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Implants for Single First Molar Replacement: Important Treatment Concerns

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The success rates of implants placed in the posterior region of both jaws are less than the anterior segments. Anatomic features, mastication dynamics, and adequate implant selection are all significant for long-term prognosis in the molar region. This article discusses important aspects in planning the use of dental implants in the areas of first molars. (Implant Dent 2004;13:328–335)

Key Words: dental implants, posterior maxilla, posterior mandible, single tooth, treatment plan

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.[1] Nonetheless, the loss of a single molar is regarded as a common cause of a nonphysiological occlusion resulting from tipping of neighboring teeth and extrusion of opposing teeth. In visible sites, esthetic concerns also play a role in the treatment plan.[2]

Differences in anatomy, biomechanics, and microbiology make the treatment of partially edentulous jaws substantially different from that of totally edentulous jaws.[3] In the past, options for replacement of a missing first molar involved either a removable or a fixed partial denture. A fixed bridge denture has been a well-accepted treatment modality. However, today it may be contraindicated to prepare healthy teeth proximal to an edentulous space for crowns.[4]

The survival of implant restorations in partially edentulous patients has been within ranges similar to those for implant survival in totally edentulous patients.[5] The use of endosseous osseointegrated implants has continued to expand as a treatment option for a missing first molar. In many instances, the implant has emerged as the treatment of choice. A number of applications have evolved, and clinical and laboratory procedures continue to undergo refinement.[6] However, the rehabilitation of the first molar region using dental implants has limited long-term clinical documentation and is still a challenge for those who practice implant dentistry. This requires a treatment plan based not only on the surgical aspects such as the distribution of the mesiodistal space related to implant diameter, but also on biomechanics.

This article discusses important aspects to plan a rehabilitation, using dental implants, in the area of first molars.

Longitudinal Studies of Implants Placed in the Posterior Region

There are numerous studies evaluating implants in partially edentulous patients; however, there are relatively few that evaluated implants placed into molar positions. Long-term success of endosseous implants placed both in the maxillary and mandibular posterior regions is inferior to other areas.[7–9] Disadvantages to these regions include poor bone quality that can compromise initial implant stabilization and load transfer to the bone; the location of the maxillary sinus or the mandibular canal, which is frequently close and does not enable placement of long implants; the occlusal loads, which are higher; and the occlusal table, which is frequently wider than the implant diameter, resulting in mesiodistal and buccolingual cantilever and off-axis forces.[10,11] The overall survival and success rates of long-term studies with implants placed at the posterior region of the maxilla and mandible are seen in Table 1.

Bone Quantity: The Shape and Contour of the Residual Alveolar Ridge

The quantity of available bone for implant placement is limited by the 3-dimensional shape and contour of the residual alveolar ridge. Atwood and Tallgren[23,24] evaluated the characteristic bone volume changes after tooth loss. The authors concluded that the amount of bone loss occurring the first year after tooth loss is almost 10 times greater than the following years,

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ISSN 1056-6163/04/01304-328
Implant Dentistry
Volume 13 • Number 4

DOI: 10.1097/01.id.0000148558.80761.bf

Table 1. Long-Term Studies With Implants Placed at Posterior Maxilla and Mandible

Study	Year	No.	Patients	Location	No.	Doc	Duration	Survival Rates	Success Rates
Van Steenberghe et al.[12]	1990	558	PE	Max post	27	Prosp	1 y	96.0%	—
				Mand post	171	Mcs			
Zarb and Schmitt[13]	1993	105	PE	Max post	41	Prosp	2–7 yrs	—	97.6%
				Mand post	64			—	92.2%
Bahat[14]	1993	732	PE	Max post	732	Prosp	30 ms	95.2%	—
Bernard et al.[15]	1995	100	PE	Mand post	100	Prosp	3 yrs	—	99.0%
Grunder et al.[16]	1999	264	PE	Max post	45	Prosp	3 yrs	88.9%	—
				Mand post	58	Mcs		94.8%	—
Testori et al.[17]	2002	405	FE/PE	Max post	123	Prosp	3 yrs	98.4%	—
				Mand post	282	Mcs		97.5%	—
Haas et al.[18]	2002	76	PE	Mand 1st molar	10	Retro	5 yrs	80%	—
Parein et al.[3]	1997	392	PE	Mand post	392	Retro	6 yrs	—	89%
Becker et al.[19]	1999	282	FE/PE	Max post	70	Prosp	6 yrs	—	82.9%
				Mand post	212			—	91.5%
Buser et al.[20]	1997	2359	FE/PE	Max post	298	Prosp	8 yrs	—	86.7%
				Mand post	621	Mcs		—	95.4%
Bahat[21]	2000	660	PE	Max post	660	Retro	5 yrs	—	94.4%
							10 yrs	—	93.4%
Block et al.[22]	1996	443	PE	Mand 1st molar	176	Retro	10 yrs	78.5%	—
				Mand post	443			79.3%	

