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Fixed-Prosthetic Implant Restoration of the Edentulous Maxilla: A Systematic Pretreatment Evaluation Method

*Edmond Bedrossian, DDS, FACD, FACOMS,**
Richard M. Sullivan, DDS,† Yvan Fortin, DDS,‡
Paulo Malo, DDS,§ and Thomas Indresano, DMD‖

Potential candidates for implant restoration of the completely edentulous maxilla may be interested in receiving a fixed prosthesis as opposed to a removable overdenture. Multiple surgical approaches are available in order to provide this type of care. Graftless approaches such as the use of tilted implants including the zygomatic implant, allow the surgeon to establish adequate support for a fixed prosthesis without bone grafting. Adjunctive procedures such as sinus grafting, maxillary osteotomies as well as horizontal augmentations are also available for surgeons who may prefer the grafting approach for the reconstruction of this group of patients. The ability to determine early in the consultation process the type of fixed prostheses necessary to provide the best functional and esthetic results is advantageous. This current therapy article examines 3 critical factors; the nature of the patient's dental condition and whether the residual ridge is visible in both the relaxed lip and smiling state, direct the choice of fixed dental prostheses. The presence or the absence of bone in the 3 radiographic zones, determines whether bone-grafting procedures are necessary to achieve the desired outcome.

Treatment of the edentulous maxilla poses a number of challenges. Expectations regarding the esthetics of the definitive prosthesis may be high. Achieving adequate phonetics and stable masticatory function are major concerns. Evaluation of the edentulous maxilla is complicated by the fact that patients may only be missing clinical crowns, or they may have experienced a combination of tooth, soft tissue, and bone loss, with associated changes in facial form. Bone and soft tissue loss can begin before tooth removal as a result of generalized periodontitis, creating the appearance of long teeth. The loss of teeth and use of a removable prosthesis can result in continued alveolar bone atrophy in both the vertical and horizontal dimensions.[1] In a study spanning 25 years, Tallgren observed that the greatest amount of alveolar bone atrophy occurs within the first year of edentulism.[1] Changes in the jaw relationship as well as facial musculature also may result in deformation or other changes in the facial form and morphology.[2]

A systematic pretreatment approach to evaluating edentulous patients allows for better communication between the implant team as well as the patients leading to a predictable treatment outcome. McGarry et al [3] developed a classification of complete edentulism that considers the quantity of the residual edentulous ridge, its morphology or topography, and the relationship of the maxilla to the mandible. Interarch space, tongue anatomy, and the attachment of the musculature to the edentulous ridge are considered. The possible need for preprosthetic surgical procedures prior to the fabrication of complete removable dentures is also evaluated.

The establishment of evaluation criteria may result in improved patient care, enhanced communication between dental professionals, and better screening and treatment of patients in dental educational centers.[3] Guidelines for the treatment of edentulous patients with implants should include consistent clinical

*Director of Implant Training, Department of Oral and Maxillofacial Surgery, University of the Pacific, San Francisco, CA; and Private Practice, San Francisco Center for Osseointegration, San Francisco, CA.

†Clinical Director, Nobel Biocare USA, Yorba Linda, CA.

‡Centre d'Implantologic Dentaire de Quebec, Ste-Foy, Quebec, Canada.

§Chief Scientist, Nobel Biocare AB, Gothenburg, Sweden.

‖Chairman, Department of Oral and Maxillofacial Surgery, University of the Pacific, San Francisco, CA.

Address correspondence and reprint requests to Dr Bedrossian: University of the Pacific, Oral and Maxillofacial Surgery, 450 Sutter Street, Suite 2439, San Francisco, CA 94108; e-mail: oms@sfimplants.com

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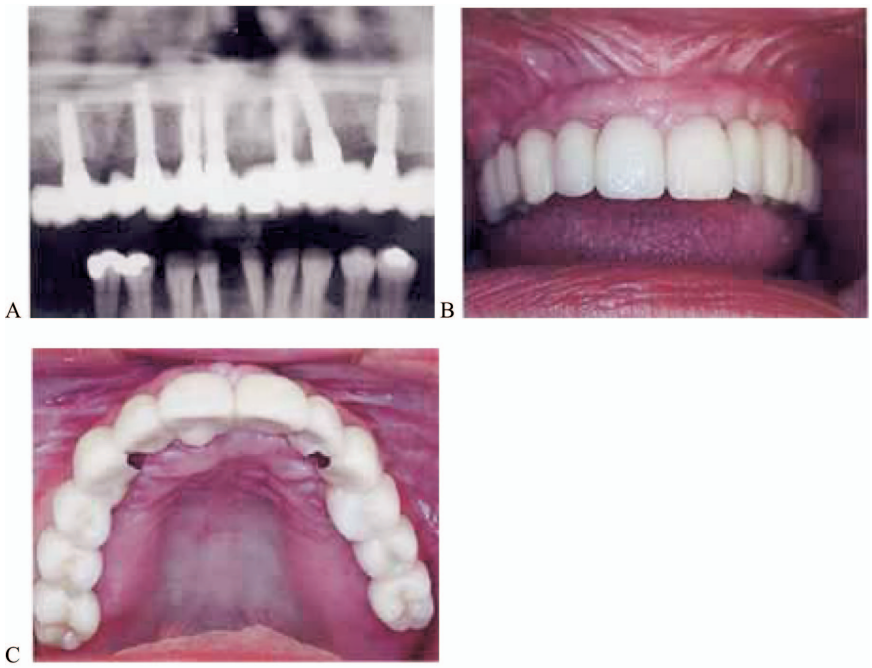

