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Treatment Options for the Replacement of Missing Mandibular Incisors

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Abstract

The replacement of a mandibular incisor is a dental treatment warranting special consideration. Some of the challenges associated with the anterior mandible are limited space, challenging surrounding anatomy, and tough esthetic requirements. Proper diagnosis and treatment planning may require a multidisciplinary approach to successfully meet the demands of replacing a missing tooth in this sextant. Several treatment options currently exist for mandibular incisor replacement. These options include (1) resin-bonded fixed dental prostheses (RBFDPs), (2) orthodontic treatment, (3) full-veneer fixed dental prostheses (FDPs), (4) dental implants for single-tooth replacement, (5) possible extraction of one or more incisors and restoration with implant-supported FDPs, (6) possible extraction of one or more teeth and restoration with FDPs from #22 to 27, (7) possible extraction of one or more teeth and restoration with removable dental prostheses (RDPs). This manuscript outlines the various treatment options for the replacement of mandibular incisors and discusses benefits and drawbacks of each.

The replacement of a mandibular incisor is a reasonably common dental need warranting special consideration. Some of the challenges associated with the anterior mandible are limited space, challenging surrounding anatomy, and potentially tough esthetic requirements. Proper diagnosis and treatment planning may require a multidisciplinary approach to successfully meet the demands of replacing a missing tooth in this sextant.

A missing mandibular incisor can be caused by dental trauma, congenital conditions, caries, periodontal disease, restoration requirements, and failed dental treatments. Patients usually desire replacement of the missing tooth due to esthetic demands. As we age, the amount of mandibular incisor display increases.[1,2] In addition, supraeruption of the mandibular incisors, and possibly the gingival complex, makes these teeth potentially more of an esthetic issue for patients.

Several treatment options currently exist for mandibular incisor replacement. These options include (1) resin-bonded fixed dental prosthesis (RBFDP), (2) orthodontic treatment, (3) full-veneer fixed dental prosthesis (FDP), (4) dental implant for a single tooth replacement, (5) extraction of one or more incisors and restoration with an implant-supported FDP, (6) extraction of one or more teeth and restoration with an FDP from # 22 to 27, (7) extraction of one or more teeth and restoration with a removable dental prosthesis (RDP).

To date, no manuscript can be found outlining the range of possible treatments for the replacement of mandibular incisors. The purpose of this article is to outline the various treatment options for the replacement of mandibular incisors and discuss benefits and drawbacks of each.

The RBFDP

The RBFDP has been regarded as a suitable form of dental treatment to restore edentulous tooth spaces.[3-5] The two main philosophies for this type of restoration are as follows: 1. No preparation of abutment teeth with the FDP relying solely on bonding for resistance and retention; 2. Judicious abutment tooth preparations in enamel for resistance and retention form. When comparing the two philosophies, significant differences in the longevity of these restorations exist.[6-8]

Indications for RBFDPs include vital and minimally restored abutment teeth, short edentulous spans (Fig 1), and minimal

dynamic occlusal contacts on abutment teeth.[9,10] The desire to conserve tooth structure is also an indication and a benefit. The condition of abutment teeth is critical to RBFDP restoration. Conditions that significantly reduce success rates are as follows: differences in abutment tooth mobility, the method of bonding (i.e., Silicoating), and the number of units.[3,5] Contraindications to this form of treatment include severely tipped or malaligned teeth and lack of adequate enamel for bonding.

If this form of treatment is chosen, it is recommended that judicious preparations in enamel be completed.[11] Preparations to improve retention and resistance form, such as proximal grooves, definitive occlusal stops, and/or staples placed in enamel, increase surface area for bonding and mechanically resist dislodging forces applicable to the prosthesis. In addition, diagnostic casts should be used to plan the extent and location of retainer coverage. A fast-setting impression material (i.e., fast-set alginate) is necessary to create a verification cast. Rapidly setting vinylpolysiloxane die material such as Mach 2® (Parkell, Inc., Edgewood, NY) can be used instead of stone. The cast can then be placed on a dental surveyor to ensure all elements of resistance and retention form draw and will function as intended by the dentist. The use of a verification cast will save costly lab remakes and lost production time.

