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Treatment of Maxillary Jaws with Dental Implants: Guidelines for Treatment

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Abstract

Maxillary implant prosthetic treatments may be considerably more difficult to accomplish when compared to the corresponding treatments for patients with edentulous or partially edentulous jaws. The objectives of this article include descriptions of diagnostic records and their impact on treatment success, and criteria clinicians should use to determine whether fixed or removable prostheses are the treatment of choice in any given situation. Specific criteria and clinical guidelines will be identified for use in the treatment planning process. Determination of optimal tooth positions and their relationships to residual ridges or extraction sites are one of the critical factors in determining designs for maxillary implant prostheses. Prosthetic designs (fixed or removable) should be determined by clinicians prior to placing implants; removable prostheses should not be considered to be the "fall-back" treatment option if fixed treatments become unavailable secondary to loss of implants or other clinical complications. Inherent differences between fixed and removable prosthetic treatments are critical for clinicians to understand, as they often include key points for clinicians explaining the features of fixed/removable-implant prostheses to patients. Appreciation of the differences between fixed and removable prostheses is critical for patients and clinicians to make informed decisions.

Treatment of edentulous patients in one or both jaws presents numerous challenges for clinicians. Locker considered tooth loss as oral impairment.[1] The authors of the present article consider edentulism to be a physical impairment with characteristics similar to a chronic disease such as diabetes: incurable, functionally/psychologically disruptive, and requiring specific management strategies to overcome or limit disruptive effects. The original tenet of osseointegration was to eliminate mandibular complete dentures and treat edentulous mandibles with fixed-implant prostheses. Treatment of patients with edentulous maxillae was not a part of the initial protocol.[2]

Clinical demands for prosthetic treatment will likely increase in the future.[3,4] Although the incidence of edentulism has been reported to be declining in the United States,[5] current economic conditions and population growth will likely result in increased numbers of edentulous patients presenting for treatment over the next 30 to 50 years.[4] According to Marcus et al, 11% of 45-year-old Americans were edentulous in one arch; this increased to approximately 15% after 55 years of age.[6] The percentages of single- or dual-arch edentulism translate into approximately 30 million people, or about 17% of the population.[7]

The curriculum for teaching complete denture prosthodontics has been reduced in US dental schools over the past several decades.[8] In light of this, there may be an insufficient number of practitioners willing or able to treat edentulous patients. Many edentulous patients wear removable prostheses that are inadequate regarding the basic needs of function, phonetics, and esthetics.[6] Many patients simply do not or cannot wear mandibular prostheses, even for social occasions. The McGill Consensus Conference concluded that the first-choice standard of care for treatment of patients with edentulous mandibles was overdentures retained by two dental implants.[9] At this time, there is no consensus for treatment of edentulous maxillae.

The purpose of this article was to review the dental literature relative to cumulative survival rates (CSRs) of maxillary dental implants and prostheses, and to suggest clinical guidelines relative to treatment options for edentulous maxillae.

Resorption of edentulous jaws

Bone requires stimulation to maintain its form and internal structure. Jawbones and teeth have a unique relationship within the human body. Wolff's law states that bone remodels relative to the forces applied to it.[10] Teeth transmit compressive and tensile forces to alveolar bone. Each time bone is modified, such as with tooth loss, definitive changes occur within the

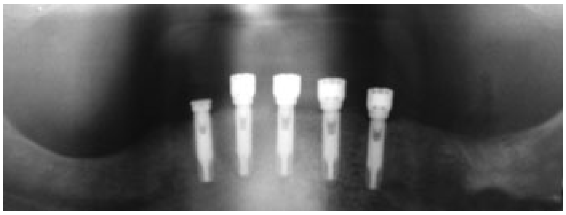

Figure 1 Panoramic radiograph of a patient with five mandibular anterior implants in place. Note the lower levels of the alveolar crest in the posterior segments and compare them to the levels of alveolar bone around the osseointegrated, anterior implants.

bone. When a tooth is lost, adjacent alveolar bone is no longer stimulated and causes a decrease in trabeculae and bone density and loss of width and height of the alveolus (Fig 1).[11] The width of the alveolus decreases by as much as 25% in the first year after tooth loss, and approximately 4 mm in alveolar height following extractions in conjunction with immediate complete dentures.[12] Tallgren reported the results of an extensive clinical study with 25 years of follow-up and demonstrated continued bone loss over time in edentulous jaws.[13] Edentulous mandibles lost bone volume more than four times quicker than edentulous maxillae.

Posterior edentulous maxillary ridges resorb medially and superiorly; anterior edentulous maxillary ridges resorb superiorly and posteriorly. The mandible resorbs inferiorly, anteriorly, and laterally (Fig 2). The differences in resorptive patterns often lead to unfavorable jaw relationships between the arches. Maxillae also have large cavities not present in mandibles (nasal cavity, maxillary sinus) (Fig 3).

Fixed maxillary implant prostheses: 1981 to 1997

Maxillary edentulous patients with adequate bone support are often restored satisfactorily with conventional complete dentures.[14] Patients with atrophic maxillae and denture challenges have been treated with dental implant-supported or -retained prostheses for several decades. These patients generally have

Figure 2 Laboratory lateral image of mounted casts demonstrating that the maxillae are retrognathic relative to the prognathic mandible as indicated by the location of the mandibular anterior denture teeth.