FIGURE 1. *A*, Bone volume allows placement of traditional implants in ideal location. *B*, Intact soft tissue contours enable tooth contours without gingival porcelain. *C*, Palatal contours of screw-retained restoration mimic natural teeth.

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and radiographic evaluation criteria for an accurate outcome assessment. Three factors available early in the examination process can be key determinants for the successful treatment of the completely edentulous maxilla with a fixed restoration. These factors are: *1*) the presence or absence of a composite defect, *2*) the visibility or lack thereof of the residual ridge crest without the denture in place, with normal smile and without use of retractors, and *3*) the amount of bone available in 3 separate zones of the maxilla, as shown in a panoramic survey. Evaluation of these 3 factors is not intended to be a substitute for thorough diagnosis and development of a treatment plan. However, such evaluation can provide differential diagnosis information specific to the esthetic, prosthetic, and biomechanical requirements of fixed, implant-supported maxillary restorations.

The purpose of this article is to outline initial screening methodology for determining which of 3 principal designs for fixed, implant-supported prostheses should be selected. Each design has been documented to fulfill aesthetic, phonetic, and hygienic demands and be a practical application for this treatment.

The Implant-Supported Fixed Dental Prosthesis

Complete dentures replace the clinical crowns of teeth, but depend on established denture-bearing areas of superficial bone and soft tissue during occlusal function for support.[4] To be maintained at normal physiologic levels, the bone requires internal loading such as that provided by the tooth roots or dental implants.[5] Fixed implant restorations are totally implant supported, with no transference of load to denture-bearing areas, thus avoiding the possibility of further resorption associated with tissue-borne prostheses.

Several approaches to restoring the completely edentulous maxilla have been published.[6-9] This discussion will focus on the application of 3 principal designs for implant-supported dental prostheses. These 3 variations have been chosen based on their ability to restore a broad range of soft tissue deficits. They are: *1*) the metal-ceramic restoration, *2*) the fixed hybrid restoration, and *3*) the fixed-removable restoration.

Metal-ceramic restorations may be either screw- or cement-retained.[10-12] Recognizing that ceramic restorations can include longer than normal length teeth and gingival replacement, emphasis will be on metal-ceramic restorations used to replace the clinical crowns of missing teeth only (Fig 1).

The hybrid prosthesis is a denture tooth and acrylic design with either a milled titanium or cast-gold framework (Fig 2). Early designs of implant-supported denture tooth and acrylic fixed dental prostheses had reported phonetic changes as a routine complication, due to air escaping during speech.[13] A later design known as the profile prosthesis[14] uses a framework design with subgingival abutment emergence that allows an acrylic resin wrap that butts up against the tissue as an ovate pontic so that air does not escape and cause phonetic problems. Because a ridge lap is avoided with the convex emergence from the ridge crest, oral hygiene access can be maintained in a manner similar to natural tooth fixed partial denture pontics.[14] A variation

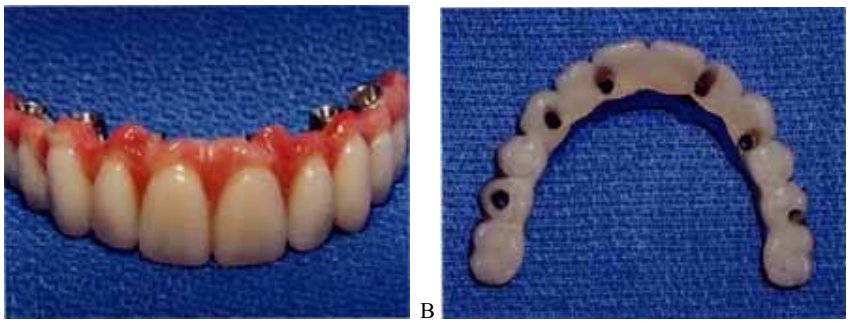

FIGURE 2. *A*, Denture teeth are supplemented with acrylic resin to replace tooth and soft tissue. *B*, Denture teeth and acrylic are veneered to milled titanium framework.

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of this design uses gingival porcelains or composite with all-ceramic crowns cemented to the framework if a porcelain restoration is desired.

For situations in which a labial flange is desirable, a fixed-removable prosthesis can be made with any number of attachments. Figure 3 shows a fixed-removable design known as a Marius bridge that is nonresilient and fully implant-supported.[15] Fixed-removable designs use a milled titanium or cast mesobar supporting a patient-removable superstructure that is held in place with a locking mechanism. This allows a ridge lap or flange design, with a suprastructure removable for oral hygiene access. Because a fixed detachable restoration does not depend on soft tissue support, no unnatural palatal extensions are required.