A number of different alloys are used for metal-ceramic (MC) RBFDPs. Today, due to low cost and rigidity of the alloy, many of the MC RBFDPs are fabricated using base-metal alloys. The longevity and proven success for MC RBFPDs make them a suitable treatment option[12-14] (Fig 2). Design of the retainers is critical, as the metal may have an increased negative effect on abutment tooth translucency if the metal is carried too far incisally.

The use of zirconia as a framework for RBFDPs is increasing. Zirconia is a polycrystalline ceramic absent of silica glass. Traditional etching with hydrofluoric acid followed by application of a silane primer does not work, because zirconia does not contain silica glass (unlike most bondable ceramics on the market).[15-17] Recently, material manufacturers have introduced zirconia bonding agents.[18] However, randomized controlled clinical trials or reports have not been conducted as of the writing of this article. Studies have shown favorable short-term results using silicoating, such as Rocatec (3M ESPE, St. Paul, MN) or CoJet (3M ESPE) to allow resin bonding of the zirconia framework.[19-21] Although a suitable method to achieve zirconia bonding, abrasion of the surface causes a phase transformation from the tetragonal form of zirconia to the monoclinical, thus potentially weakening the material. This effect may not be clinically significant, as few in vivo zirconia framework fractures have been reported in the literature.[22,23]

RBFPDs may be designed to accommodate one or more abutment teeth. MC and all-ceramic RBFDPs with a two-abutment design have been successfully used.[12-14,24] Komine and Tomic provided a clinical report of the restoration of a single mandibular central incisor with a single retainer zirconium dioxide-based RBFDP with clinical success at 2.5 years.[21] Other papers have also reported the use of cantilevered all-ceramic RBFPDs.[25,26] In vitro testing showed an increased risk for zirconia retainer fracture and debonding when a cantilevered design was used.[27]

Orthodontic treatment

Mandibular incisor crowding is a common clinical presentation. The loss of a single mandibular incisor may provide the necessary space to orthodontically reposition the remaining incisors to an esthetically pleasing arrangement. A spatial analysis with a diagnostic set-up such as a Kesling set-up should be accomplished to determine available space and may also serve as a patient education model. A Kesling set-up is performed by sectioning the orthodontically involved teeth from the cast and rearranging them in wax to the desired completed treatment position. In addition to spatial relationships, functional consequences of the orthodontic treatment should be evaluated. If a laboratory bill or additional lab time is not desired, Sandler et al recommend a technique for the fabrication of a photographic Kesling set-up,[28] although it may not allow for the evaluation of occlusion and articulation.

A combination of orthodontic treatment and additive composite resin material or ceramic veneers is another option to close minimal spacing that may result from a more aligned tooth position. The diagnostic waxing or Kesling set-up mentioned previously will provide the dentist and patient with a visual representation of expected outcome.

Full-veneer FDP

One of the most challenging aspects of the mandibular incisor replacement is available space. The average width of a mandibular central incisor at its mesial-distal height of contour is 5.3 mm and cervically it is 3.5 mm.[29] Most materials used for FDPs require a minimum of approximately 1 to 1.5 mm of axial reduction on the abutment teeth, whether they are MC or all-ceramic restorations.

Due to the limited space available for adequate reduction, preparation of abutment teeth may involve pulpal tissue, therefore requiring root canal therapy. Endodontic treatment creates additional complications for the proposed restoration. These complications include a possible lack of ferule and less than 1 mm dentinal thickness surrounding the dowel and core system.[30-32] The alternative to proper reduction for restorative materials and possible endodontic treatment is under-reduction. Under-reduction has potential complications, to include poor prosthetic contours, decreased esthetic results, and potential hygiene problems if over-bulked[33] (Fig 3). When restorations of any kind are performed, we must realize that the purpose of the restoration is to replace what was lost (a physiologically formed tooth) and restore proper function and esthetics to the oral organ. Under-reduction makes it difficult to achieve these goals.

