ENDOSTEAL IMPLANTS FOR POSTERIOR SINGLE TOOTH REPLACEMENT: ALTERNATIVES, INDICATIONS, CONTRAINDICATIONS, AND LIMITATIONS

Carl E. Misch, DDS, MDS

Patients frequently need treatment to replace single teeth in the posterior regions. A number of different kinds of therapy have been used to treat this problem, including (1) removable partial denture, (2) acid-etched resin-retained prosthesis, (3) maintenance of the missing space, (4) a fixed partial denture, or (5) an implant-supported prosthesis. The purpose of this article is to assess the strengths and weaknesses of each of these treatments. The author concludes that single tooth implants are generally the best choice for dealing with a missing single tooth in the posterior regions of the mouth.

INTRODUCTION

The posterior regions of the mouth often require the replacement of a single tooth. The first molars are the first permanent teeth to erupt in the mouth and unfortunately are often the first teeth to be lost as a result of decay. They are important teeth for maintenance of the arch form and for proper occlusal schemes. In addition, the adult patient often has one or more crowns, as a consequence of previous larger restorations required to restore the integrity of the tooth. Longevity reports of crowns have yielded very disparate results. The mean life span at failure has been reported to be 10.3 years.¹ Other reports range from a 3% failure rate at 23 years to a 20% failure rate at 3 years.²,³ The primary cause of failure of the crown is caries and/or endodontic therapy⁴–⁷ (Fig 1). The tooth is at increased risk for extraction as a result of these complications, which are a leading cause of single posterior tooth loss in the adult. It has been estimated that a $425 crown for a 22-year-old patient will cost $12,000 during the patient's lifetime to replace and/or repair.⁵,⁶

As a consequence of decay or endodontic failure, almost 30% of the 50- to 59-year-olds examined in a US National Survey exhibited either single or multiple posterior edentulous spaces bordered by natural teeth.⁸ Treatment to replace single teeth in the posterior regions represents nearly 7% of the annual dental care reimbursement from insurance companies (Fig 2).⁹,¹⁰
FIGURE 1. The primary causes of crown failure are decay, endodontic therapy, or both; crown failure may result in the loss of the tooth.

FIGURE 2. Failure to replace a first molar may result in a number of conditions that may decrease the survival or quality of the health of the surrounding teeth.

ALTERNATIVES FOR POSTERIOR SINGLE TOOTH REPLACEMENT

The alternative treatment options for the restoration of a posterior single missing tooth include (1) removable partial denture, (2) acid-etched resin-retained prosthesis, (3) maintenance of the missing space, (4) a fixed partial denture (FPD), or (5) an implant-supported prosthesis.11 The interocclusal space must be assessed carefully, regardless of the treatment selected. Patients with insufficient vertical space may be contraindicated for any prosthesis without the prior correction of the occlusal plane and maxillomandibular relationships.

Removable prosthesis

One option to replace a single missing tooth is a removable partial denture. A common axiom in restorative dentistry is to use a fixed prosthesis whenever possible.5 Removable partial dentures are usually indicated to replace spans of two or more posterior teeth, four incisors or more, and spaces missing a canine and two adjacent teeth.5 Rarely does a patient consent to a removable partial prosthesis as an acceptable substitute for a posterior single tooth. The advantages of the removable restoration include ease of hygiene of the adjacent teeth, the ability to have a soft tissue replacement around the missing tooth in aesthetic zones with gross defects, minimal preparation of the abutment teeth, and reduced cost. Function is not improved with the single tooth prosthesis, so aesthetics and fear of shifting of the arch are two primary reasons the patient will consent to wearing the restoration. A removable prosthesis allows more food debris and plaque to collect on the tooth than is allowed by the other treatment options to replace a tooth. Shugars et al10 have reported on survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. When removable partial dentures are used to replace a tooth, the survival rates of the posterior teeth that border the edentulous space are poorer than they are for any other treatment option,10,12 with ranges from 17% to 22% abutment tooth loss at 4.2 to 13.5 years.10,12,13 Patients electing not to wear the removable restoration may enjoy greater survival of the adjacent teeth than those wearing the removable prosthesis.

Resin-bonded FPD

A second option to restore the single missing tooth site that is bordered by posterior natural teeth is with a resin-bonded fixed partial prosthesis. Failure rates reported in the literature are greatly disparate and range from 10% over 11 years to 54% over 11 months.3,14,15 Unpredictable long-term results are primarily due to cement fatigue.15,16 It also appears that earlier perforated designs exhibited lower survival rates (Table 1).3,14,21 Debonding most often occurs during function, and because eating is often a social experience, debonding may cause the patient embarrassment and insecurity. Different regions of the mouth exhibit various retention rates, with the highest survival rates in the maxillary anterior, followed by the mandibular anterior, maxillary posterior, and mandibular posterior regions.16 Therefore, posterior tooth replacement is not as successful as an anterior restoration. This prosthetic option is usually driven by economics and the desire to maintain as much tooth structure as possible on the abutment teeth; this option is also usually more accepted by the patient than...
the removable tooth replacement option.