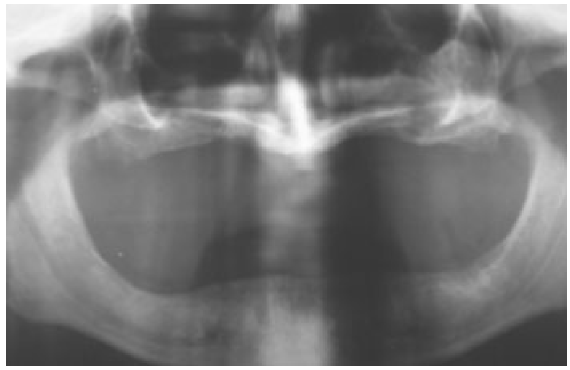

Figure 3 Panoramic radiograph of a patient edentulous for 20 years. Note the significant maxillary resorption and the increased sizes of the maxillary sinuses and nasal cavities.

reported improved function, esthetics, and self-esteem, beyond what conventional complete dentures have provided.[14–17] The initial dental implant literature reported lower survival rates for maxillary (machined) implants and prostheses as compared to mandibular implants and prostheses (Table 1).

Fixed maxillary implant prostheses: 2002 to 2009

In the past several years, implant-related treatment results associated with edentulous maxillae have been reported by numerous authors.[22,23] Testori et al reported the results of a clinical prospective study with clinical outcomes of 2-month loaded implants placed into posterior jaws with up to 3 years of functional loading (Table 2).[24]

The outcomes noted in Testori et al's report suggested that rough surface implants in posterior jaws were able to safely bear functional loads 2 months after implant placement. The results of the study were also encouraging for maxillary implants, since the healing period in the study was reduced by 4 months when compared to the 6 months suggested by the Brånemark protocol.

Del Fabbro et al published an extensive review of the literature. They reviewed numerous papers with differing numbers of implants, restored with different loading and various prosthetic protocols.[25] The mean number of implants used to treat edentulous maxillae was 8.18 (Fig 4). The primary goal of Del Fabbro's paper was to determine the survival rate of immediately loaded (IL) dental implants based on a systematic review of the literature. Secondary goals were to determine the influence of various factors on implant survival rate, such as the type of prosthetic reconstruction, implant location, and implant surface characteristics. The database included 10,491 IL implants placed in 2977 patients, with a maximum follow-up of 13 years. The overall CSR was 96.4%. Del Fabbro et al reported that immediate occlusal loading was well documented and predictable for edentulous mandibles (overdentures and full-arch prostheses) and for maxillary single implant units. Fewer data were available for maxillary full-arch reconstructions, fixed partial prostheses, and mandibular single crowns. Most failures (97.1%) occurred within the first 12 months of loading. This

Table 1 Comparisons of maxillary and mandibular implant survival rates with fixed prostheses from 1981 to 1997

Authors	Number and type of implants	Follow-up (years)	Maxillary jaws/implants	Mandibles/implants	Type of implants	CSR maxillary Implants	CSR mandibular implants
Friberg et al[18]	4641 Brånemark	3	379/1729	564/2912	Machined	99%	99.6%
Adell et al[2]	2768 Brånemark	5-9	191/981	219/1016	Machined	81%	91%
Adell, Ericksson et al[31]	4636 Brånemark	15	277/1789	482/2847	Machined	78%	86%
Jemt[19]	2199 Brånemark	1	99/586	292/1613	Machined	95.8%	99.4%
Jemt and Lekholm [20]	752 Brånemark	5	150/801	zero	Machined	85.7%	NA
Visser et al[21]	234 Brånemark	10	39/252	zero	Machined	86.1	NA

CSR = cumulative survival rate.

review demonstrated that it was possible to apply IL with high survival rates.

Removable restorations, edentulous maxillae, and dental implants: 1981 to 2003

Numerous researchers reported decreased maxillary implant survival rates and correlated the rates with decreased quantity and quality of bone, implants placed at angles consistent with resorbed edentulous maxillae, cantilevered prosthetic replacements, and increased abutment length secondary to increased thickness of masticatory mucosa in maxillae.[26-28] Implant failures reported with removable maxillary overdenture implant prostheses were consistent with results published in previous reports with fixed treatment modalities.[29,30] Careful analysis revealed that in these early studies, clinicians used one to four implants for retention/support of maxillary prostheses and that mostly short, machined implants were placed into poor quality/quantity of bone. Implant survival rates were reported between 70% to 90%, with 1 to 7 years follow-up (Fig 5).[31,32]

Maxillary implant treatment in the 1970s and 1980s generally included treatment decisions made at the time implants were uncovered and evaluated for osseointegration. If several implants were discovered to be nonintegrated at this appointment, the prosthetic design often was changed/modified to be a removable overdenture (OD). If all implants were found to be integrated, the original fixed prostheses would be made. Criteria differentiating removable and fixed prosthodontic treatments were basically nonexistent. There were no specific guidelines relative to the number of implants required for optimal support with maxillary overdentures.[29,30] However, for prosthetic treatment options without palatal coverage, there appeared to be a consensus that a minimum of four implants would yield favorable long-term prognoses.[33-37] Eckert and Carr advocated placing at least six maxillary implants to ensure prosthetic success.[38]

If surgical treatment yielded fewer osseointegrated implants than originally planned, ODs were fabricated instead of the planned fixed prostheses. The removable option was selected whether or not the patient was a candidate for removable-implant prosthetics. In many instances, these patients were not candidates for removable implant-supported/retained ODs and resulted in high prosthetic and implant failure rates. The authors speculate that these failures were actually failures in treatment planning rather than failures associated with osseointegration.