Finally, if the endodontic status of the abutment teeth is in question, the dentist may determine (based on the previously mentioned information) that the adjacent incisors are not suitable abutment teeth. If this is the case, the other treatment options presented later in this manuscript should be considered. If endodontic treatment is completed and a dowel and core system is required, then conservation of dentin and cast dowel and cores (or dowel systems with morphologic design) are recommended.[31] Sorensen and Martinoff[34] reported that close dowel adaptation caused more catastrophic failures; however, studies

Figure 1 Limited restorative space is present for edentulous site # 25.

Figure 3 Full-veneer FDP with incisors as abutment teeth. Notice the over-contoured ceramic and gingival inflammation.

completed after this report stated that 44% of the dowels in their study did not meet cast dowel and core design recommendations.[35] Later in vivo retrospective studies reported success rates greater than 90% when using custom cast dowels.[36] In an in vivo clinical study with cast dowel and core systems, Salvi et al reported an adjusted 5-year survival rate of 97.1%.[37] As always, the preservation of remaining tooth structure is vital to the successful restoration of an endodontically treated tooth.

Dental implant (endosseous root form) for single-tooth replacement

Many factors must be considered to ensure clinical success when planning dental implant placement. Dental implants are restoration based; therefore, the primary concern is restorative space, esthetic outcome, and long-term restoration of function. Other important considerations are surgical in nature, such as quality and quantity of available bone or the position of the adjacent roots. It is essential to note that the fruits of successful implant planning are not found in well-integrated endosseous implants alone; true implant success is only manifested in restorations that are functional, esthetic, and stable over time.

One of the first considerations in implant planning is the available bone at the edentulous site. Available bone for implant placement is often limited due to dental trauma, a result of periodontal disease, loss during extraction, or loss due to resorption over time following extraction. Often, grafting procedures can be accomplished if the patient desires this form of treatment. The natural anatomy of the alveolar bone in a buccolingual dimension may also limit available bone for implant placement; however, most bone level implant systems require proper depth for emergence profile of the restoration. This correct implant depth may be at a level that coincidentally has enough available buccolingual dimension.

In addition to the amount of available bone, the practitioner must be aware of other anatomical restrictions that may prevent successful restoration. These include reduced interradicular space for single or multiple implant placement and crowding or proximity of neighboring teeth.[38] Convergence of the adjacent tooth roots is a relative contraindication for implant placement. If the adjacent roots are not parallel or divergent to the proposed implant position, orthodontic movement or extraction may be required to create adequate interradicular space.

Figure 2 Full smile view of a patient with missing #25 restored with a PFM RBFDP.

Figure 4 An implant-supported all-ceramic crown with nonphysiologic contour due to the width of the implant and restorative components. A deficiency in the interdental papillae is also present adjacent to the restoration.

The fact that a narrow-diameter implant *can* fit in a given space, does not necessarily mean that it *should* be placed. A minimum of 1 mm of bone on either side of the implant shoulder is recommended to maintain the current osseous position and interdental papilla.[39] One report states that if tooth-to-implant distance was less than 3 mm, a papilla was absent 100% of the time.[40] This dimension poses a major problem for most narrow-platform endosseous root form implants. The Nobel Biocare NP Replace Select (Nobel Biocare, Yorba Linda, CA) and Biomet 3i Certain MicroMini (BIOMET 3i, Palm Beach Gardens, FL) implant have platform widths of 3.5 and 3.4 mm, respectively. Therefore, if a 3.5 mm implant is used, a minimum of 5.5 mm of interradicular space at the coronal aspect is required to maintain a 1 mm collar of bone. It has been the experience of these authors that less than 5.5 mm of space is often observed. In addition, setting the minimum requirements as a standard for dental treatment decreases prosthetic recovery from malplacement and leaves little room for complications.