No., total number of implants; no., number of implants placed according the location; Doc, documentation; FE, fully edentulous patients; PE, partially edentulous patients; max, maxilla; mand, mandible; post, posterior region; prosp, prospective documentation; retro, retrospective documentation; mcs, multicenter study.

and that the posterior mandible resorbs at a rate approximately 4 times faster than the anterior mandible. Localized ridge deformities are usually a consequence of the effects of previous dental infection-related bone loss, trauma during the extraction procedure, and alveolar bone remodeling after tooth extraction. The resulting alveolar ridge, often exhibiting reduced height and width, presents a considerable challenge to prosthetic reconstruction, in particular for placement of endosseous dental implants.

There are two distinct pathways in the attempt to replace first molars areas using dental implants: 1) preservation of osseous structures, placing (or not) an implant immediately into a fresh extraction socket, or 2) augmentation of osseous structures in deficient alveolar ridge sites for oral implant placement.

Preservation of the osseous structures in a site where a tooth extraction is performed results in simpler and more predictable placement of oral implants, simpler prosthetic restorations, a more favorable crown–root ratio for the oral implant-borne restorations, and simpler procedures leading to optimal aesthetic results.[25] Placing an implant immediately into a fresh extraction socket neutralizes the waiting time of 6 to 8 months. The longitudinal clinical effectiveness of osseointegrated dental implants placed immediately into fresh extraction sites of first and second molar teeth has been reported.[26] The 5-year cumulative survival rate was 82.3% in the maxilla and 92.3% in the mandible. A total of 14 implants were placed in maxillary first molar locations and 22 implants in mandibular first molar locations. Four implants were lost in the first molar region (three in the maxilla and one in the mandible). The authors of those articles concluded that immediate implantation in the molar region is a predictable treatment.

Indeed, implants placed immediately postextraction have proven to be a successful, predictable treatment modality.[27] However, the immediate placement of fixtures is oftentimes limited by the quantity of bone that remains after the extraction, especially on those areas that the buccal plate is lost. The augmentation of a deficient alveolar ridge with regenerated bone has been achieved and does seem to be compatible with the osseointegration of endosseous implants. A number of different techniques to maintain the ridge or regenerate bone have been used. Guided bone regeneration has been performed to augment localized ridge deformities with resorbable and nonresorbable barriers.[28–31] Placement of bone grafting materials in ridge augmentation has also been used with variable success.[32–34]

Bone Quality: Density in the Posterior Region

The density of bone is an important factor for an implant long-term success rate. When implants are placed in poor quality bone, there is a higher risk for implant failure.[7] Generally, there is poor quality of bone in the posterior region. This is a major reason for the higher failure rate, compared with the anterior region.[4] These conditions create a need to plan posterior single-tooth replacement using osseointegrated dental implants differently. This treatment plan should be guided by the bone density factor. Bone density in the posterior maxilla is generally type D4 or D3.[10] In the mandible, it ranges from D2 to D4.[10] This would lead to the choice of implant design and surface treatment developed specifically to such different types of bone density to increase the bone/implant contact area. Hydroxyapatite -prayed (HA) resorbable blast media or acid-attacked implant surfaces have been selected.

Other Anatomic Considerations

The Maxillary First Molar Region

The posterior maxilla has been described as the most difficult and problematic intraoral area for implant placement. Both anatomic features and mastication dynamics contribute to the challenge of placing implants in this region. Anatomic factors in the maxillary first molar region include decreased bone quantity and poor bone density, but also the presence of maxillary sinus or antrum, which limits the available bone height. This is especially important in implant therapy for older patients as a result of maxillary sinus pneumatization. A predictable approach to correct this condition is maxillary sinus floor elevation. This technique was first published by Boyne and James and later modified by others.[35–42] This sinus floor elevation, formerly called sinus lifting, consists of a surgical procedure in which a top hinge door in the lateral maxillary sinus wall is prepared and internally rotated to a horizontal position. The new elevated sinus floor, together with the inner maxillary mucosa, will create a space that can be filled with graft material.