Palmqvist et al reported results associated with 25 maxillary implant-supported ODs that were either planned (where implants sufficient for a fixed prosthesis could not be placed) or emergency cases (original treatments called for fixed restorations, but implants lost during the healing period made such treatment impossible).[39] In the planned group, only two of 19 OD patients lost implants during the follow-up period; in the emergency group, four of six OD subjects lost implant(s) during the same period. Total loss of implants during healing and overdenture function was 7% in the planned group and 72% in the emergency group.

Närhi et al conducted a retrospective study that evaluated the clinical performance of and patients' satisfaction with maxillary ODs retained/supported by splinted and unsplinted implants.[40] Eleven patients were treated with bar-retained ODs with three to six clips (mean follow-up = 32 months); five patients wore ODs retained by two to six ball attachments (mean follow-up = 54 months). Most subjects experienced improvement in their

Table 2 Comparisons of maxillary and mandibular implant survival rates with fixed prostheses 2002 to 2008

Authors	Number and type of implants	Patients	Follow-up years	Maxillary jaws/implants	Mandibles/ implants	Type of implant	CSR maxillary implants %	CSR mandibular implants%
Testori et al[24]	405 Osseotite	175	3	75/123	100/282	Acid etched	98.4	97.5
Calandriello and Tomatis[22]	60 TiUnite	18	1	18/60	0	Acid etched	96.7	NA
Fischer et al[23]	142 Straumann	24	5	24/142	0	SLA (Sand blasted, Large grit, Acid etched)	95.1	NA

CSR = cumulative survival rate.

oral function after treatment with implant-retained ODs. At the conclusion of the study, 92% of the implants were functioning satisfactorily. The implant CSR after 72 months was 90%.

Goodacre et al combined raw data from multiple studies and calculated means to identify trends relative to reported complications.[41] The most common implant complications (those with greater than 15% incidence) were loosening of OD retentive mechanisms (33%), implant loss in irradiated maxillae (25%), hemorrhage-related complications (24%), resin veneer fracture with fixed partial dentures (FPDs) (22%), implant loss with maxillary ODs (21%), ODs needing to be relined (19%), implant loss in type IV bone (16%), and OD clip/attachment fracture (16%). Although implant data were obtained from different studies, Goodacre et al described a trend toward a greater incidence of complications with implant prostheses than single crowns, FPDs, all-ceramic crowns, resin-bonded prostheses, and dowels and cores.[41]

Removable restorations, edentulous maxillae, and dental implants: 2003 to 2010

Maxillary implant and prostheses survival rates were extensively studied in the past decade. With the advent of improved microtextured implant surfaces, improved diagnostics such as computerized tomographic (CT) scans, and improved restorative technology such as computer-assisted design/computer-assisted machining (CAD/CAM), prosthetic and implant survival rates improved from those reported in the 1980s (Table 3). Clinically, once the anatomic and physiologic differences between edentulous jaws were understood and compensated for, the obvious differences and difficulties between the two jaws related specifically to prosthetic treatments and their impact on esthetics, phonetics, and masticatory function (Fig 6).

Guidelines for maxillary implant treatment: Diagnostics

Radiographs

In the absence of natural anatomic landmarks, jaw relationships, lip support, and optimal tooth positions are generally more difficult to identify in edentulous patients. Conventional radiographic examinations relative to maxillary implant treatment usually consist of panoramic, lateral cephalometric, occlusal, and/or periapical films; conventional radiographs do not reveal bone volumes that help to determine the number/location of implants in preparation for implant prosthetic treatment. Tomographic and CT radiographic studies of edentulous maxillae provide the implant team critical information with which to appropriately treatment plan specific, custom treatments for individual patients. It is the authors' opinion that the additional cost of the latter radiographic examinations is justified because it allows for better predictability in terms of accurate location and angulation of implants, and may actually save patients additional time, surgeries, and expense by informing surgeons preoperatively of anatomic limitations not visualized on plane films (Fig 7).

Denture evaluation

Clinicians need to evaluate the complaint(s) or conditions that brought the patients to make evaluation appointments: ill-fitting dentures; poor esthetics, phonetics, and function; recurring soreness. Dissatisfaction with existing dentures may be the result of deficiencies treatable by fabrication of new conventional complete dentures. Clinicians need to know how to evaluate existing dentures relative to tissue adaptation, border extension, and adequacy of posterior palatal seals. Unstable dentures during function may be related to nonoptimal occlusal relationships that may include uneven occlusal schemes, and/or excessive or insufficient vertical dimensions. Clinicians also need to determine the appropriateness of a patient's existing denture relative to lip support; incisal display during speaking, smiling, and at rest; size, shape, and tooth arrangement; denture fit; location and orientation of the occlusal plane. Ill-fitting dentures should not be used as starting points for implant treatments. Optimal tooth positions must be established prior to deciding upon a surgical treatment plan (Figs 8 and 9).