**Maintenance of the posterior space**

A third treatment option when a posterior single tooth is missing is to not replace the tooth, but instead to maintain the missing space. A common doctrine has been to replace a missing tooth to prevent complications such as tipping, extrusion, increased plaque retention, caries, periodontal disease, and collapse of the integrity of the arch (Fig 2).5,11 However, to the author’s knowledge, no sound scientific studies describe the eventual loss of all the posterior teeth as a consequence of not replacing a missing posterior tooth.10 Instead, reports indicate that the loss of teeth adjacent to a long-term edentulous space may range from 45% to less than 12% at 8 to 12 years.10,12,13

The location of a missing posterior tooth often influences the treatment plan selected by the patient. In general, when third molars are missing, the second mandibular molar is not replaced (Table 2).22,23 The mandibular second molar is not in the aesthetic zone of the patient; furthermore, 90% of the masticatory efficiency is generated anterior to the mesial half of the mandibular first molar, so function is rarely a reason to replace the second molar. A 10% greater occlusal force is found on the second molar compared to the first. This tooth is more likely to exhibit working or nonworking interferences during mandibular excursions. The interarch and space crown height decrease as they proceed posteriorly. If a screw-retained implant restoration is used, access for screw placement or removal is often challenging, especially with an opposing natural dentition (this interarch interference also pertains to the surgical insertion of a screw-type implant body). As a result of increased forces, occlusal interferences, limited abutment height, reduced retention, and cement surface area, there is a greater incidence of porcelain fracture and/or uncemented restorations. In addition, the course of the mandibular canal anterior to the mid–first molar corresponds to the level of the mental foramen. Implant placement in this region is safe and free of paresthesia risk when placed above the height of the foramen.24 However, in the region of the second molar, the mandibular canal course becomes highly variable with an associated risk increase of paresthesia and/or neurovascular bundle damage during implant surgery and insertion. The bone quality in the second mandibular molar region is often less dense than in other regions of the mandible, which increases the risk of bone loss or implant failure. The submandibular fossa is more accentuated in this region and mandates greater angulation of an implant body compared to the direction of the occlusal forces. This increases the stresses at the crestal region of the implant, thereby increasing the risk of bone loss. Cheek biting is more common in this region because of the proximity of the buccinator muscle. Finally, the cost of an implant and/or fixed prosthesis to replace the second molar often does not warrant the benefits achieved. As a consequence, the mandibular second molar is often not replaced when it is the only posterior mandibular tooth missing.

The primary disadvantage of electing not to replace this tooth is the potential extrusion and loss of the maxillary second molar. However, extruded maxillary second molars are often not an occlusal plane concern in mandibular excursions when the mandibular second molar is missing, because the mandibular first molar usually moves forward, away from this tooth position. If extrusion of the maxillary second molar is a concern for the patient or doctor, a crown on the mandibular first molar may include a contact with the mesial marginal ridge of the maxillary second molar. Another indication for not replacing the missing tooth is when the intratooth space is small, and the existing occlusion prevents the tipping of adjacent teeth and the extrusion of the opposing teeth. A missing mandibular second premolar may fulfill these criteria.

**FPD**

The most common treatment of choice for replacement of a posterior single tooth is the three-unit fixed restoration. In 1990, more than 4 million FPDs were placed in the United States.25 This type of restoration can be fabricated
within 1 to 2 weeks and satisfies the criteria of normal contour, comfort, function, aesthetics, speech, and health. Because of these benefits, FPD has been the treatment of choice for the last six decades. 26,27 There are few bone and soft tissue considerations in the missing tooth site. Every dentist is familiar with the procedure, and it is widely accepted by the profession, patients, and dental insurance companies.

A three-unit FPD also presents survival limitations to the restoration and to the abutment teeth. 15 In an evaluation of 42 reports since 1970, Creugers 27 calculated a 74% survival rate for FPDs for 15 years. Mean life spans of 9.6 to 10.3 years have been reported by Walton et al. 1 and Schwartz, 1 respectively. However, reports are very inconsistent, ranging from as little as 3% loss over 23 years to 20% loss over 3 years (Table 3). 1,2,4,7,26±28 Caries and endodontic failure of the abutment teeth are the most common causes of prosthesis failure. 1,4,27 Up to 15% of abutment teeth for a fixed restoration require endodontic therapy, compared to 3% of nonabutment teeth (Table 4). 37 The long-term periodontal health of the abutment teeth may also be at greater risk, including bone loss. 28 Unfavorable outcomes of FPD failure include not only the need to replace the failed prosthesis, but also the loss of an abutment and the need for additional pontics and abutment teeth in the replacement bridge. The abutment teeth of an FPD may be lost at rates ranging from 2% to 30% for 8 to 14 years (Fig 3). 10,12,13

