveolar crest. Finally, one patient was treated with implants. For these reasons, the authors concluded that implants are not an appropriate treatment to introduce into

large-scale public health programs, and RDPs must still be considered as a valid therapeutic procedure.[115]

More recent surveys[116,117] conducted for treatment preferences in partially edentulous patients have shown that although RDPs have unsatisfactory retention, they are preferred by older patients, as RDPs are associated with low cost and less complexity and time of treatment. FDPs are associated with high satisfaction rate (by both young and old age group patients) in terms of appearance, mastication, and speech.[116,117] Refusing FDPs is associated with the need for removal of the tooth structure, fear of a negative effect on the remaining teeth, and hygiene difficulties.[116] Implant-supported restorations are preferred by patients with higher education levels (especially young patients), and a significant aspect of patient satisfaction is the esthetic level.[116,117] Cost, desire for removability, complexity, time of treatment, and risk of problems during surgical procedures are variables that predict the refusal of an implant-supported restoration.[116]

In recent years, psychosocial outcomes (satisfaction and quality of life, QOL) of oral health and prosthodontic therapy have been studied. Oral health-related quality of life (OHQOL) is the part of QOL affected by a person's oral health, that is, how oral health affects the person's ability to function (bite, chew, speak), psychological states (self-esteem and satisfaction with appearance), social factors, and pain/discomfort related to oral health.[118] There is a dearth of literature on the effect of conventional FDP treatment on OHQOL.[118] Implant therapy has been shown to have a positive effect on the OHQOL[119] and in patients with implant-supported FDPs, OHQOL is less impaired as compared to that in patients with RDPs.[120]

Collectively, it seems that advantages, disadvantages, and the cost of treatment are the factors governing the choice of restoration for rehabilitation of partially edentulous patients, thus ruling out superiority of any of the restorations. Furthermore, the patient-centered outcome measures of various tooth- and implant-supported restorations (in terms of effect on OHQOL) need to be further investigated to derive any conclusive statements.

Conclusions

Periodontitis is a microbial infection responsible for most tooth loss globally. Oral rehabilitation of a periodontally compromised partially edentulous patient requires special attention, considering the reduced periodontal support around the prospective abutment teeth and possible transmission of periodontal pathogens from teeth to implants, which may affect the long-term survival and success of the prosthodontic treatment performed. Also, the decision to use either implant- or tooth-supported restorations needs to be based on the available scientific evidence, operator's skill/experience, and oral and systemic conditions, including patient preference. The present review attempted to search through literature to derive evidence-based conclusions for oral rehabilitation of periodontally compromised partially edentulous patients with traditional tooth-supported and implant-supported restorations. Within the limitations of the reviewed literature and the methods of evaluation, the following evidence-based conclusions can be drawn:

- With their own individual indications and reported advantages, conventional tooth-supported RDPs and FDPs can fail due to technical or mechanical complications, but the incidence of complications is less than with implant-supported restorations.
- In the absence of systematic reviews, limited evidence suggests that with design modifications and strict oral hygiene measures, RDPs may be used in periodontal patients.
- Evidence in the form of both systematic reviews and literature reviews based on the number of longitudinal studies indicates that FDPs are a viable treatment option with high survival rates in periodontal patients, but need to be preceded by a thorough periodontal maintenance program.
- Ample evidence in the form of numerous systematic reviews indicates a high long-term survival rate of implants in implant-supported restorations in periodontitis patients, especially after adequate infection control and an individualized maintenance program; however, minimal information is available for the long-term survival rates of FDPs and SCs supported by implants in periodontitis patients.
- Little is known about patient preferences for conventional and implant-supported restorations and the effect of these restorations on OHQOL. The few available studies have shown that: patients (especially the elderly) prefer conventional RDPs for low cost, less complexity and time of treatment despite their unsatisfactory retention; conventional FDPs provide a high level of satisfaction to patients; and, although implant-supported restorations provide higher esthetic satisfaction, the high cost, desire for removability, complexity, time of treatment, and surgical risks limit their wide acceptance among patients.

In the present review, most of the quantitative information available to derive the above evidence-based conclusions was based on the survival and complication rates of the restorations, as a result of the limited data regarding patient-centered outcomes and OHQOL. To derive more concrete conclusions than those described by the present review regarding the prosthodontic rehabilitation of periodontal patients, a need exists for standardization among the studies of tooth- and implant-supported restorations with respect to treatment protocol and research methodology as well as a necessity for long-term clinical trials to evaluate and compare the conventional tooth- and implant-supported restorations with regard to survival rates, cost, maintenance, and patient-centered outcomes.

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