Maxillary anterior/posterior resorption

Nonoptimal anterior tooth relationships for phonetics and incising, and dissatisfaction with esthetics, are issues that also need to be resolved prior to implant therapy. The reasons for deciding to proceed with implant treatment must be such that the problems cannot be eliminated by conventional means (or the patient does not want to wear a maxillary complete denture). The reasons should be documented in the patient's chart. In evaluating an existing denture relative to the edentulous ridge, the thickness of the denture's labial flange required for lip support is important. If the labial flange of an existing denture is essential for optimal lip support, it is unlikely that fixed-implant prostheses will provide support without significant compromises

Table 3 Comparisons of maxillary implant and prosthesis survival rates with removable prostheses from 2003 to 2010

Authors	Number of implants	Patients	Follow-up years	Maxillary jaws/implants	Type of implant	CSR maxillary implants %	CSR maxillary prostheses %
Krennmair et al[42]	179	34	5	34/179	Camlog Frialit-II	97.5-98.4	100
Cavallaro and Tarnow[43]	25	5	1-4	5/25	Microtextured surfaces	100	100
Romeo et al[44]	40	9	7	9/40	Straumann SLA	92.5	100

CSR = cumulative survival rate; SLA = sand blasted, large grit, acid etched.

Figure 4 Clinical maxillary occlusal image of a patient with eight implants designed to retain maxillary fixed implant-retained prostheses; abutments are in place. This patient had undergone minimal anterior/posterior (A/P) resorption; the maxillary fixed prostheses provided adequate lip support without a labial flange.

in either ridge lap pontic designs or lack of pontic/tissue contact. Wheeler established that the buccal/lingual diameter of maxillary central incisors at the cementoenamel junction is 6 mm and the maximum buccal/lingual diameter of maxillary central incisors is 7 mm.[45] If the anterior/posterior (A/P) resorption is 7 mm or less, the authors suggest that fixed prostheses are probably indicated. If the A/P resorption is in the range of 8 to 10 mm, fixed or removable prostheses may be indicated. In situations where this distance exceeds 10 mm, consideration should be given to designing prostheses as implant-supported removable ODs or as fixed prostheses with removable labial veneers (Fig 10).[46,47]

Maxillary vertical resorption

The degree anterior maxillary soft tissues are visible during speaking or smiling must be carefully evaluated; this information may be used to determine implant position and the amount,

Figure 5 Clinical maxillary labial view of a patient with an implant-retained framework in place. The framework measured approximately 10 mm in vertical height. For the prosthesis to be successful, the maxillary restorative volume had to allow for the framework, denture base, and denture teeth.

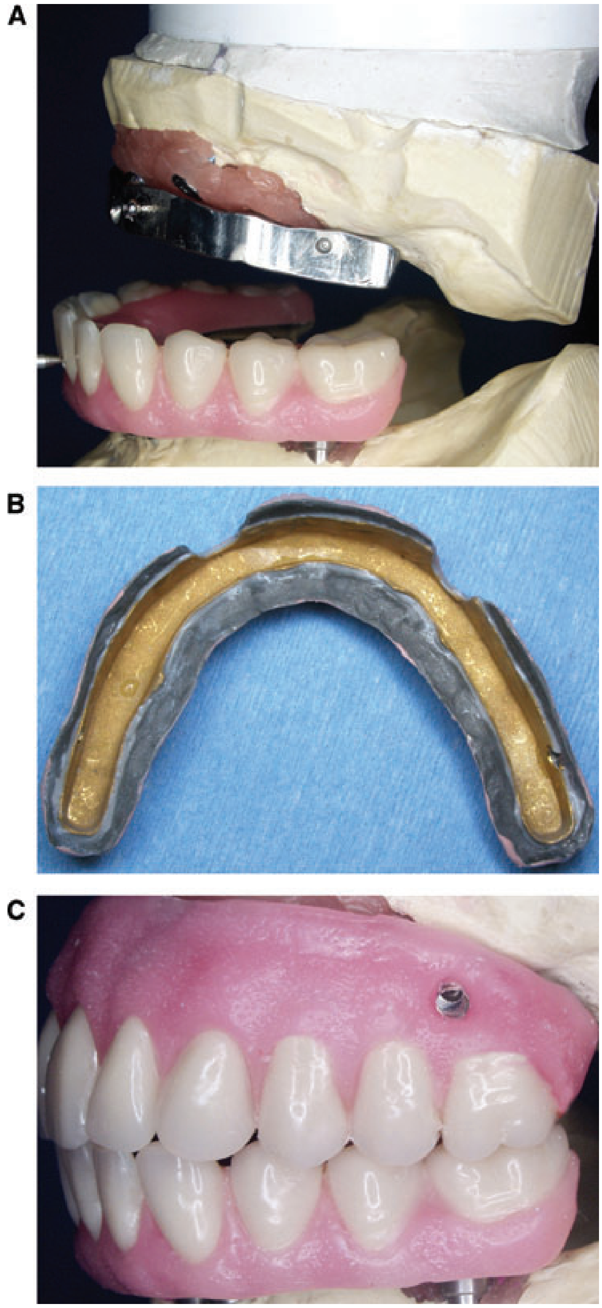

Figure 6 (A) Lateral laboratory image of primary computer-assisted design/computer-assisted machining (CAD/CAM) bar in place on a maxillary master cast. (B) Intaglio surface of secondary framework that fits onto the primary bar in Figure 6(A). (C) Lateral image of denture teeth set on the secondary framework in place on the primary bar. This is an excellent example of a complex maxillary implant-retained/supported overdenture.

