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Treatment Planning for the Single-tooth Implant Restoration — General Considerations and the Pretreatment Evaluation

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ABSTRACT This article reviews relevant clinical and radiographic information necessary to formulate an appropriate treatment plan for a patient requiring a single-tooth implant restoration. A step-by-step approach to collecting and analyzing this information at the pretreatment evaluation is presented. General considerations affecting implant treatment planning are discussed as are the parameters dictating ideal implant position and angulation.

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Several criteria must be met for the successful restoration of a missing single tooth with a dental implant restoration. Understanding how the patient's pretreatment presentation impacts the method of how, and to what degree, these criteria may be met, is critical to formulating an appropriate treatment plan and improves one's ability to restore natural esthetics, function, long-term health, and patient comfort. The purpose of this article is to present a step-by-step approach to collecting relevant clinical and radiographic information necessary to formulate an appropriate treatment plan for a patient with a missing single tooth. The Pretreatment Evaluation Form (**TABLE 1**) may be utilized to document clinical and radiographic findings that determine the need for adjunctive procedures and treatment prognosis.

Pretreatment Evaluation Appointment

Determining the Patient's Perspective

When a patient presents with a chief complaint that requires a single tooth replacement, the first step in the authors' evaluation process is to determine their preferences and expectations for treatment. Potential treatment options for replacement of a missing single tooth may include a single-tooth dental implant restoration, a three-unit fixed dental prosthesis, a removable partial denture, or a resin-bonded

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prosthesis.[1] Each option has advantages and disadvantages that may or may not meet the patient's expectations for treatment. A brief discussion of these advantages and disadvantages will help the patient determine those potential options to which they are amenable.

A single-unit implant may eliminate the need for adjacent tooth preparation, unlike a three-unit fixed dental prosthesis. On the other hand, dental implant treatment involves surgical procedures that the patient may not be agreeable to, or be able to undergo, due to medical health or other concerns. Although it is generally one of the least expensive treatment options, the patient may not wish to wear a single-unit removable partial denture due to the potential infringement of the major connector upon speech and masticatory enjoyment. Once the patient has made an informed decision to explore the dental implant option, the next step is to determine if the patient is a candidate for dental implant treatment.

Patient Evaluation

Systemic Evaluation

A number of factors may determine whether a patient presenting with a missing single tooth is a candidate for a single-implant restoration. Systemic contraindications to dental implant therapy are well documented.[2,3] While there are no true absolute contraindications to dental implant treatment that have been reported, diabetes, heavy smoking, history of radiation therapy, chemotherapy, and any other condition that may compromise the immune response may be considered relative contraindications.[2] Patients with such pre-existing condition should be treated with caution and be made aware of the potential guarded prognosis.[2]

Clinical Exam

Esthetic and Smile Analysis

Although it is beyond the scope of this article to fully elucidate the myriad considerations involved in dental esthetics and smile analysis, it should be noted that patients may vary widely in their level of esthetic demands and expectations. While failure to meet certain esthetic expectations may result in varying degrees of patient disappointment, failure to meet patient demands can be more problematic. These demands and expectations may not be limited to areas of tooth and gingival exposure when smiling, or areas exposed during normal speech and function. In other words, rather than being limited to the zone of visible teeth or gingiva, it is worth noting that "the esthetic zone is what the patient thinks it is."

A SINGLE-UNIT IMPLANT may eliminate the need for adjacent tooth preparation, unlike a three-unit fixed dental prosthesis.

In order to determine whether the patient's pretreatment physical presentation meets, or can be modified to meet, dental and gingival contours acceptable to the patient (whether visible under normal function or not), it is important to carefully document the patient's esthetic expectations and demands in detail. Documentation may include the degree of acceptance of asymmetries or discrepancies in 1) gingival balance; 2) papilla morphology; 3) root eminences; 4) gingival color and texture; 5) tooth morphology; and 6) tooth shade. Various biologic parameters such as those determining peri-implant soft tissue contours are then evaluated to determine whether absolute patient demands can be met and to what degree patient expectations can be fulfilled.

Photographic imaging and analysis

Digital photographs serve not only as a record of the patient's pretreatment condition but also facilitate diagnosis and treatment planning. In conjunction with diagnostic study casts, digital photographs facilitate making more accurate and convenient measurements of dental and gingival contours than may be made intraorally at the time of the pretreatment evaluation appointment.