**Table 3**

<table>
<thead>
<tr>
<th>Principal Author</th>
<th>Patients/Prostheses/Units</th>
<th>% Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schwartz, 1 1970</td>
<td>3 1320</td>
<td>20</td>
</tr>
<tr>
<td>Glantz, 2 1984</td>
<td>5 109</td>
<td>2</td>
</tr>
<tr>
<td>Coenaert, 26 1984</td>
<td>7 2181</td>
<td>2.4</td>
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<tr>
<td>Reuter, 21 1984</td>
<td>11 121</td>
<td>5.8</td>
</tr>
<tr>
<td>Leemopel, 22 1985</td>
<td>11.5 917</td>
<td>4.8</td>
</tr>
<tr>
<td>Karlsson, 24 1989*</td>
<td>14 140</td>
<td>17</td>
</tr>
<tr>
<td>Cheung, 7 1990</td>
<td>5 169</td>
<td>20.7</td>
</tr>
<tr>
<td>Valdenhang, 35 1991</td>
<td>15 77</td>
<td>32</td>
</tr>
<tr>
<td>Glantz, 36 1993</td>
<td>23 103</td>
<td>3.0</td>
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*Adapted from Reference 3.

**Table 4**

<table>
<thead>
<tr>
<th>Fixed partial dentures—Causes of failure</th>
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</thead>
<tbody>
<tr>
<td>1. Caries</td>
</tr>
<tr>
<td>2. Endodontic problems (15% abutments vs 3% nonabutments)</td>
</tr>
<tr>
<td>3. Porcelain fracture</td>
</tr>
<tr>
<td>4. Uncemented prosthesis</td>
</tr>
<tr>
<td>5. Abutment fracture</td>
</tr>
<tr>
<td>6. Aesthetics</td>
</tr>
</tbody>
</table>

The fifth treatment option to replace a posterior single missing tooth is a single tooth implant (Figs 4, 5). For years, patients were advised to place their de-|sire aside and to accept the limitations of an FPD. 22 However, many feel the most natural method to replace a tooth is to use an implant, rather than preparing adjacent teeth and joining them together with a prosthesis. The primary reasons for suggesting the FPD were its clinical ease and reduced treatment time. However, if this concept were expanded, extractions would become necessary for additional pontics, and abutment teeth in the replacement bridge. The abutment teeth of an FPD may be lost at rates ranging from 2% to 30% for 8 to 14 years (Fig 3). 10,12,13

**Single tooth implants**

The fifth treatment option to replace a posterior single missing tooth is a single tooth implant (Figs 4, 5). For years, patients were advised to place their desires aside and to accept the limitations of an FPD. 22 However, many feel the most natural method to replace a tooth is to use an implant, rather than preparing adjacent teeth and joining them together with a prosthesis. The primary reasons for suggesting the FPD were its clinical ease and reduced treatment time. However, if this concept were expanded, extractions would replace endodontics and dentures could even replace orthodontics. The primary reason to suggest or perform a treatment should not just be related to treatment time or to the difficulty of performing the procedure but should instead be the best possible long-term solution for the individual (Figs 6–9).

Before 1990, few long-term studies focusing on single tooth replacement with osteointegrated implants in any region of the mouth had been published (Table 5). Early reports indicate that single tooth implant results were less predictable than than they have become in the last 7 years. In 1990, Jent et al. 28 reported a 9% implant failure within 3 years of prosthesis completion on 23 implants with screw-retained restorations (21 in the maxilla, 2 in the mandible). In 1992, Andersson et al. 30 published a preliminary report of a prospective study of 37 implants restored with cemented single tooth crowns in 34 patients. A 3-year follow-up included this “developmental group” and an additional 23 patients with 28 crowns. The final group included 52 anterior single tooth and 13 posterior single tooth replacements. The cumulative success rate recorded was 93.7%, with 89% of the “developmental group” in function 3 to 4 years.

From 1993 to the present, single tooth implant survival has become very predictable. In 1993, Schmitt and Zarb reported no failures for 40 implants placed in 32 patients (28 in the maxilla and 12 in the mandible, with 27 in the anterior region and 13 in the posterior). After a period of up to 6.6 years, all implants were in function. 40 In 1994, Eklund et al. 41 reported on a 4- to 7-year retrospective study of 77 patients who received 93 implants. The restorations were cemented or screw-retained. Two implants were lost, both within the first year of function (2% failure rate, 1 each in the anterior and posterior). The most common complication was abutment screw loosening, with 43% of the abutment screws becoming loose at least once. Nine cemented crowns had to be remade in order to treat the abutment screw loosening. In the same year, Cordioli 42 evaluated 67 endosteal implants for single tooth replacement over a 5-year period and observed an implant loss of 5.6%.

Engquist et al. 43 reported on a 1- to 5-year retrospective study of 82 implants placed in 58 patients in 1995. Two implants were lost before loading, and...
there was an overall survival rate of 97%. The bone loss averaged 0.9 mm in the first year, and then 0.1 mm in each consecutive year. Becker et al. reported on 24 molar implants in 22 patients, each of which used a single wide-diameter implant with a screw-retained crown. A cumulative success rate of 95.7% for 2 years was obtained with this approach. The main complication was a 38% incidence of loosening of the gold screws used to maintain the crowns. In 1995, Haas et al. also reported on 76 single tooth implants. Their evaluations extended for 6 years and a 2.6% implant loss was observed. Rangert et al. reported that the most common complication (9%) was screw loosening.