if any, of abutment restorative components visible during speaking, smiling, and at rest. Too much bone in anterior maxillae can have detrimental impacts on maxillary prosthetic design, as OD frameworks are space-sensitive (Fig 11). For patients

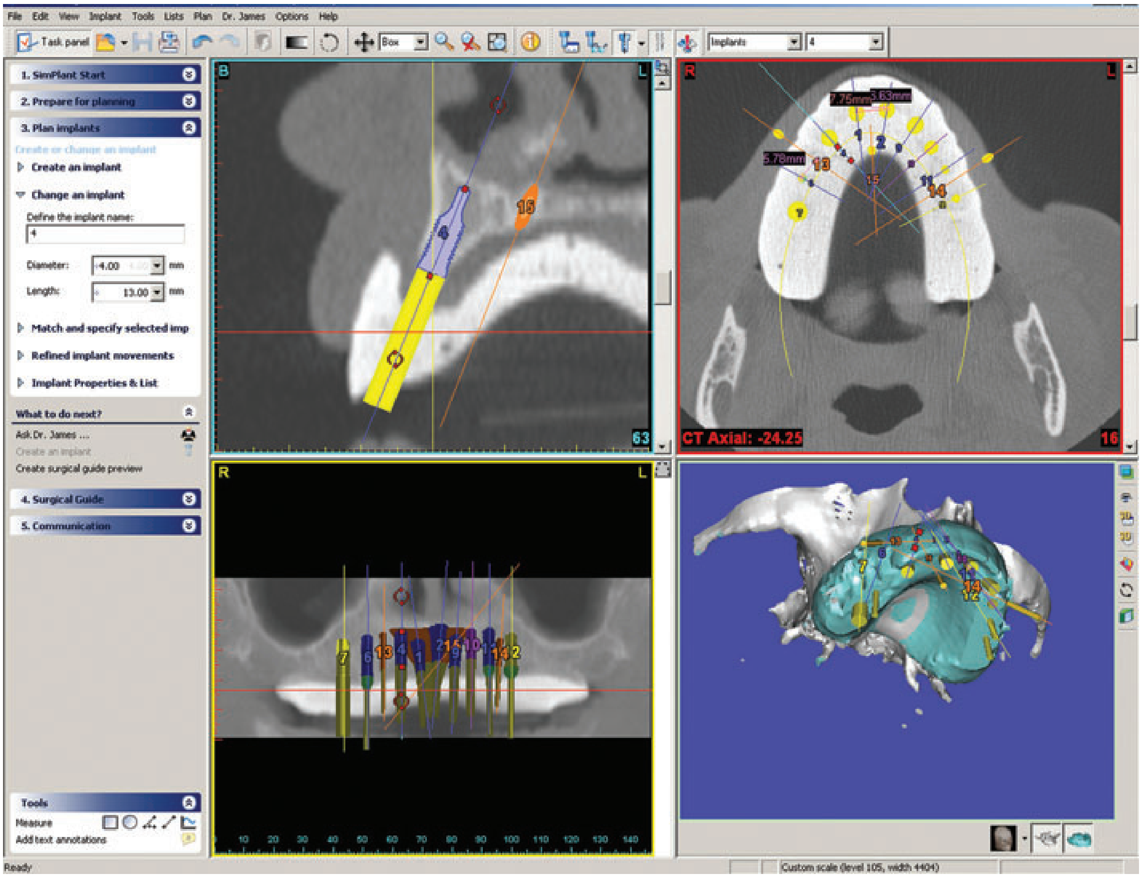

Figure 7 Three-dimensional (3D) treatment planning with CT scans. Screen shot taken during the decision-making phase relative to implant placement and restoration of an edentulous maxillary patient. The upper left image reflects a cross-sectional slice in the right anterior maxilla corresponding to the placement of the fourth implant. The virtual 4-mm diameter implant was placed into adequate bone relative to the virtual location of the maxillary right central incisor. The other views were used to precisely align the implant within the virtual prosthesis.

with high smile lines and minimal resorption of the alveolar process, the restorative dentist and surgeon may elect not to place implants in the incisal areas to preclude esthetic concerns secondary to abutments placed into embrasures of the prosthesis.[48] If there is sufficient bone in the posterior maxilla, it may be desirable to place implants in the canine and posterior regions to support prostheses without involving the premaxilla (Fig 12). The implant team may also decide to remove bone to obtain adequate restorative volume for implant prostheses.

Figure 8 Clinical anterior image of a patient with skeletal and dental malocclusions. The jaws and natural teeth are not in optimal positions. A trial wax denture was needed to identify optimal tooth positions prior to proceeding with CT scanning and definitive treatment planning.