An esthetics evaluation and documentation would generally include the following photographs: 1) facial views, both frontal and profile; 2) lips at a relaxed position; 3) natural smile view; 4) most extended lip position (like when pronouncing the letter "E"); 5) frontal and lateral views of the teeth with the cheeks retracted; 6) occlusal views of each arch, taken with an intraoral mirror; 7) teeth in protrusive and lateral excursive positions; and 8) regional occlusal, frontal, and lateral views of the edentulous area highlighting residual ridge contours.

Utilizing a graphic arts computer program, or simply a pen and ruler on a digital print, several reference lines can be drawn to illustrate asymmetries between the single-unit edentulous span and the dentate contralateral side. Occlusal views of the edentulous area may be compared with the contralateral root eminence to help determine the buccal extent of any contour deficit. In the frontal view, the height of each papilla is marked, as is the location of each interproximal contact. In addition, the height of the residual ridge crest is compared with the marginal gingival contour of the contralateral tooth.

FIGURE 1. Comparison of edentulous span dimensions with corresponding contralateral tooth dimension. The purple arrow indicates the excess space that is present as the black arrows are of the same length. Green arrow indicates the height of the contralateral tooth and relates it to the edentulous span.

FIGURE 2A. Thick gingival biotype with a less scalloped (flat) gingival architecture. Note the square tooth form.

FIGURE 2B. Moderately thin and scalloped gingival biotype. Note a more triangular tooth form.

FIGURE 3. Use of a periodontal probe to clinically assess the buccal contour of the residual ridge. Note lack of labial root prominence.

FIGURE 4A. Measurements made on a periapical radiograph (yellow: crestal bone contour; green: crestal bone to interproximal contact area; red: inter-radicular space available at ridge crest and apex.)

FIGURE 4B. Clinical photograph digitally superimposed on periapical radiograph illustrating hard and soft tissue relationships used to predict esthetic results.

In conjunction with periapical radiographs to determine underlying interproximal and crestal bone height, these pretreatment photographs may be utilized to predict post-treatment soft tissue contours by applying biologic principles and measurements dictating papilla and marginal gingival contours. Either a digitally manipulated image of the expected results, or a simple hand-drawn overlay over the pretreatment image may be produced for the patient to illustrate any potential asymmetries with the contralateral periodontium, such as the presence or absence of "black triangle disease" or any tooth length discrepancies.

Diagnostic Study Casts

Study casts are essential to collect and analyze clinical information for the treatment planning process. If study casts are available at the clinical exam visit, the smile line and amount of tooth display as previously discussed, may be transferred to the casts. A periodontal probe can be used to measure the distance from a specific landmark, such as the incisal edges and transfer the markings onto the casts. When multiple points are transferred, a connecting line can be drawn to indicate the overall lip curtain. The other dimensions that will be discussed subsequently can also be measured from a set of mounted diagnostic casts. As described in more detail later, study casts are also utilized to fabricate radiographic and surgical templates to help facilitate communication and coordination of treatment between surgical and restorative implant team members.

Adjacent Tooth Contour and Effect on Gingival Embrasure

The adjacent tooth contours play an important role in developing proper esthetics, contours of the final restorations, proper embrasures, and soft tissue architecture.[4] They should be assessed in terms of their size, shape (form), and color.[4] The size of the edentulous space should closely resemble its corresponding tooth on the contralateral side (FIGURE 1). Minor discrepancies may be adjusted by changing the contours and line angles of the restoration in the anterior zone. In moderate to severe cases, orthodontic tooth movement or other restorative procedures may be planned to distribute the spaces evenly.[5,6]

Teeth may be broadly classified into a square, ovoid, or triangular tooth form.[4] The longer and broader contact area between teeth that exhibit a square form facilitates masking of a deficient papilla (FIGURE 2). On the other hand, the more triangular tooth form tends to have a narrower contact point, which is usually away from the gingival crest. This increases the risk of an unesthetic dark space (aka black triangle disease) interproximally.[4]

For the anterior single-tooth implant restoration, of particular importance is the anatomy of the cingulae of contralateral anterior tooth. Making the cingulum contour of the single-implant restoration consistent with the natural lingual anatomy of the adjacent teeth minimizes the potential for phonetic difficulties and a "curious" tongue. While prominent natural cingulum contours may provide more "leeway" with regard to space for restorative material, patients presenting

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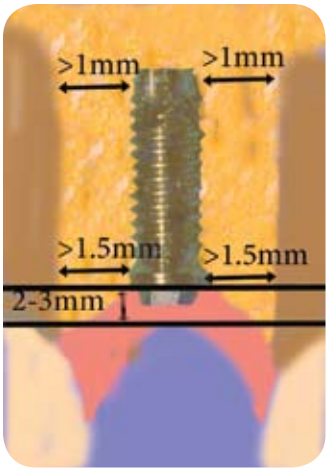

FIGURE 5A.