Once it is determined that the bone is of adequate dimension, it is still critical to evaluate if a restoration will be successful, or even feasible at that location. This requires consideration from both a materials perspective as well as an anatomic perspective. The average width of a mandibular central incisor, as stated previously, is 5.3 mm at the height of contour and 3.5 mm cervically.[29] This extremely small spacing creates several restorative challenges and limitations. Regardless of the type of abutment selected (i.e., stock vs. custom abutment), it can be difficult to create a healthy emergence profile that mimics the adjacent natural teeth (Fig 4). An additional limitation comes from the space requirements for the materials used. With such limited space available, adequate thickness for esthetic ceramic systems may not be possible. Therefore, if a screw-retained restoration was fabricated, it would only allow a maximum of 0.9 mm for veneering porcelain. A cement-retained implant crown would require an additional 0.3 mm for the crown coping material, leaving only 0.6 mm for porcelain. The inadvertent result of inadequate room for these restorative materials is either a restoration that is over-contoured, and therefore unhealthy for the surrounding tissues, or one that is opaque and unesthetic. Implant systems are available with differing dimensions; therefore, it is the restorative dentist's responsibility to dictate implant sizes prior to placement and understand the implant system being used.

Finally, the predictability of gingival esthetics is less consistent than implant survival.[41,42] The change in position, or lack thereof, of the gingival tissue facial to dental implants in the anterior maxilla is well reported in the literature; however, the lack of studies in the anterior mandible makes this outcome more questionable. Depending on the patient, gingival esthetics in the anterior mandible may or may not be an issue.[41] As we age, however, mandibular anterior tooth display increases[1,2] along with the esthetic demands of this aging patient population. Ideal implant placement in three dimensions is required for an optimum esthetic outcome[43] (Fig 5). Due to the potential negative esthetic consequences, the next treatment option may be considered.

Extraction of one or more incisors and restoration with an implant-supported FDP

Often the condition of adjacent mandibular incisors is compromised by extensive restoration, less-than-ideal endodontic treatment, mobility, and bone loss secondary to trauma or periodontal disease. In addition, occasionally the adjacent teeth are excessively worn and supraerupted, carrying the gingival-alveolar complex with them. Crown lengthening for esthetics and prosthetic retention can make tooth preparation challenging due to the narrowing of the teeth from the incisal to the apical portion. Orthodontic intrusion or segmental osteotomy can be considered, but may not be desired by the patient. Considering all factors, extraction of one or more incisors may be necessary to restore the teeth in question. This is often a confusing and jarring realization for the dentist and patient alike. Prior to proposing this form of treatment, a thorough understanding of the prosthetic treatment, end result, limitations, esthetic outcome, and esthetic complications should be known by the dentist to ensure a confident treatment plan delivery and to avoid potential posttreatment regret by the patient. If this extensive knowledge is not present, the dentist may wish to consult with or refer to a prosthodontist to avoid potential unpleasant consequences and patient relationships.

If two adjacent mandibular incisors are missing, enough space may be present to position a single endosseous implant and restore the teeth with a cantilevered implant restoration or bifurcated custom abutment supporting two crowns. Assuming there is adequate bone volume and spacing to correctly position the dental implant, single tooth replacement may be possible. Implant position is critical to esthetic outcome, as it has been reported by Buser et al[43] and Cordaro et al[44] that a worse, but still acceptable (by the patient) result was achieved when two adjacent implants were present. In addition, Cordaro et al reported a variation in esthetic outcome depending on the type of restoration provided.

Extraction of all remaining mandibular incisors creates the possibility for an implant-supported FDP to replace the incisor teeth. Dental implants can be placed at the #23 and #26 sites or at approximately the #24 and 25 sites. Based on spacing recommendations previously mentioned, 15 mm of edentulous space should be present to allow for proper maintenance of proximal bone between implants (using 4.1 mm diameter implants) and teeth and implants. If interdental spacing allows, more than two implants may be desired to restore this edentulous anterior segment (Fig 6).