To determine which of these prosthetic concepts is most appropriate, 2 criteria should be considered: the nature of the patient's defect and the visibility of the residual crest. These findings help ascertain appropriate prosthetic design elements based on the combination of missing structures and unique esthetic requirements of the patient. A third criterion, radiological status, helps formulate an early strategy for achieving the structural support requirements for a fixed restoration, including type of implants to be used and probability of bone grafting procedures.

Prosthetic Selection Criteria

PRESENCE OR ABSENCE OF A COMPOSITE DEFECT

Edentulous patients may present with intact alveolar bone volume and only be missing the clinical crowns, or they may also present with resorption of their alveolar bone and loss of soft tissue as well as missing teeth (Fig 4). Differentiating between these 2 types of patients is key to creating an esthetic definitive fixed prosthesis. Patients who are missing soft tissue and underlying supporting bone in addition to teeth may be considered to have a composite defect. To evaluate the relative amount of soft tissue defi-

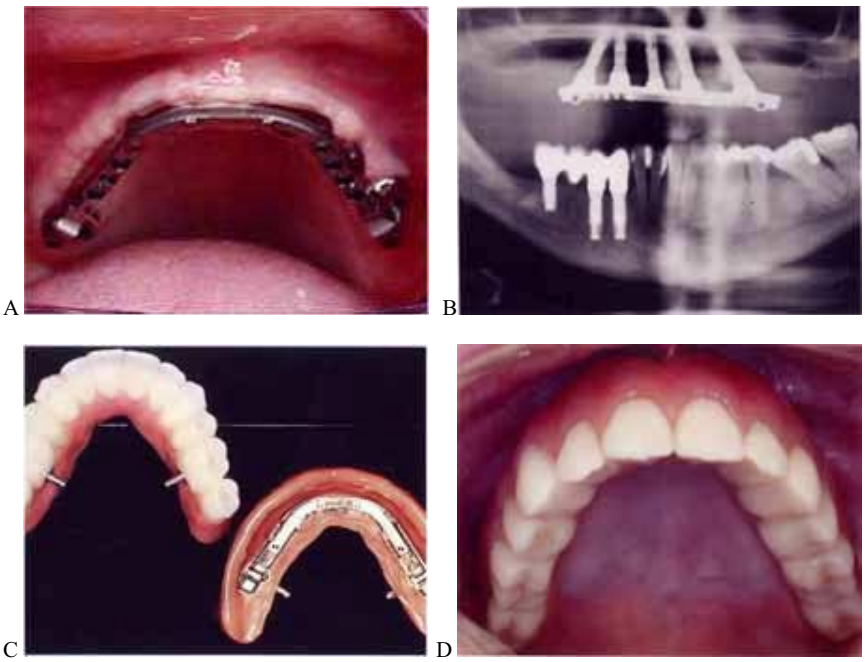

FIGURE 3. *A*, Mesobar with anterior 25 degree angle connected to implants. *B*, Radiograph of mesobar shows path of insertion not dependent on implant alignment. *C*, Two views of superstructure with posterior lock mechanism retracted. *D*, Prosthetic superstructure rigidly in place. This is implant supported without resilience.

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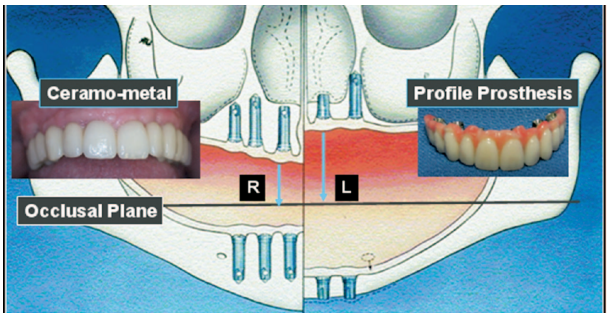

FIGURE 4. Missing only teeth (*left*) versus composite defect (*right*).

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ciency, it is advisable to utilize a denture or denture set-up in wax that has been confirmed for proper tooth position, border extension, and interarch relationship. With a satisfactory denture, the presence or absence of a composite defect can be quickly identified by assessing the thickness of the maxillary denture base and flange. Moderate to advanced resorption of the maxilla will be indicated by a denture base and flange which are generally thick. The opposite will be true in situations where minimal resorption has occurred and defects involving only teeth are present. For the latter patients, a thin denture base and a very thin or absent flange, especially in the anterior sextant, indicate an intact alveolus.[16]

It should be noted that defects due to resorption of bone and missing soft tissue occur in both the horizontal and vertical planes and may not be immediately obvious. To fully assess the presence or absence of a composite defect, duplication of the confirmed denture or tooth set-up by the dental technician or dentist using a denture duplicator (Denture Duplicating Flask; Lang Dental Mfg Co, Inc, Wheeling, IL) can be useful (Fig 5). A transparent acrylic resin (Ortho-Jet; Lang Dental Mfg Co, Inc) duplicate of the patient's denture is then placed intraorally, and the position of the cervical portion of the teeth and their relationship to the crest of the edentulous ridge is noted. For patients who present with no space between the cervical portion of the duplicated denture teeth and the edentulous ridge in either horizontal or vertical planes, a tooth-only defect is designated (Fig 6). In this situation, interarch space minimum requirements for the implant system and desired restoration still need to be observed. For patients who present with moderate to significant space between the cervical portion of the duplicated denture teeth and the edentulous ridge, a composite defect is identified (Figs 7, 8). Table 1 illustrates these considerations.