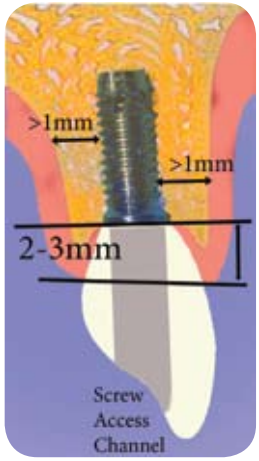

FIGURE 5B.

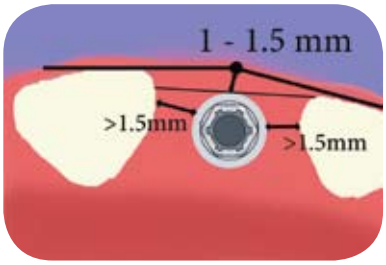

FIGURE 5C.

FIGURES 5A-C. Ideal 3-D implant placement. 1) 2-3 mm apical to the cementoenamel junction (CEJ); 2) 1-1.5 mm palatal to the proposed buccal contour of the tooth; 3) minimum of 1.5 mm of interproximal bone at the ridge crest; 4) minimum of 1.5 mm of bone bucally; 5) minimum of 1.0 mm of clearance at the radicular apex; 6) axial angulation commensurate with screw access opening in a nonesthetic tooth surface.

with minimal lingual contours provide little room for error, particularly in the case of a screw-retained prosthesis. This places an added responsibility on the restorative dentist and the laboratory technician to precisely dictate implant position and angulation via the surgical/radiographic template, and on the implant surgeon to precisely place the implant fixture.

In addition to the adjacent teeth, the residual ridge can also be clinically assessed at this point, as shown in **FIGURE 3**. A periodontal probe can be placed at the buccal height of contour of the adjacent teeth and the edentulous site is visually assessed. This may provide additional information to determine if additional bone grafting procedures are needed. This will be addressed in the subsequent article on hard tissue augmentation.

Adjacent teeth with overcontoured restorations or teeth that are mesially drifted or angled, those that are periodontally compromised and are already lacking a papilla may require a preprosthetic procedure prior to the implant placement. Orthodontic treatment may be a useful adjunctive procedure.[7] The location of the contact area on adjacent teeth may also need an adjustment prior to fabricating the final restoration. Teeth with contact areas that are located too coronally may require reshaping in order to prevent excessive gingival embrasures from appearing, or to achieve greater symmetry between contralateral papilla heights.

Soft Tissue Contour Assessment

Both the quality and quantity of soft tissue architecture should be noted in addition to the periodontal probing depths. The information to note would include: 1) the thickness of fibrous connective tissue; 2) the amount of attached tissue; 3) the amount of keratinized tissue; and 4) the degree and symmetry of the gingival scallop.

Thick and fibrous gingival biotype are considered more resistant to recession and generally result in a more predictable and stable outcome, as opposed to a thin biotype.[8] In addition, an adequate collar of keratinized tissue surrounding the implant restoration provides a healthy emergence, suitable to resist trauma from mastication, oral hygiene measures and allows for a prosthetic procedures more conveniently.[9]

The scallop of the gingival architecture would also be important to note.[4] The highly scalloped gingival would lend itself to be a more complex situation to maintain as opposed to the flat gingival contours as shown in **FIGURE 2**. This usually corresponds to the tooth form where the triangular form usually has a more scalloped gingival contour and vice versa.[8] The digital photographs can be used at this stage to mark the height (zenith) of the gingival contour with a straight line (**FIGURE 1**) so as to plan for the ideal apicocoronal position for the implant fixture.

The degree of papilla preservation can be predicted by the height of the adjacent bone when a single edentulous site is bounded by natural dentition. A distance of 5 mm from the interproximal crest of the adjacent teeth to the interproximal tooth contact point has been shown to maintain the papilla predictably.[10] This position is dictated by the interproximal bone level of the adjacent teeth rather than that of the implant site. When multiple teeth are missing in an edentulous site, papilla regeneration becomes more difficult and less predictable.[11] An in-depth discussion on the parameters and predictability of papilla preservation and reconstruction is presented in the following article on soft tissue procedures.