Ulm et al. evaluated the height and width of the available bone at the maxillary molar region.[43] The mean ridge heights ranged between 9.30 and 3.23 mm, the highest and lowest values being 13.8 and 0.8 mm, respectively. The ridge widths generally proved to be sufficient for placement of endosseous implants.

The Mandibular First Molar Region

There is an anatomic structure in the posterior region of the mandible, relevant to the placement of osseointegrated implants. It is the mandibular canal. Therefore, a prerequisite for the implant surgery on the posterior region of the mandible is the localization of the mandibular canal. Even until today, panoramic radiography has remained the standard and simplest diagnostic method used to locate the mandibular canal. Although limitations of this technique are the distortion factor and that the buccolingual location of the mandibular canal cannot be obtained in the panoramic view. To obtain the more precise location of the mandibular canal, the clinician may use computed tomography (CT). Comparing the tomographic techniques with panoramic radiography, CT scans have been found to be more precise in measuring the distance between the bone crest and the mandibular canal compared with panoramic radiography,[44] and the tomographic radiographs have an additional advantage in presurgical planning, because they reveal the horizontal dimension and shape of the mandible, and the topography and buccolingual location of the mandibular canal.

According to the report of Gowgiel[45] on dissections of the inferior alveolar nerve, the neurovascular bundle from the mandibular foramen to the mental foramen is always in contact with, or in close proximity to, the lingual mandibular cortex. In the study of Tamas,[46] the buccal position of the inferior alveolar nerve was observed only in 6% (10 of 164) of the mandibles.

In a study using 40 partially dentate mandibles, Oliveira et al.[47] measured radiographically the distance between the residual alveolar process and the roof of the mandibular canal in the edentate region of the inferior first molar. The results showed an average distance of 14.7 mm. The authors concluded that in the majority of the cases, there is enough bone in height for osseointegrated implants.

Another important aspect when implants are placed in the posterior region is the lingual mandibular bone concavity first described by Mainous and Boyne.[48] This anatomic mandibular structure increases the risks of fenestrations or perforations during implant installation, if a proper buccal–lingual angulation is not performed.

Biomechanical Concerns

Biomechanical concerns, in the area of first molars, concentrate on unfavorable stress distribution owing to bone density, anatomic reasons that lead to the placement of inadequate number and length of implants, and excessive loads compared with anterior regions. These factors may compromise osseointegration.[5]

Another important factor to be considered is that the maximum bite force differs from mastication force, varies widely among individuals, and depends on the state of dentition and masticatory musculature. It is interesting to note that the natural teeth are narrower in the anterior regions of the mouth, where the amount of force generated is less. The natural teeth increase in diameter in the premolar region and again in the molar region as the amount of force increases.[49] Furthermore, the occlusal stress placed on the osseointegrated implant is very important to determine long-term success.[50]

Occlusal force correlates positively with muscle cross-sectional size, and it has long been known that unilateral occlusal forces increase as the bite point moves posteriorly,[51] not only because the dental lever arm gets shorter, but because more muscles groups are active. Whereas masticatory forces of 155 N and 288 N have been reported in the incisor and premolar region, respectively, the molar region has exhibited 565 N.[52] Parafunction can increase these forces as much as 3-fold,[53,54] applying significant stress to the bone–implant interface. These values are just part of a wide range found in normal subjects.[54]

Implant Selection

The implant treatment options for the restorations of a single first molar tooth include: 1) a single narrow or medium-diameter implant, 2) a single wide-diameter implant, or 3) double narrow or medium-diameter implants.

Single Narrow/Medium Diameter Implant

Single narrow (3.0- to 3.5-mm) or medium (3.75- to 4.5-mm) implants are incapable of predictably withstanding molar masticatory function and occlusion loading forces. With the use of one small-diameter implant, even if it is long, to replace first molars, there will be a discrepancy between the implant length and width and the size of the restored crown. Placement of a crown that extends beyond the long axis of the implant could generate cantilevering forces on the crown and implant.[55] Lateral forces create a bending moment relative to the implant at its marginal

Table 2. Treatment Options to Replace Single First Molar Using Endosseous Implants