Recently, there has been a large marketing push to use dental implants <3 mm in diameter for definitive restorative purposes. Although these implants have been available for some time, their efficacy for definitive purposes is not very well documented. The only reports available place the restorations out of occlusion or provide no qualifying data for "optimal occlusion."[45,46] Lack of occlusion may be acceptable for a single tooth when adjacent teeth can maintain proper oral function; however, the replacement of an entire segment of the mouth (anterior mandible) without function is simply cosmetic and not restorative dentistry. In addition, if adequate space is present

Figure 5 Adequate spacing is available for the implant crown, but the implant was placed too shallow. Coupled with potentially unpredictable gingival margin position, this result may be considered a prosthetic failure. The photograph was made the day of crown # 23, 24, 25 cementation, explaining the erythematous gingiva surrounding crowns #23 and 25.

for multiple mini implants, a prudent clinician not conducting experimental research may want to consider other implant-supported treatment options. Froum et al most appropriately stated that mini dental implants require additional multicenter prospective longitudinal studies to evaluate their long-term use.[47]

Extraction of one or more teeth with a conventional FDP

If the aforementioned unfavorable clinical presentations are present with regard to the remaining mandibular incisors, and extraction is indicated, another treatment option is the conventional full-veneer FDP from #22 to 27. If both central incisors are missing, it is not recommended to use #22, 23, 26, or 27 as abutments. Double abutting of teeth greatly increases the complexity of the preparations due to path of draw requirements and can be more difficult to fabricate in a laboratory to accurately fit all retainers. In addition, the mandibular incisors are at risk for

Figure 6 Mandibular incisors restored with a three-implant supported FDP. Due to excessive restorative space, the patient was restored with five incisors.

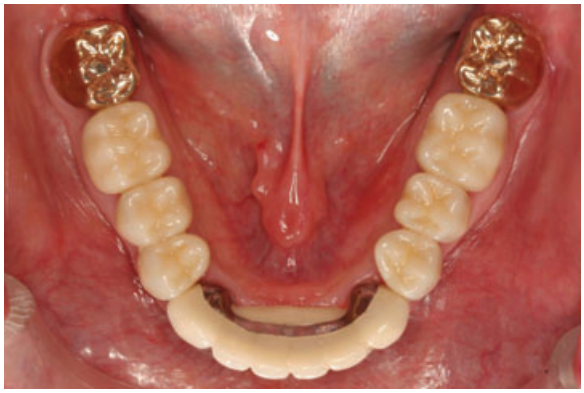

Figure 7 FDP from #22 to 27 showing the anterior-posterior spread to be no greater than the width of the abutment teeth.

underreduction, causing the laboratory to overbulk the lateral incisor retainer, making oral hygiene very challenging for the patient. Finally, the mandibular incisors play a different role in the mouth than the canines do and withstand forces of different magnitude and vector. It is the opinion of these authors not to use double abutments.

For this treatment to have long-term success several criteria must be met. First, analysis of the patient's occlusion, smile, esthetic index, oral hygiene, motivation for dental treatment, and manual dexterity should be determined prior to proposing an FDP from #22 to 27.

Second, the anterior–posterior spread of the pontics should not be wider than the width of the abutment support[48] (Fig 7). We typically think of cantilevers being present where there is no distal or mesial retainer adjacent to a pontic; however, potentially destructive class 1 lever forces can be present if excessive distance is present between the abutment teeth and the pontic teeth set on a curve. Therefore, patients who present with a square-shaped arch form[49] are ideal for this form of treatment. If anterior–posterior spread is in question, a diagnostic waxing should be accomplished to determine feasibility of the restoration. When the abutment teeth are prepared, the reduction should be accomplished using reduction guides based on

Figure 8 PFM FDP demonstrating predictable gingival esthetics and adequate connector height.

the diagnostic waxing. Once the dentist feels that the preparations are completed, a fast-set impression should be made, and a verification cast poured to check the path of draw on a dental surveyor. Due to the differing magnitude and direction of forces placed upon the FDP,[50,51] these authors recommend that additional features of resistance and retention form be added to the abutment preparations. Even in this age of adhesive dentistry, retention of restorations of this nature should not be left solely up to the cement. Cements degrade over time, and successful dentin bonding is not universal to all practitioners or adhesive systems.[52]