A series of reports in 1991, 1994, and 1996 by a group of authors reported on a multicenter prospective study consisting of 92 patients who received 107 implants; the implants had a cumulative survival rate of 97.2% at 3 and 5 years. The mean marginal bone loss (measured from the first thread, which is 2 mm below the crestal bone) did not exceed 1.0 mm. Plaque and gingival indices were indicative of soft tissue

FIGURE 3. The failure of a fixed prosthesis may result in the loss of the abutment teeth.

FIGURE 4. A periapical X-ray of a D2 BioHorizon implant replacing the mandibular first molar.

FIGURE 5. A single tooth crown on an implant replacing the mandibular first molar.

FIGURE 6. Panoramic radiograph of a four-unit fixed prosthesis in the mandibular right posterior region.

FIGURE 7. Caries of anterior abutment resulted in the loss of the fixed prosthesis and of the mandibular second premolar.

FIGURE 8. An autogenous bone graft from the ramus area restored the width of bone in the pontic region of the fixed prosthesis.

FIGURE 9. Three BioHorizons implants replace the missing teeth, without the need to include additional teeth for a fixed restoration, which would include three pontics.
were treated with 84 endosteal screw.

A prospective study of 75 patients who were treated with 47 implants in the anterior region; this type implants (with 71% of the implants in the anterior region); this study found a cumulative failure rate of 2.4% at 5 years. The mean annual bone loss from radiographs was 0.8 mm during the first year, and then 0.1 mm per year for the following 1-year periods. In the same year, Avivi-Arber and Zarb\textsuperscript{21} reported a 98% survival rate for 41 patients who received 49 single tooth implants. The mean annual bone loss after the first year was 0.1 mm. However, nine implants lost more bone than the ideal criteria, with two demonstrating progressive bone loss. The most common complication was screw loosening or fracture.

In 1996, Bahat \textit{et al}\textsuperscript{38} reported on 20 sites restored with two 5-mm-diameter implants with 100% success at up to 26 months. Thirty-four sites were restored with a 5-mm-diameter and a smaller-diameter implant, and 162 sites were restored with two standard 4-mm-diameter implants. The overall failure rate was 1.2%, with the 5-mm- and 4-mm-diameter implant combination failure rate at 2.5% and the two 4-mm implant combination failure rate at 1.6%.

In the same year, Balshi \textit{et al}\textsuperscript{39} compared the use of one implant versus two implants to replace a single molar (47 implants received one implant, and 25 received two). The 3-year cumulative success rate was 99%, with marginal bone loss of 0.1 mm for one implant and 0.24 mm for two implants. Prosthesis mobility and screw loosening were the most common complications for the one implant group (48%); these complications were reduced to 8% in the two implant group.

In 1997, Gomez-Roman \textit{et al}\textsuperscript{40} published a 5-year report on 696 endosteal implants in 376 patients. Almost 300 of these were single tooth implants, with a 96% overall survival rate (with 97.6% recall rate). In 1998, Mufftu and Chapman\textsuperscript{41} published a 4-year prospective study on replacing posterior teeth with freestanding implants using a press-fit plateau implant design (Bicon). A total of 404 restorations were placed (170 in the maxilla and 234 in the mandible; 82 single tooth and 350 multiple tooth with implants unsplinted to each other) in 168 patients. A 90% survival rate in the maxilla and a 96.8% survival rate in the mandible was obtained. In 1999, Moberg \textit{et al}\textsuperscript{42} reported on 30 implants, with a cumulative success rate of 96.7% at 3 years.

A multicenter prospective clinical study was initiated with the Maestro Dental Implant System in 1996. This implant design is coordinated to the four bone densities described by the author.\textsuperscript{58} Since the higher posterior bite forces of the mouth are usually associated with a decrease in bone density in the region, this implant is designed to decrease the stress to bone by correspondingly increasing functional surface area to the implant body (Fig 10).

Nineteen women (one of whom had a bilateral molar implant) and 18 men, ranging in age from 17 to 68 years, participated in this study. The posterior regions of the jaws received a total of 38 implants: 15 in the maxilla and 23 in the mandible (Table 6). The bone density recorded was D2 for 21 implants (6 maxillary and 15 mandibular) and D3 for 17 implants (9 in the maxilla and 8 in the mandible) (Table 6). There were 6 second molars (3 maxillary and 3 mandibular), 22 first molars (6 maxillary and 16 mandibular), 7 second premolars (3 maxillary and 4 mandibular), and 3 first premolars (2 maxillary and 1 mandibular) (Table 7). All crowns were cement-retained. The implant survival rate was 100% over the last 2 years. The mean bone loss from implant insertion to uncovering was 0.4 mm from the original crest of the ridge, the additional mean bone loss over the first year of loading averaged less than 0.3 mm, and no bone loss over the following year was observed. There has been no incidence of abutment screw loosening and no incidence of fracture of any components in this study.