Radiographs

A full-mouth series of periapical and a panoramic radiograph are a good initial tool for determining the overall quantity of the bone. Root spacing and angulations

FIGURE 6. Sequence of pretreatment planning. Note the difference in the angulation of the proposed channel in the guide and the residual ridge. In this case, a decision had to be made to change the angulation of the implant or perform additional grafting procedure prior to placing an implant.

are adequately observed on the periapicals or panoramic radiographs (**FIGURES 2–6**). The crestal bone levels can be traced and connected (yellow line). The height from this crestal bone level and the anticipated interproximal tooth contact can be measured from the radiographs as well (green line) in order to calculate expected interdental papilla contours. Roots that are converging toward the edentulous space may create a surgical implant placement problem and so measuring this space, both at a crestal and apical position (red arrows) would aid in selecting the appropriate diameter of the dental implant.

However being a 2-D film, conventional radiographs do not provide an indication of the buccal lingual width of the edentulous site. A 3-D scan, like a tomogram or a cone-beam CT scan may be indicated at times. Previously, practitioners had mapped or sounded the bone to get an idea of the width of bone. The site was anesthetized and soft tissue is mapped with a periodontal probe or an explorer with an endodontic stopper. The thickness of the soft tissue is measured at multiple sites from the buccal to the lingual vestibule. This process may be quick but is also a little inconvenient and uncomfortable for the patient. The CT scans are generally more accurate and are also able to determine the quality of the bone by providing a density value. Moreover, there are several implant planning software programs that allow 3-D digital surgical planning utilizing CT data in order to anticipate whether the implant can be place ideally or if any adjunctive graft procedure may be needed. These scans are best done with a radiographic guide in place in order to obtain the location of an ideally contoured restoration and its relationship to the amount of bone available. If orthodontic treatment is anticipated, the periapicals and the panoramic radiographs are generally sufficient initially. At the completion of orthodontic treatment, a CT scan may be performed for more diagnostic information, prior to implant placement.

Ideal Implant Positioning
(REFER TO FIGURES 5A–C)

Spacing Requirements

As a general guideline, for a typical 4 mm regular platform implant, a 7 mm mesial-distal space between adjacent teeth at the coronal portion is the minimal requirement. This allows for 1.5 mm of crestal bone interproximally, which, in turn, will allow for proper development of a healthy papilla.[12,13,4] An article on soft tissue procedures, included in this issue, will discuss how the concept of "biologic width" is applied to the soft tissue around an implant restoration. Apically, 6 mm between adjacent roots is recommended, to allow at least 1 mm space from the implant to the root. These guidelines generally allow for adequate blood supply to maintain the interproximal bone.

Implant Bodily Position

Occlusal-gingivally, the vertical position of the implant is determined by the level of cementoenamel junction of the proposed restoration at the edentulous site. The implant should be placed just deep enough to allow for a proper emergence profile but not excessively deep as to cause a periodontal maintenance issue.[12] Ideally implants should be placed 2-3 mm apical to the facial CEJ position of the planned final restoration, not the adjacent teeth. With regard to length of the implant, ideally it should be in the range between 10 to 13 mm. A shorter implant may be more prone to occlusal overload while implants longer than 13 mm do not necessarily improve the biomechanics.[14]

Facial-lingually, a minimum of 1 mm of bone present on either side of the implant may help keep the soft tissue levels stable. This may be more crucial on the facial aspect since any changes in bone resorption will esthetically affect the position of the gingival margin.[15] As a precaution, a 0.5 mm palatal shift in implant position is often elected for having about 1.5 mm of buccal bone remaining. This will also allow a more favorable screw access hole through the cingulum of an anterior tooth and may reduce the need to correct for angulations issues.