Third, the connector dimension is often favorable in the absence of excessively short mandibular canines. The amount of gingival and osseous remodeling following mandibular incisor extraction can be a positive contributing factor for additional connector height. Furthermore, connector height is more important for connector rigidity than connector width.[53]

Often, this treatment option can meet several preferences for dental treatment. If the teeth are prepared just before extraction, an interim restoration can be fabricated and cemented directly after the extractions are completed. With proper pontic design (convexity in all directions and highly polished),[54] the restoration can be cleansable and esthetic, and tissue shaping can occur during healing. In addition to esthetics and tissue contour, the restoration also prevents loss of patient function.

Lastly, the conventional FDP provides a more predictable esthetic result with regard to the gingival tissues (Fig 8). Since natural teeth serve as the abutments, the gingival esthetics can be more predictable with proper tissue management. This is not to say that gingival esthetics are always unfavorable with regard to implant restorations. Reasonable gingival stability is reported in the literature with regard to implant restorations; however, implants are not teeth. Therefore, if esthetics are a primary concern and the above criteria have been met, a conventional full-veneer FDP from #22 to 27 may be the best treatment option for the patient.

The material choice for the FDP is practitioner dependent, but should be based on the functional demand of the restoration, patient occlusion, and esthetic potential. These authors, recommendation and opinion is to use a metal framework when restoring this area. With proper reduction and an experienced laboratory technician, good esthetics can be achieved with MC restorations. The cost of replacing multiple failed restorations is great in a monetary sense to the dentist and may have a negative impact on patient confidence.[55]

Extraction of one or more teeth and treatment with an RDP

Finally, if the remaining teeth are to be extracted and the patient presents with a history of poor oral hygiene, the need to replace large amounts of missing tissue, the lack of motivation in their dental treatment, poor manual dexterity preventing them from adequately cleaning the teeth/elaborate prosthetics, or has limited finances, an RDP may be the treatment of choice. Unfortunately, RDP treatment is viewed by some clinicians as a second-tier treatment when it is simply another tool in our dental toolbox. These authors have observed that when a patient is unsatisfied with an existing RDP it is because of poor treatment execution, poor lab work, or both.

Several design features may provide a very esthetic outcome with regard to the RDP. First, adequate guiding planes and rest seats should be present on #22 and #27. The guiding planes assist with resistance and retention form and decrease the "dead space" between the acrylic flange and the abutment tooth. Next, more advanced design concepts, such as the Twin-Flex clasp or a rotational path RDP, can be employed. These authors' RDP philosophy (broad stress distribution) is to use a cast metal framework; however, if this is not desired, an acrylic resin RDP or Valplast® (Valplast International Corp., Long Island City, NY) RDP can be fabricated.

Conclusion

In summary, the replacement of mandibular anterior teeth is a complex process, which often requires multidisciplinary or multispecialty care. A thorough assessment of the patient, clinical knowledge of treatment options, patient medical history, dental history, occlusion, and patient desire must all be appropriately considered in planning for and accomplishing successful restoration of missing teeth in the anterior mandible.