FIGURE 5. Denture duplicating flask using silicone putty for denture impression to make clear acrylic duplicate.

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FIGURE 6. Defect of teeth only.

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FIGURE 7. Mild composite defect.

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FIGURE 8. Advanced composite defect.

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FIGURE 9. Maxillary edentulous ridge not seen during animation.

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Preoperative determination of the presence or absence of a composite defect allows the clinician to determine the restorative space available for abutments and framework design. In the absence of a composite defect, a metal-ceramic restoration without extensive gingival porcelains can be used. The presence of a composite defect points toward the use of a fixed dental prosthesis in either the profile prosthesis or Marius bridge variations.

VISIBILITY OF THE RESIDUAL RIDGE CREST

To maximize the esthetic prosthetic result, the potential for visibility of the transition between the prosthesis and the soft tissue of the edentulous maxillary ridge without the maxillary denture in place should be evaluated, both in the anterior maxilla and the buccal corridor.

With the patient's maxillary denture removed, the patient should be asked to smile (Fig 9). If the soft tissue of the edentulous ridge cannot be seen, the transition between an implant-supported prosthesis and the residual soft tissue crest will not be visible, allowing a degree of flexibility for issues such as color match, shadows, and changes of contour in the junction of the restoration against the soft tissue (Fig 10). For those patients who do display the residual ridge soft tissue crest while smiling, the transition between an implant restoration and the soft tissue will be visible, and the esthetic consequences of this will depend upon whether or not the patient also has a composite defect. If the patient is missing only teeth but has an intact soft tissue volume, a metal-ceramic restoration can be used, and the fact that the gingiva is visible will improve the aesthetics rather than detract from them. This assumes that the implants are placed in planned tooth positions, and special consideration is given to anterior ridge lap pontics for the

Table 1. PRESENCE OR ABSENCE OF A COMPOSITE DEFECT

Intraoral Status	Diagnosis	Definitive Prosthesis
No space between the cervical portion of the duplicate denture teeth and the edentulous ridge	Tooth-only defect	Metal-ceramic
Moderate to significant space between the cervical portion of the duplicate denture teeth and the edentulous ridge	Composite defect	Marius bridge (fixed-detachable) or profile prosthesis (hybrid)

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FIGURE 10. Transition of prosthesis and residual ridge soft tissue is not visible.

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FIGURE 11. Unesthetic demonstration of transition line between prosthesis and residual ridge soft tissue.

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appearance of the papillae. Having fewer or no implants in the incisor areas if an adequate number of implants for the arch form can be placed in the posterior also allows for achieving esthetic goals with pontic designs.

However, when a composite defect is present, a metal-ceramic tooth-only restoration involves esthetic compromises due to longer than normal teeth. If a profile prosthesis is used with a visible residual ridge crest, the junction of the artificial gingiva and the natural soft tissue will be visible, and the differences in texture and contour between the 2 may be obvious (Fig 11). One method for avoiding this is to first reduce the residual ridge height to the point where the crest no longer is visible. Implants can then be placed and restored with a profile prosthesis. If the ridge is not reduced, the use of a Marius bridge with a flange that overlaps the gingival junction is indicated. This prosthesis can be removed by the patient so that oral hygiene is not compromised, yet it provides the stability of a fixed restoration.

Table 2 presents these guidelines.

Table 2. GUIDELINES FOR OPTIMAL FIXED DENTAL PROSTHETIC CHOICE

	Composite Defect	Tooth-Only Defect
Ridge visible	Marius bridge (fixed-removable)	Metal-ceramic restoration
Ridge invisible	Profile prosthesis (fixed hybrid) or Marius bridge (fixed-removable)	Metal-ceramic restoration

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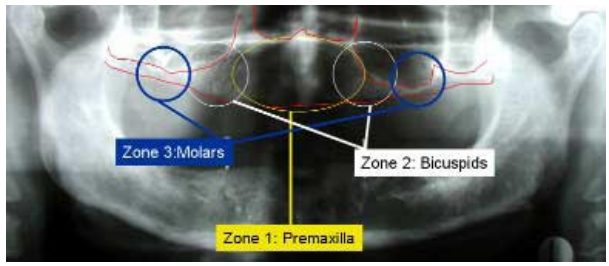

FIGURE 12. Three zones of maxilla are indicated.