Although posterior single tooth replacement is a relatively new treatment alternative, many articles have been published on the procedure since 1990. If early reports are excluded, survival

<table>
<thead>
<tr>
<th>Principal Author/Year</th>
<th>Years</th>
<th># Implants*</th>
<th>Failure Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jemt,\textsuperscript{61} 1990</td>
<td>3-5</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>Andersson,\textsuperscript{62} 1992</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Schmitt and Zarb,\textsuperscript{63} 1993</td>
<td>1.4-6.6</td>
<td>65: &lt;52A, 13P</td>
<td>6.3–11</td>
</tr>
<tr>
<td>Ekedahl,\textsuperscript{38} 1994</td>
<td>4-7</td>
<td>40: &lt;27A, 13P</td>
<td>0</td>
</tr>
<tr>
<td>Cordoia,\textsuperscript{64} 1994</td>
<td>5</td>
<td>93: &lt;72A, 21P</td>
<td>2 (1P, 1A)</td>
</tr>
<tr>
<td>Engquist,\textsuperscript{65} 1995</td>
<td>1-5</td>
<td>82</td>
<td>3</td>
</tr>
<tr>
<td>Becker,\textsuperscript{39} 1995</td>
<td>2</td>
<td>24P</td>
<td>4.3</td>
</tr>
<tr>
<td>Haas,\textsuperscript{66} 1995</td>
<td>0-6</td>
<td>76</td>
<td>2.6</td>
</tr>
<tr>
<td>Jemt,\textsuperscript{60} 1991; Laney,\textsuperscript{60} 1994; Henry,\textsuperscript{67} 1996</td>
<td>3-5</td>
<td>107 N/A</td>
<td>2.8</td>
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<tr>
<td>Malevez,\textsuperscript{68} 1996</td>
<td>5</td>
<td>84: &lt;60A, 24P</td>
<td>2.4</td>
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<tr>
<td>Avivi-Arber and Zarb,\textsuperscript{69} 1996</td>
<td>5</td>
<td>49: &lt;31A, 18P</td>
<td>2 (1A)</td>
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<tr>
<td>Bahat, Handelssman,\textsuperscript{70} 1996</td>
<td>2</td>
<td>216 P</td>
<td>1.2</td>
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<td>Balski,\textsuperscript{38} 1996</td>
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<td>Balski,\textsuperscript{71} 1997</td>
<td>7</td>
<td>120 P</td>
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<td>Gomez and Roman,\textsuperscript{38} 1997</td>
<td>5</td>
<td>300 N/A</td>
<td>4</td>
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<td>Mufftu and Chapman,\textsuperscript{72} 1998</td>
<td>4</td>
<td>82 N/A</td>
<td>3.2–10</td>
</tr>
<tr>
<td>Moberg,\textsuperscript{73} 1999</td>
<td>5</td>
<td>30A</td>
<td>3.3</td>
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<tr>
<td>Misch, 1999</td>
<td>2</td>
<td>38P</td>
<td>0</td>
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*A, anterior region; P, posterior region.
FIGURE 10. Four implant designs of BioHorizons, a quality-based implant designed for each bone density observed in the mouth.

rates reported range from a low of 94.6% to a high of 100% for 1 to almost 7 years. The median of these reports is a 2.8% implant loss with a mode of 5 years. The most common complication reported was abutment screw loosening, which did not cause the prosthesis or implant to fail.

As a result, the single tooth implant exhibits the highest survival rates of the five treatment options presented for single tooth replacement. In addition, no reports indicate a loss of an adjacent tooth, which is a considerable advantage. On the other hand, the longevity of the implant crown has not been adequately determined, since the method has not been in use long enough to have the long-term data that are available for other treatment options.

CONTRAINDICATIONS AND LIMITATION OF POSTERIOR SINGLE TOOTH IMPLANTS

Local contraindications that are unique to single tooth implants (Table 8) include inadequate bone volume and observable mobility of the adjacent teeth. Inadequate bone volume, either in height or width, may be modified by grafting. When the adjacent teeth are mobile, the implant crown may be difficult to equilibrate under occlusal forces because it is the only rigid component in a span of three to five teeth. Posterior healthy teeth move vertically 28 μm and exhibit lateral movement of less than 75 μm. A heavy bite force occlusal adjustment allows the teeth to move within this physiologic range prior to the implant crown contacting in occlusion. However, when the surrounding teeth are mobile, an equilibration of force is not possible, since the implant crown will come into contact prior to the conclusion of tooth movement. As a result, the implant bears the load of all the mobile teeth. Therefore, an implant may be contraindicated when surrounded by mobile teeth.

Limitations of treatment are related to the time of treatment, the transitional prosthesis type, and the risk of treatment. Traditionally, the time period for a rigidly fixed implant to heal and be restored is approximately 5 to 7 months, by which time adequate bone volume is present. If bone grafting is required, the treatment may extend to more than a year.

The transitional restoration for a three-unit bridge is an acrylic fixed prosthesis that is fabricated the day the procedure is started, at no additional cost to the patient. The transitional restoration for a single tooth implant is often a removable prosthesis in aesthetic regions or no replacement during healing in nonaesthetic regions. These removable restorations often lack stability and retention.
The consequences of early failure may be greater for a single tooth implant, compared to a three-unit fixed prosthesis. Although surgical success is very high, the implant failure almost always results in bone loss. As a result, if an implant is still the treatment of choice, bone grafting may be required. This is often at the expense of the doctor, since most patients believe that the early implant failure is, at least in part, the doctor's responsibility. Bone grafting is not as predictable as implant surgery; therefore, if a graft is required (especially in height), the procedure may not be successful. However, contrary to failure of a fixed prosthesis, implant failure does not compromise the adjacent teeth and increase the risk of their loss.