References

1. Sackstein M: Display of mandibular and maxillary anterior teeth during smiling and speech: age and sex correlations. Int J Prosthodont 2008;21:149-151
2. Vig RG, Brundo GC: The kinetics of anterior tooth display. J Prosthet Dent 1978;39:502-504
3. Ketabi AR, Kaus T, Herdach F, et al: Thirteen-year follow-up study of resin-bonded fixed partial dentures. Quintessence Int 2004;35:407-410
4. Hussey DL, Linden GJ: The clinical performance of cantilevered resin-bonded bridgework. J Dent 1996;24:251-256
5. Pröbster B, Henrich GM: 11-year follow-up of resin bonded fixed partial dentures. J Prosthet Dent 1997;10:259-268
6. Rammelsberg P, Pospiech P, Gernet W: Clinical factors affecting adhesive fixed partial deentures: a 6 year study. J Prosthet Dent 1993;70:300-307
7. De Kanter RJ, Creugers NH, Verzijden CW, et al: A five-year multipractice clinical study on posterior resin-bonded bridges. J Dent Res 1998;77:609-614
8. Behr M, Leibrock A, Stich W, et al: Adhesive-fixed partial dentures in anterior and posterior areas. Results of an on-going prospective study begun in 1985. Clin Oral Investig 1998;2:31-35
9. Hagiwara Y, Matsumura H, Tanaka S, et al: Single tooth replacement using a modified metal ceramic resin bonded fixed partial denture: a clinical report. J Prosthet Dent 2004;91:414-417
10. Barrack G: Recent advances in etched cast restorations. J Prosthet Dent 2005;93:1-7
11. Simon J, Gartrell RG, Grogono A: Improved retention of acid-etched fixed partial dentures: a longitudinal study. J Prosthet Dent 1992;68:611-615
12. Corrente G, Vergnano L, Re S, et al: Resin bonded fised partial dentures and splints in periodontally compromised patients: a 10 year follow-up. Int J Periodontics Restorative Dent 2000;20:628-636
13. Zalkind M, Ever-Hadani R, Hochman N: Resin-bonded fixed partial denture retention: a retrospective 13-year follow-up. J Oral Rehabil 2003;30:971-977