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Radiographic Evaluation

Division of the edentulous maxilla into 3 radiographic zones allows for a systematic assessment of the residual alveolar bone available for implant placement. In this pretreatment screening procedure, the maxillary anterior teeth are designated as zone 1. The premolar region is considered to be zone 2, while the molar region is designated as zone 3 (Fig 12). Analysis of the radiographic results according to this schema can enable the surgical and restorative team to devise a preliminary treatment plan. In complex or borderline situations, 3-dimensional radiographic evaluation may still be necessary to confirm the preliminary conclusions.

For a fully implant-supported, non-resilient maxillary restoration, the implant-support requirements of all 3 fixed restorative options discussed in this article are the same. A minimum of 4 implants should be used, although the option to place more than 4 may be considered, depending upon the available bone volume and other functional considerations.[17,18] Rather than the number of implants used per se, once a minimum of 4 implants is achieved what is most

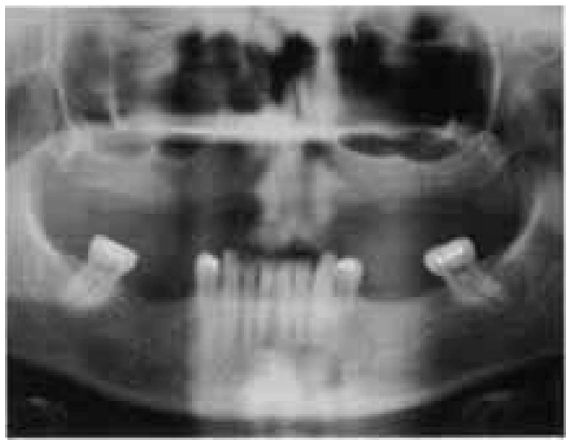

FIGURE 13. Provided adequate buccolingual width of bone is verified, presence of all 3 zones in maxilla allows straightforward placement of implants.

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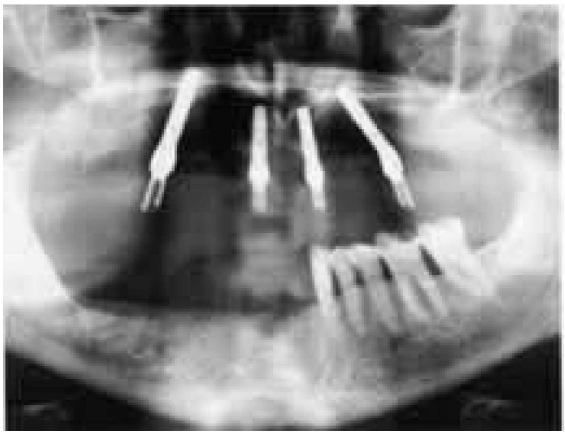

FIGURE 14. Tilted posterior and traditional anterior implant concept; presence of zones 1 and 2 only.

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important is the arch-form distribution of those implants with both posterior and anterior support. As a general principle, cantilevers in fixed maxillary restorations should be avoided or minimized to 1 tooth to achieve an adequate functional occlusion.[12,19-21] Evaluation of the 3 radiographic zones allows for a preoperative determination of whether adequate arch form support for a fixed restoration is achievable to support the planned occlusal plane.

Presence of Zone 1, 2, and 3 Bone

For patients where alveolar bone is present in all 3 zones of the edentulous maxilla, conventional implants may be placed (Fig 13). This would allow for a favorable arch form of anterior, posterior, and possibly intermediate implants so that any of the 3 fixed restorative designs may be used.[23,24]

Presence of Zone 1 and 2 Bone

For patients who have zone 1 and zone 2 bone but lack zone 3 bone secondary to large pneumatized maxillary sinuses, inclining the implants posteriorly along the anterior wall of the maxillary sinus may allow for an adequate anterior and posterior distribution of implants to support a fixed restoration while avoiding the need for grafting[15,17,25-29] (Fig 14). Use of inclined implants has also been shown to be successful with immediate-loading procedures of the completely edentulous maxilla.[18,25] An alternative to the use of inclined implants is sinus inlay grafting, followed by subsequent implant placement. When extensive sinus inlay grafting is performed to provide posterior support, a staged approach waiting for graft maturation may be preferable due to lower survival when implants are simultaneously placed.[30] This has the effect of delaying restoration compared with the use of inclined implants.

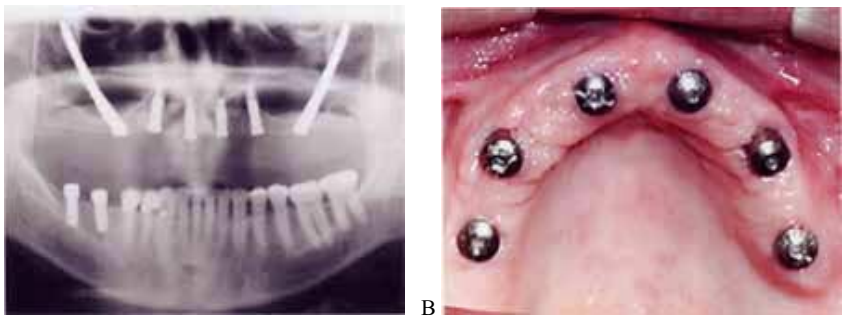
Presence of Zone 1 Bone Only

To establish posterior support for a fixed prosthesis, implants in the second premolar or first molar region are required. However, placement of implants in these positions is not possible when patients only have bone available in zone 1. Grafting of the sinus with autogenous or xenographic bone is an option in this situation. A 90% overall survival rate with 3 to 5 year follow-up has been shown with this approach.[31]