Clinical Situation	Implant Selection	Advantages	Limitations
≤7 mm of mesiodistal space	One narrow or medium-diameter implant	—	Inappropriate emergence profile and esthetics Inadequate biomechanical stability
8–11 mm of mesiodistal space	One wide-diameter implant	Immediate implant placement Biomechanical stability Wide abutment screw (tightened to 45 Ncm)	Usually requires recent extraction sites or osseous grafting Needs 7–10 mm of buccolingual ridge width A "backup/rescue implant" or wider implant for immediate replacement is not available
11–12.5 mm of mesiodistal space	Gain additional space: enameloplasty or orthodontic repositioning	—	—
12.5–14 mm of mesiodistal space	Double narrow or medium-diameter implants	Biomechanical stability Elimination of the anterior–posterior cantilever Reduction of the rotational forces Reduction of screw loosening	Insufficient mesiodistal space More difficult oral hygiene

bone, and axial forces introduce bending if offset from the implant axis in a mesiodistal or buccolingual direction.[56] These forces could contribute to screw loosening and eventual implant or abutment fatigue.[55] In addition, the presence of a "cantilever" can make it difficult for home care and cause peri-implant bone loss.[57]

To reduce the risk of implant failure and increase the ability of posterior implants to tolerate occlusal forces, it may be beneficial to create a wider base. One option is the use of wider (5.0- to 6.0-mm) implants; the other is the placement of two narrow or medium-diameter implants at one site.[58]

Single Wide-Diameter Implant

Recently, Wang et al. evaluated the stress induced in the implants and peri-implant bone of a loaded molar supported by a wide-diameter implant or two standard/narrow-diameter implants.[59] The models were designed to restore a 13-mm edentulous space using a 3-dimensional finite element method (FEM). Under horizontal loads, the maximal stress in bone and implant was highest in 3.25-mm-narrow-diameter implant, whereas the use of 5-mm-wide-diameter or two 3.75-mm implants was performed equally well.

The choice between 5-mm and double implants should be influenced by the quality and quantity of the bone, the amount of bone below the sinus or above the nerve in relation to the length of the implant that is desired, and the availability of adequate mesiodistal space (Table 2).

The wide-diameter implants were used initially to replace failed standard-diameter implants.[60] Several advantages are derived from wider implant platforms at first molar areas: they have stronger screws, larger hex designs on flaptop implants, they support higher torque forces applied to retaining screws, internal hex, and octagon configurations, and combinations of these. These improvements have contributed to greater success with molar restoration.[61] Wider-diameter implants have a distinct use in smaller molar spaces (8–11 mm) with a crestal width greater than or equal to 8 mm.[62] A recent study recommended the use of wide implants cautiously and only when necessary.[63] The disadvantage of starting with the wide-diameter implant is that if the implant fails to osseointegrate; a "rescue implant" or wider implant for immediate replacement is not available.[4] Even more recently, Small et al. reported a distinct trend of soft tissue recession around wider implants compared with a standard-diameter implants.[64]

The success with wide-diameter implants in replacing molar teeth has been documented in clinical studies. In a 2-year study with 266 wide-diameter implants placed in a posterior region, Graves et al. reported a success rate of 98% in the maxilla and 94% in the mandible.[65] In a retrospective report by Becker and Becker,[55] on the replacement of single molars with implant-supported restorations in 22 patients using 24 wide-diameter implants, a cumulative success rate of 95% was achieved (only one implant was lost).

Double Narrow/Medium-Diameter Implants

In 1990, Balshi suggested placement of two implants in first molar position to compensate for poor-quality bone usually found at the posterior region.[66] Double implants more closely mimic the anatomy of the roots being replaced and doubles the anchorage surface area. Other advantages include: elimination of the anterior–posterior cantilever, reduction of the rotational forces exerted, and reduction of screw loosening. However, daily oral hygiene may be more difficult, and is the major limitation of placing two implants continuously to be insufficient mesiodistal space. According to Saaduon et al.,[67] a minimum of 12.5 to 14.0 mm of interdental space is needed to successfully replace double standard implants for a missing molar. Ideally, the interproximal re-

gion between the implant body and adjacent natural tooth roots should be at least 1.5 to 2 mm to accommodate for the surgical, periodontal, and prosthetic requirements.[49] More recently, it was demonstrated that there is a lateral component to the bone loss after abutment connection of a 2-stage implant. This lateral component can result in greater interimplant crestal bone loss if the two implants are not spaced more than 3 mm apart.[68] When 11 to 12.5 mm of mesiodistal space is present, additional space may be gained to allow placement of double implants. The options include: 1) enameloplasty of the adjacent tooth, which often can be up to 0.5 mm on each tooth; or 2) orthodontic repositioning to upright a tilted second molar or increase intertooth space.[4,50] Misch also suggested placing implants on a diagonal position when there is insufficient interdental space and the ridge width is wide. The diagonal dimension is then increased by 0.5 to 1.0 mm.[50] 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 interimplant space. The occlusal contacts are also slightly modified on the buccal aspect of the central fossa. For the maxilla, the anterior implant is placed toward the buccal aspect and the distal implant toward the palate to improve the aesthetics of the more visible half of the tooth. The distal occlusion contact is placed over the lingual cusp, and the mesial occlusal contact is located in the central fossa position.[1]