Maxillary medial/superior posterior resorption

Posterior edentulous maxillary ridges resorb medially and superiorly. Mandibular posterior edentulous ridges resorb inferiorly and laterally. Schropp et al demonstrated that major changes in extraction sites occurred during the first year after tooth extraction.[49] These resorptive patterns can lead to unfavorable fixed-implant designs and prostheses (Fig 13). Differences in resorptive patterns between the jaws often lead to unfavorable jaw/tooth relationships between the jaws and could lead to increased prosthodontic maintenance issues and costs for clinicians and patients.

Figure 9 Lateral profile view of a patient with 25-year-old dentures in place. As the maxillae resorbed superiorly and posteriorly, the tissue-supported complete denture also moved superiorly and posteriorly with resultant loss of lip support and vertical dimension.

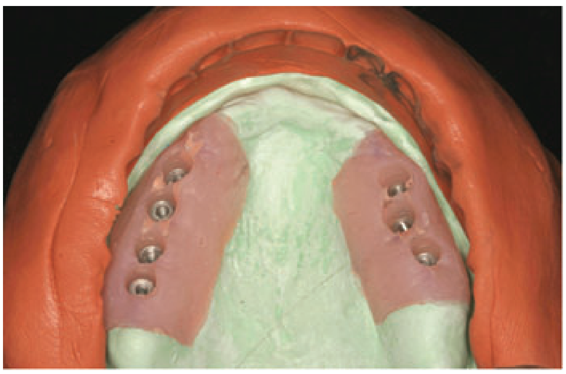

Figure 10 Laboratory occlusal image of a maxillary master cast with a silicone index in place that identified tooth locations associated with the agreed-upon esthetics of the interim prosthesis. The distance from the crest of the maxillary edentulous anterior ridge to the labial surfaces of the maxillary central incisors was in excess of 10 mm. This patient was treatment planned for a maxillary removable overdenture, supported by two screw-retained posterior frameworks.

Guidelines for maxillary implant treatment

The American College of Prosthodontists Prosthodontic Diagnostic Index (ACP PDI)

The ACP developed a PDI whereby diagnostic criteria are organized objectively: bone height (mandible), residual ridge morphology (maxillae), muscle attachments (mandible), and maxillary/mandibular relationships.[50] Clinicians assess patients and then qualify them as Class I, II, III, or IV. Class I patients may be treated and experience satisfactory results with conventional, complete dentures. Class IV patients describe the

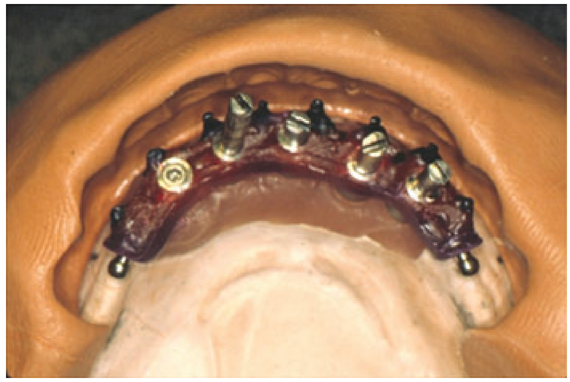

Figure 11 Laboratory occlusal image of a maxillary master cast with silicone index in place. A resin framework was waxed that splinted the implants. Minimal restorative volume was available between the resin framework pattern and the positions of the anterior teeth for the denture teeth and denture base. Decreased restorative volume is a predictor of increased risk of prosthodontic maintenance for clinicians and patients.

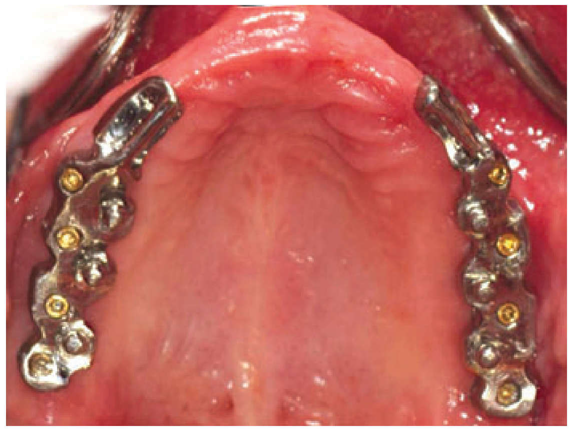

Figure 12 Clinical maxillary occlusal image of a patient with three implants in the right and four implants in the left posterior segments. The patient had an excess amount of alveolar bone in the anterior maxillae, precluding the use of anterior implants and their respective restorative components.

most debilitated edentulous conditions that practitioners may encounter. Treatment of Class IV patients should be performed by clinicians with extensive prosthodontic, implant, and surgical experience—not by clinicians new to implant dentistry or with limited prosthodontic expertise. Surgical reconstructive techniques are almost always indicated for these patients, but cannot always be accomplished because of patient health, preferences, dental history, and/or financial considerations. When surgical revisions are not viable options, prosthodontic techniques of a specialized nature must be used to achieve adequate treatment outcomes. Patients with severe atrophy of edentulous ridges are generally considered to be Class IV patients; endosseous implants may provide these patients with the retention and support needed to successfully adapt to their edentulous conditions.