**DISCUSSION**

There are few indications to use a removable prosthesis as a definitive treatment when replacing a single posterior tooth. The most common situation is to use this restoration as a transitional restoration in aesthetic regions during implant healing. A removable transitional restoration may load the soft tissue over a bone graft and compromise the result and volume of the augmentation. It may also cause bone loss, or perhaps even implant failure from the early loading around the implant during Stage I healing; it may also depress the interdental papillae of the adjacent teeth, resulting in an aesthetic compromise. As a result, it is suggested that a resin-bonded fixed restoration be fabricated when replacing teeth in the aesthetic zone, in order to provide an improved functional transitional prosthesis and to protect the region. Usually, both a removable and a resin-bonded fixed prosthesis are fabricated for the transitional restoration. The removable restoration is worn immediately following surgery to protect the suture line during initial healing. Once the sutures are removed, the resin-bonded restoration (without tooth preparation) may be delivered. Since both resin-bonded and removable restorations are fabricated, if the bonded restoration becomes uncremented, the removable restoration can be inserted by the patient to eliminate the aesthetic embarrassment until rebonding can be performed. However, this approach increases the overall cost of treatment.

The posterior resin-bonded prosthesis may not be indicated in the case of short clinical crowns or unfavorable occlusal relationships. The absence of replacement of the posterior tooth is the most common transitional treatment during bone augmentation and/or implant healing in a nonaesthetic region such as the posterior aspect of the mouth.

To summarize, the primary indications for the selection of a three-unit FPD correspond to the limitations of single tooth treatments: (1) limited time frame, (2) lack of available bone in crestal height and poor prognosis or impossibility to augment, (3) inadequate intratooth space, (4) both adjacent teeth require crowns to repair their integrity, and (5) mobility of adjacent teeth (>1).

On rare occasions, the time needed to replace the missing tooth constitutes the primary determinant of the treatment. An FPD can be fabricated in less than a week and allows the placement of a fixed transitional prosthesis. Bone grafting for additional height is not as predictable as implant insertion and healing. When there is inadequate crestal bone height in the missing space, bone augmentation is less predictable, regardless of the technique employed. Therefore, an FPD is usually indicated. Inadequate intratooth space may be corrected by a three-unit prosthesis or by crowns on the adjacent teeth, with slight overcontouring. Flossing is easier between unsplit crowns than for a fixed prosthesis, and the cost is reduced. When both adjacent teeth require crowns to adequately restore them, a traditional FPD is usually the treatment of choice. When the adjacent teeth are mobile, but all other periodontal indices are within normal limits, a three-unit fixed restoration is superior to the other treatment options.

Some contraindications for a posterior FPD include poor abutment teeth support, inadequate edentulous bone for proper contour in aesthetic regions, adjacent teeth that the patient will not allow to be prepared, or, in young patients, large pulp horns in the clinical crowns. In the past, these contraindications indicated a removable prosthesis or a resin-bonded restoration. Today, an implant or bone graft and implant represent the treatment of choice. Despite some limitations and obvious clinical challenges, the single tooth implant represents a highly desirable and justified treatment option (Table 9). When adjacent teeth are healthy or when the patient refuses their preparation for the fabrication of a traditional three-unit fixed partial restoration, a posterior single tooth implant is an elegant solution. Other advantages of this modality over FPD include the decreased risk of caries on the abutment teeth, a decrease in risk of endodontics for abutment teeth, the improved ability to clean the proximal surfaces of the adjacent teeth (which decreases the risk of decay and/or periodontal disease), a decrease in risk of cold or contact sensitivity with a brush or scaler on the abutment teeth, improved aesthetics of the adjacent teeth, the maintenance of bone in the edentulous site,

![Table 9: Advantages of posterior single tooth implant replacement](image-url)
the psychological advantage (especially with congenitally missing teeth or the loss of a tooth after a crown restoration), and the decreased risk of abutment tooth loss from endodontic failure or caries (Figs 11–26). These advantages are so significant to the health and periodontal condition of the adjacent teeth and maintenance of the arch form that the single tooth implant has become the treatment of choice in most situations.

The ideal posterior tooth to replace with an implant is the first premolar. The canine abutment crown of a three-unit FPD presents an increased risk of material fracture or cerumenation of the abutment because of the lateral component of forces applied to the canine. The canine is often more difficult to restore to its original appearance than are other anterior or posterior teeth. The vertical available bone is usually greater in the first premolar locations than in any other posterior tooth positions. The maxillary premolar is almost always anterior and/or below the maxillary sinus, and the mandibular first premolar is almost always anterior to the mental foramen and associated mandibular neurovascular complex. The bone trajectory is more favorable in the mandibular first premolar than for any other tooth in the arch.