Single versus Double Implants

Several clinical studies have been conducted to compare single wide-diameter and double standard implants. Balshi et al. compared the use of one single-wide implant with the use of two implants to replace a single molar.[56] The 3-year cumulative success rate was 99% with 0.1-mm marginal bone loss for one implant and 0.24 mm with two implants. The authors hypothesize that the decreased access between the implants in the two-implant group could be a contributing factor for bone loss. However, this was not supported by clinical observations or the bleeding index, which both demonstrated very healthy soft tissue in this area. Prosthesis mobility and screw loosening were the most common complications for the one-implant group (48%) and were reduced to 8% in the two-implant group. In the same year, Bahat and Handelsman reported higher failure rates for single wide-diameter implant (2.3%) as compared with double implants (1.6%) placed in the posterior region.[58]

Conclusions

Management of the first molar region presents many challenges for the implant practitioner. A preliminary detailed planning is of particular importance. This includes detailed analysis of anatomic features, soft tissue management, and adequate selection of number, diameter, length, and surface of the implants. Based on the scientific literature, restoring first molars with one wide-diameter implant or double implants provides more surface area and better biomechanical properties than single narrow or medium-diameter implants.

Disclosure

The authors claim to have no financial interest in any company or any of the products mentioned in this article.

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Abstract Translations [German, Spanish, Portugese, Japanese]

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Einzelzahnimplantierung zum Ersatz der vorderen Mahlzähne: wichtige Behandlungsgrundlagen

ZUSSAMENFASSUNG: Allgemein verzeichnet man eine geringere Erfolgsquote bei Implantierungsbehandlungen im hinteren Kieferbereich als bei Implantatverwendung im vorderen Ober- oder Unterkiefer. Spezifische anatomische Gegebenheiten, die Eigendynamik des Kauvorgangs sowie die Auswahl des geeigneten Implantats spielen eine wesentliche Rolle für den langfristigen Erfolg einer Implantierungsbehandlung im Bereich der Mahlzähne. Der vorliegende Artikel befasst sich mit der Diskussion wichtiger Aspekte zur Anwendungsplanung von Zahnimplantierungen im Bereich der vorderen Mahlzähne.

SCHLÜSSELWÖRTER: Zahnimplantate, hinterer Oberkiefer, hinterer Unterkiefer, Einzelzahn, Behandlungsplan

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Implantes para el reemplazo de un primer molar solo: Cuestiones importantes sobre el tratamiento

ABSTRACTO: Las tasas de éxito de los implantes colocados en la parte posterior de ambas mandíbulas es menos que para los segmentos anteriores. Características anatómicas, la dinámica de la masticación y una selección adecuada del implante son todos importantes factores para la prognosis a largo plazo en la región molar. Este artículo explica aspectos importantes en la planificación del uso de implantes dentales en las zonas de los primeros molares.

PALABRAS CLAVES: implantes dentales, maxilar posterior, mandíbula posterior, diente único, plan de tratamiento

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Implantes para Substituição Única de Primeiro Molar: Preocupações Importantes com Tratamento

RESUMO: As taxas de êxito de implantes colocados na região posterior de ambos os maxilares são menores que os segmentos anteriores. Características anatômicas, dinâmica de mastigação e seleção adequada de implante são todas significativas para prognóstico de longo prazo na região molar. Este artigo discute aspectos importanes no planejamento do uso de implantes dentários nas áreas dos primeiros molares.

PALAVRAS-CHAVE: implantes dentários, maxila posterior, mandíbula posterior, dente único, plano de tratamento.

単独第1小臼歯交換のためのインプラント：インプラント治療における注意点

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概要：上下顎後部に設けられたインプラントの成功率は前部インプラントに比べて低い。臼歯部分における長期的予後にとって、解剖学的特徴、咀嚼運動、インプラントの正しい選択はすべて大きな影響力を持つ。本論文は、第1小臼歯部分のデンタルインプラント使用計画について重要な要素について考察する。

キーワード：デンタルインプラント、上顎後部、下顎後部、単独歯、治療計画

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