Figure 13 Clinical image of a patient with an implant-retained, maxillary fixed prosthesis that demonstrated the resorptive pattern of posterior maxillae (medial and superior) noted in the text. The implants were placed into maxillary bone at angles consistent with the 3D anatomy of the edentulous ridges; the clinical crowns of the prosthesis were significantly buccal to the implants and implant restorative platforms, as dictated by the position of the mandibular teeth. Significant cantilevers were present in this design. This could lead to increased prosthodontic maintenance during the lifespan of this particular prosthesis.

Patients with acceptable maxillary complete dentures

If a patient's existing maxillary complete denture is acceptable to the patient and clinician, the denture may be duplicated in clear acrylic resin for use as a scanning guide for diagnostic radiographs and a surgical guide for implant placement. Surgical guides may be fabricated conventionally by dental laboratory technicians or be fabricated as rapid prototypes, from digitized data associated with CT scans.

Patients with unacceptable maxillary complete dentures

If a patient's existing maxillary complete denture is unacceptable, the restorative dentist should at the very least proceed with preliminary impressions, construction of record bases and

Figure 14 Laboratory occlusal image of a maxillary radiopaque scanning appliance fabricated with a mixture of barium sulfate and autopolymerizing acrylic resin. The scanning appliance was a duplicate of a maxillary wax trial denture.

Figure 15 Laboratory occlusal image of a maxillary stereolithographic surgical guide fabricated from the digitized data of a CT scan. The blue- and gold-colored tubes were of 4.1- and 5-mm diameters, respectively.

Figure 16 Clinical image of a patient restored with a maxillary fixed implant-retained prosthesis. Note the posterior and superior resorption of the anterior maxillae, and the significant anterior cantilever associated with the anterior artificial teeth relative to the implants. This will likely increase the risk of prosthetic complications such as screw loosening, screw fracture, and/or issues with phonetics.

occlusion rims, tentative determination of jaw relationships/vertical dimension, articulator mountings, and trial denture setups. Alterations in vertical dimension, lip support, tooth form, tooth shade, and tooth arrangement should be accomplished such that patients and clinicians are comfortable with the tooth arrangement in the wax trial denture(s). Wax trial dentures would then be duplicated in barium sulfate/acrylic resin for use as scanning guides for preoperative radiographs and as surgical guides during implant placement as noted above (Fig 14). Scanning appliances should be tried-in clinically so that they are comfortable during the scanning procedures.

These diagnostic procedures involve more appointments, laboratory expense, and thought by clinicians, and are more complex. Therefore, clinicians should charge appropriate fees consistent with their efforts.

If implants cannot be placed relative to the planned positions of the artificial teeth due to lack of bone volume, bone grafting should be considered such that optimal bone volumes be established prior to or in conjunction with implant placement. Implants should not be placed into sites inconsistent with the proposed prosthetic designs. Implants need to be placed into adequate bone, but relative to the planned locations of the artificial teeth.

Fabrication of surgical guides (conventional, stereolithographic)

Surgical guides may be fabricated with various materials including, but not limited to, autopolymerizing acrylic resin, heat-processed acrylic resin, and heat-sensitive vinyl. The requirements of surgical guides are more important than the materials with which they are made. Guides should be stable when seated onto the remaining anatomic structures (soft tissue, bone, or teeth). Bone- and tooth-supported guides have proven to be more accurate than soft-tissue-supported surgical guides.[51] Other features for surgical guides include: ease of fabrication, reproducibility, transparency, and adaptability (Fig 15).

Implant angulations should be determined at the diagnostic stage. This has proven to be more easily and predictably accomplished with the advent of preoperative CT scans.[52] Clinicians can now visualize implant positions and angles relative to teeth and bone preoperatively, instead of having to make decisions at the time of surgery. Clinicians can take into account locations of screw access openings and whether the definitive prostheses will be cement- or screw-retained prior to ordering restorative components.

Fixed/removable prosthetics

The authors suggest that decisions regarding fixed- or removable-implant prostheses be made at the diagnostic phase of treatment. Key factors include the amount of A/P maxillary resorption that has occurred and the relationship between the optimal locations of the maxillary anterior teeth and maxillary edentulous bony ridge. If the distance is greater than or equal to 10 mm, the authors suggest that this is a primary indication for removable-implant prostheses, as patients typically require flanges for optimal lip support. In these cases, fixed, implant-retained prostheses appear to be contraindicated due to the length of the anterior cantilever and the strong potential for ridge lapping in the design of the prostheses (Fig 16).