**FIRST MOLAR IMPLANT REPLACEMENT**

The first molar is one of the more common teeth lost in a posterior segment. The mesiodistal dimension of a first molar ranges from 8 to 14 mm, depending on the original tooth size and on the amount of mesial drift of the second molar prior to implant placement (Table 10). When a mesiodistal crown dimension is greater than 13 mm, one 4-mm implant may create a greater than 4-mm cantilever and associated offset loads on each marginal ridge of the crown (Fig 27). This can magnify occlusal forces in these regions (especially important in parafunction) and cause bone loss, complicate home care, increase abutment screw loosening occurrence, and increase implant failure due to overload. Sullivan9 reported a 14% implant fracture rate for single molars fabricated on standard-diameter Nobel Biocare implants and concluded that this is not a viable treatment. Rangert et al56 reported that overload-induced bone resorption appeared to precede implant fracture in a significant number of single molar implant restorations. According to the findings of several reports in the literature and basic biomechanical principles, two implants or a larger-diameter implant should be considered whenever possible (Fig 28).46,52,59-61 When two implants replace the first molar, the mesiodistal offset loads to the prosthesis can be eliminated. The total surface area of support is greater for the two implants compared with the surface area provided by one larger-diameter implant. In addition, the two implants provide more stress reduction than just one implant, which in turn reduces the incidence of abutment screw loosening. When the mesiodistal dimension of the missing tooth is 8 to 11 mm, with a buccolingual width greater than 6.5 mm, a 5-to 6-mm implant body is suggested (Fig 29); this is the case of the implant restoration presented in Figs 11–26. Langer et al60 also recommended the use of wide-diameter implants in bone of poor quality or for the immediate replacement of failed implants. In addition, the force factors are greater in the posterior regions, and the crestal stresses are best reduced through the implant diameter width and design, not through implant body length (similar to posterior compared with anterior teeth).11 The larger-diameter implant does not require as long an implant, which is a benefit because of the reduced posterior vertical bone height due to anatomic limitations/landmarks present, such as the maxillary sinus or mandibular canal.11

When the posterior single tooth space is greater than 13 mm, the ideal implant diameter for the two implants may be calculated by subtracting 4.5 mm (1.5 mm from each tooth for soft tissue and surgical risk and 1.5 mm between the implants) from the intratooth distance and dividing by 2. (ie, \((15.5 \text{ mm} - 4.5 \text{ mm}) \div 2 = 5 \text{ mm}\) for each implant). It should be noted that the diameter used in the calculation is the crest module dimension, which is often 0.35 mm greater than the implant body dimension (ie, Nobel Biocare, SteriOss, 3-I, LifeCore).

In 1996, Bahat et al52 reported on the results of various implant numbers and size selections. The overall failure rate was 1.2%, with the two 5-mm-diameter implants achieving 100% success. In the same year, Balshi et al53 compared the use of one implant and two implants to replace a single molar. The 3-year cumulative success rate was 99%. Prosthesis mobility and screw loosening were the most common complications for the one-implant group (48%); this complication rate was reduced to 8% in the two-implant group. Therefore, whenever possible, two implants should be used to replace a single molar to reduce cantilever loads and abutment screw loosening.

When 11 to 13 mm of mesiodistal space is present, the treatment plan becomes more difficult. A 5-mm-diameter implant may result in cantilevers of up to 5 mm on each marginal ridge of the crown. However, two implants present a greater surgical, prosthetic, and hygiene risk. The primary goal is to obtain at least 13 mm of space, instead of 11 to 13 mm. Additional space may be gained in several ways.11

1. An enamoplasty of the adjacent tooth’s proximal contours may be performed to increase the mesiodistal dimension up to 0.5 mm on each tooth (Fig 30). It is not unusual that the distal natural tooth has tipped toward the edentulous space. An enamoplasty may be even more productive in these cases to increase space when this occurs.

2. Orthodontics may be the treatment of choice to upright a tilted second molar or to increase the intratooth space. One anterior implant may be

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**POSTERIOR SINGLE TOOTH REPLACEMENT**

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FIGURE 11. Mandible first molar missing with abundant bone and keratinized tissue.

FIGURE 12. A periapical X-ray of the first molar region demonstrates available bone height.

FIGURE 13. A 5.5-mm trephine bur removed the keratinized tissue in the site of the desired implant.

FIGURE 14. A pilot drill prepares the bone in the center of the site created by the removal of the soft tissue plug.

FIGURE 15. A 2-mm twist drill evaluates the bone density and prepares the osteotomy to the ideal depth.

FIGURE 16. The ideal bone depth for D2 bone is 10 mm for a 5-mm BioHorizon Maestro implant.
Figure 17. The implant osteotomy is gradually increased in diameter under copious cooled irrigation (by 0.5-mm increments) to minimize bone overheating during preparation.

Figure 18. The final drill dimension is 4.4 mm for the 5.0-mm implant body for the specific implant system and bone density selected.

Figure 19. A crest module drill is used to prepare for the larger dimension crest module of the implant (5.2 mm).

Figure 20. A bone tap with a high torque and low rpm (less than 30 rpm) is then used.