If a graftless approach is preferred, zygomatic implants have been shown to provide bilateral posterior maxillary support with a 97% to 100% implant survival measured up to 4 years.[32-34] Such implants have the added benefit of not requiring a staged approach and a period of bone graft maturation. This can shorten the overall treatment time required to achieve a fixed restoration. By placing 1 zygomatic implant in each zygoma, predictable posterior support can be established. When used in conjunction with 2 to 4 anterior implants, the restorative dentist is able to fabricate any of the 3 fixed, implant-supported prosthetic alternatives (Fig 15).

Bone Missing from Zones 1, 2, and 3

With complete resorption of the maxillary alveolus, clinical examination reveals a flat palatal vault. No maxillary vestibule is present, and the patient is unable to function with his or her conventional complete denture. Such patients present with a significantly thick denture base as well as a thick circumferential flange, confirming the presence of a significant composite defect. Physiologic reconstruction of this debilitated group of patients requires ad-



A B

FIGURE 15. *A*, Zygoma concept; presence of zone 1 bone only. *B*, Zygoma implants allow posterior support similar to traditional implants for restoration.

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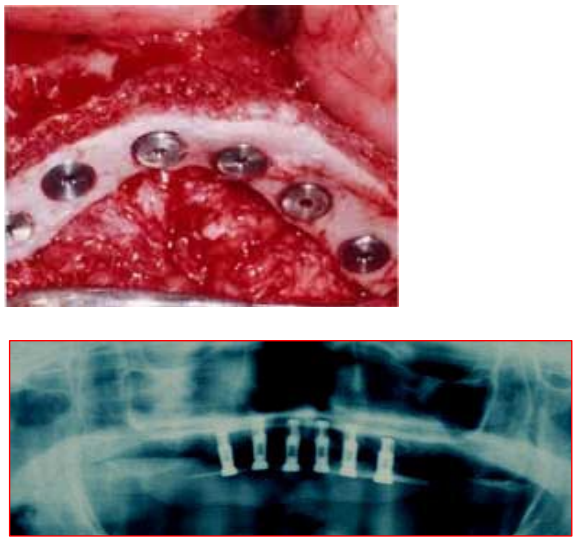

FIGURE 16. *A*, When bone is missing in all 3 zones, autogenous onlay grafting is one alternative. *B*, Previous lack of bone in all 3 zones of maxilla.

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equate implant support to stabilize an implant-supported prosthesis.

To enable prosthetic rehabilitation of such patients, Brånemark introduced the idea of using extensive onlay bone grafts in conjunction with bilateral sinus inlay grafts and placement of 6 implants.[35] The Brånemark horseshoe graft requires hospitalization and harvesting of autogenous iliac bone from the patient (Fig 16). The patient is unable to wear a denture during the 6-month osseointegration period. The social consequence of this form of treatment renders it unpopular with patients. An alternative, graftless approach is the use of 4 zygomatic implants (Fig 17). The placement of 2 zygomatic implants in each zygoma allows for the fabrication of an implant-supported fixed maxillary prosthesis without bone grafting and can be accomplished in an office setting.

Table 3 presents the guidelines for optimal implant selection.

Table 3. GUIDELINES FOR OPTIMAL IMPLANT SURGICAL APPROACH

Bone Present for Implants	Posterior Surgical Approach
Zone 1, 2, 3	Traditional implants
Zone 1, 2	Inclined implants, posterior implants Traditional anterior implants
Zone 1 only	Zygomatic implants or sinus-inlay grafting followed by implants Traditional anterior implants
Insufficient bone in any zone	4 zygomatic implants or Brånemark horseshoe graft followed by traditional implants

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Discussion

From an implant placement perspective, there is growing recognition that a large number of people with fully edentulous maxillae are able to be given a stable foundation to support a fixed restoration with fewer implants and fewer bone grafts.[15,18,25,26] Advances in computer-guided surgery allow placement of implants in the fully edentulous maxilla in a minimally invasive manner with increased precision to support the fixed prosthetic outcome.[36,37] Demonstrated viability of immediate function[18] and minimally invasive protocols [38] for fixed full-arch restorations may further increase demand and acceptance of this treatment by the public.