Loading protocols

Current loading protocols have changed significantly from the first published delayed loading protocol. Branemark et al[53] reported on the survival of endosseous, machined, commercially pure titanium implants in 235 edentulous jaws where 85% prosthetic success was noted for patients followed from 9 months to 8 years. In a prospective, longitudinal, multicenter study conducted approximately 20 years later with a similar unloaded healing protocol, Becker et al evaluated clinical outcomes after placement and restoration of maxillary and mandibular Branemark implants.[54] The average amount of time between implant placement and prosthetic abutment connection was 170 days for maxillary implants and 147 days for mandibular implants. At 1 year, the implant success rate was 95.6%. In 1988, Albrektsson et al reported the results of a retrospective multiclinic study that included 14 Swedish teams outside the University of Gothenburg.[32] Total number of consecutively inserted implants at 14 clinics was 8139. The outcome of every implant was reported, and all implant failures, irrespective of when they occurred, were published. In the mandible, 334 implants were followed for 5 to 8 years, with only three failures, for a success rate of 99.1%. One hundred and six maxillary implants were followed for 5 to 7 years, with a success rate of 84.9%. Albrektsson et al concluded that osseointegrated implants, if inserted according to Brånemark guidelines, resulted in a high degree of clinical success, thereby meeting any published oral implant success criteria. This protocol has proven clinical effectiveness and should not be dismissed simply because it is "old." The major limitation of this protocol is that it may require 4 to 6 months of unloaded healing. In edentulous patients, this means that they will have to continue to wear their existing removable prostheses during this period. This is generally disappointing to them as the ill-fitting dentures or debilitated dentitions were among the reasons they sought treatment.

Early loading, as defined by Testori et al, involved fabrication of restorations with full occlusal function 8 weeks postimplant placement.[24] Galli et al compared periimplant bone and soft tissue levels of immediate, nonocclusal loaded versus nonsubmerged early loaded implants in partially edentulous patients up to 14 months after placement.[55] Fifty-two patients were randomized in five private practices: 25 were IL and 27 were early loaded (8 weeks). Immediate implants (n = 52) were provided with nonoccluding interim prostheses within 48 hours of implant placement. After 2 months, the interim prostheses were placed into full occlusion. The early loaded implants (n = 52) were placed into occlusal function 2 months postimplant placement. One IL implant failed 2 months after placement. There were no statistically significant differences between the two loading strategies for periimplant bone and soft tissue level changes ($P > 0.05$). Galli et al concluded that there were no clinically significant differences between immediate and early loading of dental implants with regard to implant survival, periimplant bone, and soft tissue levels. Multiple authors have evaluated early loading protocols and also found high survival rates for implants and prostheses.[56,57] Early loading protocols may be used with certain implant systems with efficacy similar to the Branemark protocol; however, they are not applicable for all patients, and certain surgical parameters must be met prior to deciding upon early loading protocols. Early loading protocols allow clinicians to treat patients quicker without losing efficiencies related to osseointegration.

Immediate loading represents a protocol where multiple implants are placed and splinted into full functional occlusion within 48 to 72 hours of implant placement. Schnitman et al[58] placed 63 3.75-mm Nobel Biocare machined implants of varying lengths into mandibular sites in 10 patients and followed them for up to 10 years. Of the 28 implants placed into immediate function, four ultimately failed. All 35 submerged implants osseointegrated and were in function at the time the article was published. Life-table analysis demonstrated an overall 10-year survival rate of 93.4% for all implants. The 10-year life-table analysis of survival was 84.7% for the IL implants and 100% for submerged implants.

Romanos and Nentwig also studied maxillary immediate occlusal loading that included progressive thread design and platform switching.[59] Ninety implants were placed (six into each maxillary arch) in 15 patients. Implants were loaded with provisional acrylic resin prostheses immediately after implant placement. Implants were splinted with interim prostheses for 6 to 8 weeks. In patients with augmented sites, a 3-month period of provisionalization was necessary to ensure implant stability. Definitive fixed restorations were fabricated and delivered. After a mean loading period of 42.4 (±19.15) months, Romanos and Nentwig reported three implant failures (CSR = 96.66%). They reported no complications during the study. They concluded that based on their results, immediately loading maxillary implants with fixed, splinted prostheses can be used successfully when implant primary stability, cross-arch stabilization, and a soft diet for the initial stages of healing are considered. Immediate occlusal loading has also proven to be a viable option in implant therapy; however, researchers have specified strict surgical criteria (high implant primary stability measured quantitatively is one of the most important) that must be obtained prior to immediate occlusal loading. If the surgical criteria are not met, immediate loading should not be used; patients must then be treated with either single- or two-stage unloaded healing protocols.

Implant loading protocols should be discussed after the diagnostic phase of treatment has been accomplished. The decision as to when implants should be loaded should be a joint decision of the clinicians involved, also taking into consideration the patient's perspective; however, even with all the improved diagnostics described in this article, the definitive decision may not be made until after the implants have been placed. Dental laboratory technicians should be included in the definitive treatment planning session, as they likely will be responsible for fabricating interim prostheses.

Conclusions

It may be considerably more difficult to obtain successful results in maxillary implant treatment than corresponding mandibular implant treatment. Thorough and complete diagnostics play a key role in achieving successful implant treatment. Determination of optimal tooth positions and their relationships to residual ridges or extraction sites is critical in determining the design for maxillary implant prostheses. Fixed/removable prosthetic designs should be determined prior to placing implants; removable prostheses should not be considered to be the "fall back" treatment option in the event of implant loss. Specific prosthodontic criteria need to be identified and understood by clinicians during the process. Long-term success can be predictably achieved by clinicians relative to maxillary implant treatment if the treatment guidelines described in this article are followed.

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