Figure 21. A BioHorizon D2 Maestro implant is inserted (5.0 × 10 mm) with a handpiece at low rpm.

Figure 22. The abutment/inserting mount is evaluated. The flat side is rotated toward the facial to improve the conditions for the crown.
FIGURE 23. A permucosal healing abutment is placed into the implant body to assist in a one-stage implant placement for initial healing.


FIGURE 25. Four months after surgery, the permucosal abutment is removed and the abutment for cement reinserted. A 30-Ncm torquing device is used to screw in the abutment screw.

FIGURE 26. One year after crown insertion, a radiograph demonstrates no crestal bone loss.

<table>
<thead>
<tr>
<th>TABLE 10</th>
<th>Single first molar replacement options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesio-</td>
<td>Implant Diameter (mm)</td>
</tr>
<tr>
<td>distal</td>
<td></td>
</tr>
<tr>
<td>Dimen-</td>
<td>5 mm or greater</td>
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<tr>
<td>(mm)</td>
<td></td>
</tr>
<tr>
<td>8–11</td>
<td>Gain additional space, and then place 2</td>
</tr>
<tr>
<td>11–13</td>
<td></td>
</tr>
<tr>
<td>&gt;13</td>
<td>2 × 4-mm-diameter or greater</td>
</tr>
</tbody>
</table>

placed and an orthodontic spring incorporated in the transitional crown. The spring pushes the distal tooth distally, and after orthodontic movement, the second implant may be inserted with decreased risk and improved hygiene between each implant.

(3) The implants are not placed in the middle of the crestal width of bone. Instead, one implant is placed buccally, and the other implant is placed on a diagonal toward the lingual aspect of the ridge (Fig 31). The diagonal dimension increases the mesiodistal space by 0.5 to 1 mm. When implants are placed in such a fashion, consideration is given to oral hygiene and occlusion. In the mandible, the most anterior implant is placed to the lingual aspect of the crest, and the more distal implant is placed toward the facial aspect to facilitate access of a floss threader from the vestibule into the intra-implant space. The occlusal contacts are also slightly modified on the buccal aspect of the mesial implant to occlude over the central fossa. For the maxilla, the anterior implant is placed toward the buccal aspect and the distal implant towards the palate in order to improve the aesthetics of the more visible half of the tooth. The distal occlusal contact is placed over the lingual cusp, and the mesial occlusal contact is located in the central fossa position. The cervical aesthetics of the maxillary molar are compromised on the distal half of the tooth only to the benefit of greater intratooth distance and easier access for home care. This maxillary
FIGURE 27. A mesiodistal crown dimension of more than 13 mm creates a cantilever of more than 4 mm when a 4-mm-diameter implant is used.

FIGURE 28. Intratooth spaces greater than 13 mm should be restored with two implants that are 4 mm or larger in diameter.

FIGURE 29. For an intratooth space of 8 to 11 mm, one implant 5 to 6 mm in diameter is indicated.

FIGURE 30. Enamoplasty of the adjacent teeth proximal contours may be performed to increase the mesiodistal dimension of the edentulous segment.

FIGURE 31. The implants may be placed in a diagonal to increase the mesiodistal dimension between the teeth. The maxilla and mandible are treated differently to improve hygiene on the mandible and aesthetics in the maxilla.

Implant placement requires the intra-implant “furcation” to be approached from the palate, rather than from the buccal approach, as is done for the mandible.11

COST CONSIDERATIONS
The laboratory fee for a three-unit FPD is approximately $375. The implant body, abutment, analog, and final crown fee usually reach $400. The scheduled operating room time for setup, preparation, impression, temporization, and insertion for a three-unit FPD is approximately 1.5 to 2 hours. The setup, surgery, transitional restoration, uncovering, abutment selection, preparation, impression, transitional Stage II restoration, and crown insertion for a posterior single tooth implant and crown is less than 1 hour for adequate bone anatomy, in the absence of a transitional prosthesis such as in nonaesthetic posterior regions. The usual posterior single tooth implant fee is therefore often comparable to that of an FPD.

CONCLUSION
Treatment options for single tooth replacement include a removable prosthesis, a resin-bonded restoration, a three-unit fixed prosthesis, not replacing the tooth, and a single tooth implant. In the past, the most common choice to replace the missing tooth was the three-unit FPD. The resin-bonded restoration was initially designed to decrease economic hardship in patients, but this method typically exhibits greater complication rates and lower survival rates. This type of prosthesis is suggested for an aesthetic zone of a healing bone graft prior to implant insertion. A removable prosthesis provides the poorest prosthesis survival
and highest risk for abutment teeth loss. However, it still represents the easiest interim treatment modality during implant submerged healing for posterior teeth in aesthetic regions. Not replacing the tooth is more frequent for mandibular second molars, but this option may also be selected when the intratooth space is small and when proper opposing occlusal contacts prevent migration. Today, with the improvements in implant materials, design, surgical approach, and prosthetic guidelines, and with reported success rates above 97%, using implants to replace a single tooth is often the treatment of choice. Improved hygiene, decreased risk of decay, maintenance of bone, and prosthesis longevity all favor an implant restoration compared to the three-unit FPD.

REFERENCES