Definitive preoperative prosthodontic work-up for an implant-supported fixed maxillary prosthesis is a multifactor process. Steps of this process include surgical, medical, and laboratory consultations, transference of facial and occlusal records for analysis, radiographic templates, scanning procedures and subsequent interpretation, and development of a written comprehensive plan including potential complications and treatment alternatives. Completion of these preoperative steps requires significant commitments of time, resources, and ultimately patient investment. Results

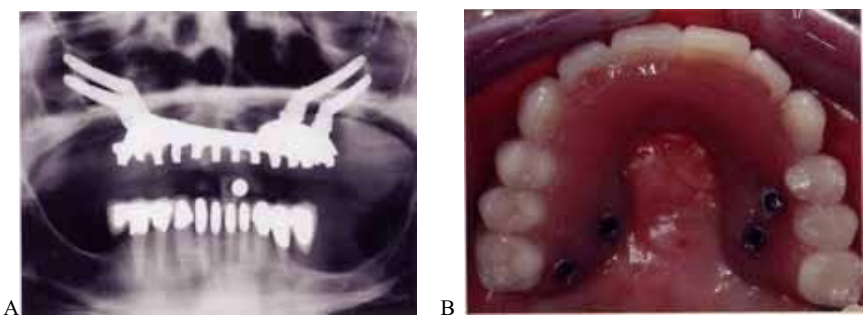

FIGURE 17. *A*, Bilateral zygoma implant concept; lack of all 3 zones of maxilla. *B*, Bilateral dual zygoma implant restoration.

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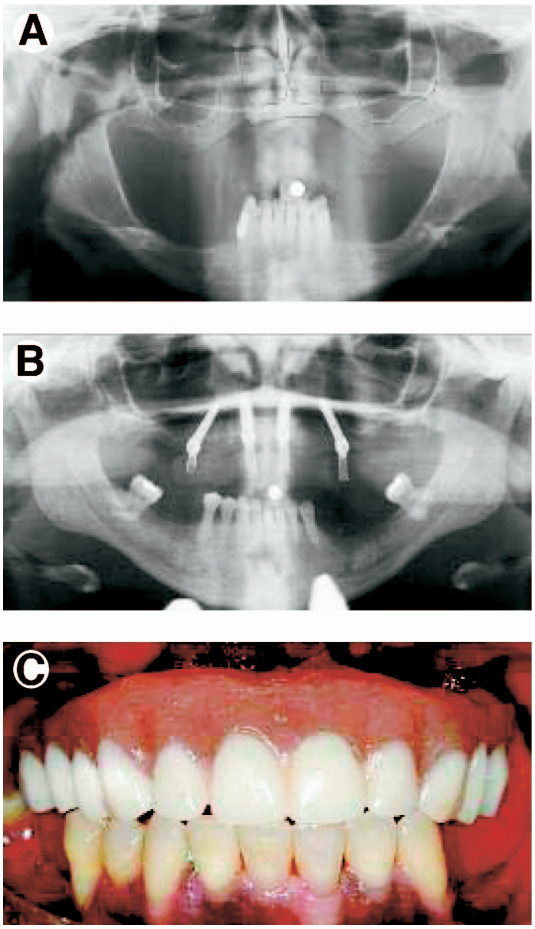

FIGURE 18. *A*, Preoperative panorex: Available zone 1 and 2 maxillary alveolar bone. *B*, Postoperative panorex: All-on-4 concept. *C*, Immediate postoperative profile prosthesis.

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of these findings will indicate but still not assure that a postoperative outcome is in accord with patient expectations identified in the preoperative subjective symptom interview.

Two prosthodontic diagnostic criteria have been coupled with 3 variations of implant-supported fixed maxillary prostheses to form a table. Each prosthesis alternative represents a potential restorative solution appropriate for the 4 possible combinations of these 2 diagnostic criteria.

The third preoperative diagnostic criterion divides a panoramic radiograph into 3 zones that have potential for implant placement. Due to a range of resorption, there are 4 potential zone combinations on each side of the maxilla that would allow for implant placement or suggest consideration of bone grafting. From a structural support perspective, there are no differences in implant requirements to support any of the 3 implant-supported fixed maxillary prosthesis variations given. Furthermore the clinical success rates for the various implant approaches are similar.[15,18,35,38] It should be noted however that for the metal-ceramic variation, the ridge position of the implants ideally corresponds with mesial-distal cervical tooth position; for the Marius bridge and profile prosthesis variations, implant alignment coincident to cervical tooth anatomy is not a factor. This second table suggests implant or grafting strategies for the posterior maxilla appropriate for different resorptive patterns.

CASE 1

A 48-year-old female presents with a full upper denture which is not retentive. Upon review of the preoperative panorex (Fig 18 *A*), she has maxillary alveolar bone in zones 1 and 2. She has minimal zone 3 bone. Using our pretreatment criteria, the All-on-4 technique was applied to establish implant support for her fixed prosthesis (Fig 18 *B*). The provisional prosthesis is a fixed, implant supported, profile prosthesis (Fig 18 *C*).

CASE 2

A 46-year-old female presented with a nonfunctional mandibular partial denture as well as a nonretentive maxillary full denture. The preoperative panorex (Fig 19 *A*) showed available bone in zone 1 and lack of alveolar bone in zones 2 and 3. The Zygomatic concept was utilized in her treatment (Fig 19 *B*). Adequate distribution of implants to support the profile prosthesis was established (Fig 19 *C*). Patient's transition line is apical to her smile line and therefore, not visible. This allows for an esthetic outcome (Fig 19 *D*).