14. Creugers NH, Van't Hof MA: An analysis of clinical studies on resin bonded bridges. J Dent Res 1991;70:146-149
15. Blatz MB, Sadan A, Kern M: Resin-ceramic bonding: a review of the literature. J Prosthet Dent 2003;89:268-274
16. Borges GA, Sophr AM, de Goes MF: Effect of etching and airborne particle abrasion on the microstructure of different dental ceramics. J Prosthet Dent 2003;89:479-488
17. Della Bona A, Anusavice KJ, Shen C: Microtensile strength of composite bonded to hot-pressed ceramics. J Adhes Dent 2000;2:305-313
18. Suh BI, Chen L, Brown DJ: Bonding to zirconia: innovation in adhesion. Compend Contin Educ Dent 2010;31(Special Issue 1):2-7
19. Bottino MA, Valandro LF, Scotti R, et al: Effect of surface treatments on resin bond to zirconium-based ceramics. Int J Prosthodont 2005;18:60-65
20. Qeblawi DM, Muñoz CA, Brewer JD, et al: The effect of zirconia surface treatment on flexural strength and shear bond strength to a resin cement. J Prosthet Dent 2010;103:210-220
21. Komine F, Tomic M: A single-retainer zirconium dioxide ceramic resin bonded fixed partial denture for single tooth replacement: a clinical report. J Oral Sci 2005;47:139-142
22. Beuer F, Edelhoff D, Gernet W, et al: Three-year clinical prospective evaluation of zirconia-based posterior fixed dental prostheses (FDPs). Clin Oral Investig 2009;13:445-451
23. Al-Amleh B, Lyons K, Swain M: Clinical trials in zirconia: a systemic review. J Oral Rehabil 2010;37:641-652
24. Turker SB, Guvenli SY, Arikan A: Replacement of two mandibular central incisors using a zirconium resin-bonded fixed partial denture: a clinical report. J Prosthet Dent 2005;94:499-503
25. Kern M, Glaser R: Cantilevered all-ceramic resin bonded fixed partial dentures: a new treatment modality. J Esthet Dent 1997;9:255-264
26. Koutayas SO, Kern M, Ferraresso F, et al: Influence of framework design on fracture strength of mandibular anterior all-ceramic resin bonded fixed partial dentures. Int J Prosthodont 2002;15:223-229
27. Rosentritt M, Ries S, Kolbeck C, et al: Fracture characteristics of anterior resin-bonded zirconia-fixed partial dentures. Clin Oral Investig 2009;13:453-457
28. Sandler J, Sira S, Murray A: Photographic 'Kesling set-up'. J Orthod 2005;32:85-88
29. Woelfel JB, Scheid RC: Dental Anatomy, Its Relevance to Dentistry (ed 5). Baltimore, Williams and Wilkins, 1997
30. Joseph J, Ramachandran G: Fracture resistance of dowel channel preparations with various dentin thickness. Fed Oper Dent 1990;1:32-35
31. Gluskin AH, Radke RA, Frost SL, et al: The mandibular incisor: rethinking guidelines for post and core design. J Endod 1995;21:33-37
32. Kivanc BH, Alacam T, Ulusoy OI, et al: Fracture resistance of thin-walled roots restored with different post systems. Int Endod J 2009;42:997-1003
33. Youdelis R, Weaver J, Sapkos S: Facial and lingual contours of artificial complete crown restorations and their effects on the periodontium. J Prosthet Dent 1973;29:61-66
34. Sorensen JA, Martinoff JT. Clinically significant factors in dowel design. J Prosthet Dent 1984;52:28-35
35. Morgano S, Milot P: Clinical success of cast metal posts and cores. J Prosthet Dent 1993;70:11-16
36. Weine FS, Wax AH, Wenckus CS: Retrospective study of tapered, smooth post systems in place for 10 years or more. J Endod 1991;17:293-297
37. Salvi GE, Siegrist Guldener BE, Amstad T, et al: Clinical evaluation of root filled teeth restored with or without post-and-core systems in a specialist practice setting. Int Endod J 2007;40:209-215
38. Belser UC, Mericske-Stern R, Bernard JP, et al: Prosthetic management of the partially dentate patient with fixed implant restorations. Clin Oral Impl Res 2000;4:87-97
39. Buser D, von Arx T: Surgical procedures in partially edentulous patients with ITI implants. Clin Oral Implants Res 2000;11(Suppl 1):83-100
40. Gastaldo JF, Cury PR, Sendyk WR: Effect of the vertical and horizontal distances between adjacent implants and between a tooth and an implant on the incidence of interproximal papilla. J Periodontol 2004;75:1242-1246
41. Smith, RB, Tarnow DB, Brown M, et al: Placement of immediate imiplants and a fixed provisional restoration to replace the four mandibular incisors. Compend Cont Ed 2009;30: 408-416
42. Small PN, Tarnow DP: Gingival recession around implants: a 1-year longitudinal prospective study. Int J Oral Maxillofac Implants 2000;15:527-532
43. Buser D, Martin W, Belser UC: Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. Int J Oral Maxillofac Implants 2004;19(Suppl):43-61
44. Cordaro L, Torsello F, Torresanto VMD, et al: Retrospective evaluation of mandibular incisor replacement with narrow neck implants. Clin Oral Impl Res 2006;17:730-735
45. Flanagan D: Immediate placement of multiple mini dental implants into fresh extraction sites: a case report. J Oral Implantol 2008;34:107-110
46. Vigolo P, Givani A: Clinical evaluation of single-tooth mini-implant restorations: a five year retrospective study. J Prosthet Dent 2000;84:50-54
47. Froum SJ, Cho SC, Cho YS, et al: Narrow-diameter implants: a restorative option for limited interdental space. Int J Periodontics Restorative Dent 2007;27: 449-455
48. Shillingburg HT: Fundamental of Fixed Prosthodontics (ed 3). Carol Stream, IL, Quintessence, 1997, pp. 95-118
49. House M: The relationship of oral examination to dental diagnosis. J Prosthet Dent 1958;8:208-220
50. Jacobi R, Shillingburg H, Duncanson M: Effect of abutment mobility, site, and angle of impact on retention of fixed partial dentures. J Prosthet Dent 1985;54:178-183
51. Smyd ES: Advanced thought in indirect inlay and fixed bridge fabrication. J Am Dent Assoc 1944;31:759-768
52. De Munck J, Van Landuyt K, Peumans M, et al: A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res 2005;84:118-132
53. Smyd ES: Mechanics of dental structures: guide to teaching dental engineering at undergraduate level. J Prosthet Dent 1952;2:668-692
54. Stein RS: Pontic-residual ridge relationship: a research report. J Prosthet Dent 1966;16:251-285
55. Spear FM: The risk of the metal-free practice! J Esthet Restor Dent 2009;21:71-74