APPLICATION OF BEDROSSIAN'S SCREENING

There are many factors to consider before treatment with implants for a fully edentulous maxilla takes place. At the same time, there is a clear benefit to identify early on as a screening procedure if there is likelihood of satisfying patient expectation with a prosthesis alternative realistically indicated by not only tooth loss but the degree of soft tissue and alveolar deficit that must be restored.

Similarly, systematic panoramic radiograph analysis based on zones of support can provide an early indication of the straightforwardness or surgical difficulty likely to be encountered. The combination of prosthodontic and radiographic diagnostic criteria can give an early impression of treatment possibilities from both surgical and restorative perspectives to help professionals clarify and communicate the potential treatment requirements and outcome. This understanding may then be used to advise the patient to proceed with commitment and investment for more definitive diagnostic procedures, confident that at

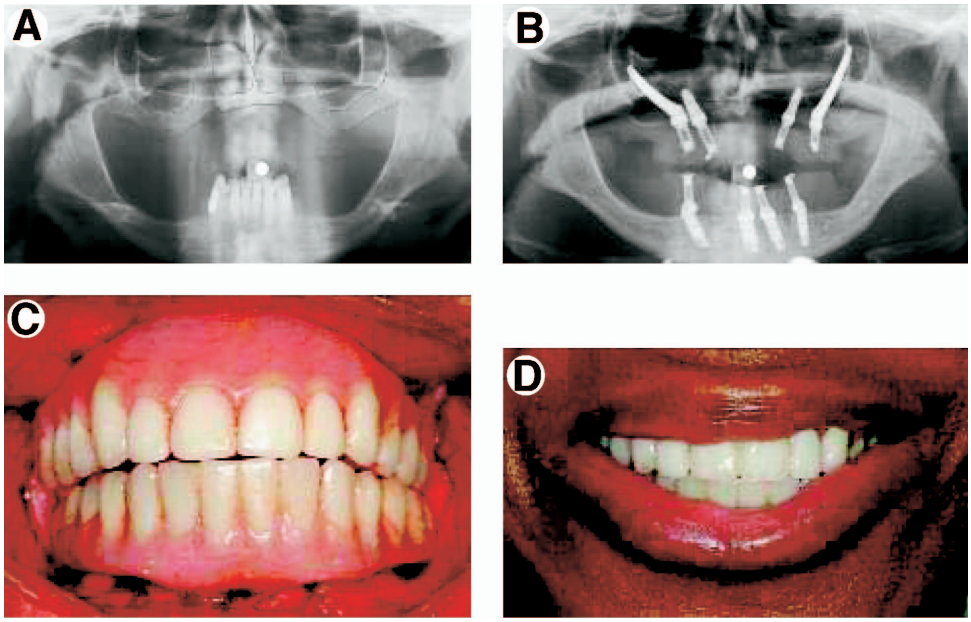

FIGURE 19. *A*, Pre-operative Panorex. Available Zone 1 and 2 bone only. *B*, Postoperative panorex. Zygoma concept, maxilla. All-on-4 concept, mandible. *C*, Immediate postoperative maxillary and mandibular profile prosthesis. *D*, Transition line is not visible resulting in an esthetic outcome.

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least the possibility for the desired prosthetic outcome exists.

One limitation of this approach is that the critical factor of sufficient alveolar ridge width still needs to be verified; this would only be discovered either after a tomographic film or scan, or intraoperatively. In either event, lack of sufficient ridge width could change the surgical approach significantly. Another limitation is that these criteria still need to be put into the overall perspective of health, medical, and dental history, and the knowledge that there can be deviations in desired outcome with even the most thorough planning. The criteria presented in this article are best looked upon as a preliminary screening apparatus to help guide patient and clinical decisions as more information is gathered. They are subject to change, however, at any time more definitive analysis or radiographic information does not support the preliminary impression.

There are also clinical situations where the objective is to remove remaining hopeless teeth and simultaneously place implants. While this preliminary diagnostic method is still applicable, it cannot account for variations in tissue height that may result subsequent to dental extraction.

Summary

The Bedrossian pretreatment screening method systematically considers the presence or absence of a composite defect, the visibility of the residual soft tissue crest, and the availability of bone in 3 radiographic zones as guidelines for the selection of 3 potential fixed implant restorative designs, as well as the optimal implant surgical approach. Use of these differential diagnosis criteria allows an early determination of the treatment necessary to meet patient expectations before a significant amount of time and resources has been invested.

A limitation of this protocol is the inability to measure the width of the residual alveolar bone available. While the panoramic survey film is a valuable 2-dimensional scouting radiograph and allows the practitioner to evaluate the height and length of the residual alveolar bone, use of 2-dimensional tomography that can precisely measure the width of the remaining ridge can aid the clinician in making a final determination of the likely outcome of the planned treatment. Communication between dental colleagues, students, and faculty, as well as third-party payment providers, can be made more uniform by the adoption of this evaluation method.

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