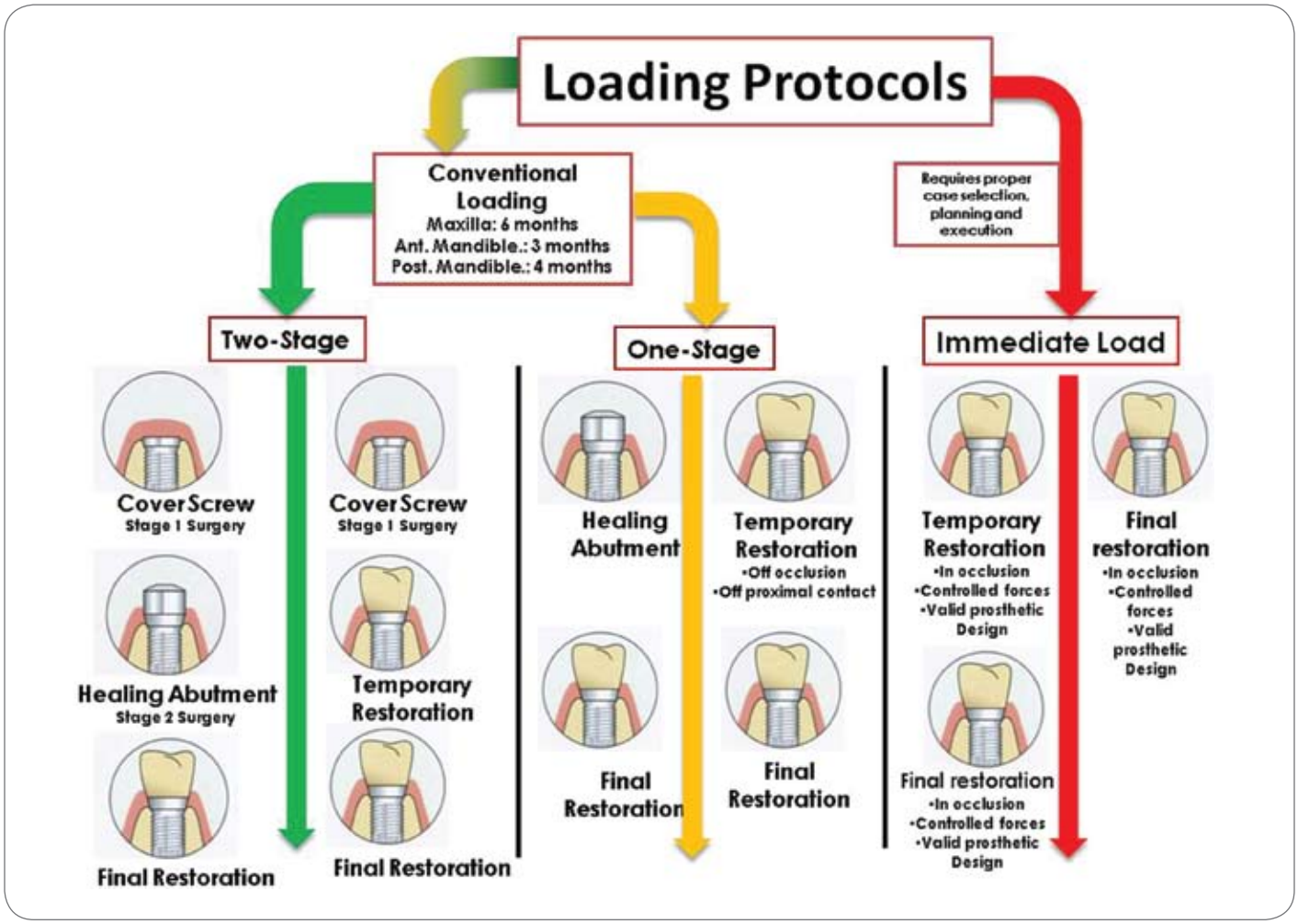

FIGURE 7. The various loading protocols for an implant replacing a single missing tooth.

Angulation

Implant angulation should be determined by the ideal contours of the final restoration. Occlusal forces are best tolerated when they are directed down the long axis of the dental implant fixture. Maxillary anterior implants would have a slight proclination while maxillary posterior implants may be angled slightly toward the buccal. Mandibular posterior implants may be angulated slightly lingual following the resorption pattern and direction of masticatory forces (Curve of Spee and Wilson). If there is insufficient bone, grafting procedures should be done and an attempt be made to position the implant in a more favorable angulation thereafter.

Diagnostic Work-up

A set of mounted cast and diagnostic work-ups are useful in the dental implant treatment planning process. **FIGURE 6** indicates the sequence of this planning process. A idealized diagnostic wax-up is done to mimic final restorative contours regardless of underlying bony or soft tissue deficiencies. The laboratory technician would then duplicate it and fabricate a radiographic/surgical guide or template. There are a variety of methods of fabricating a radiographic/surgical guide.[16] A rigid vacuum-formed stent may be formed over a duplicate of the diagnostic wax-up in order to duplicate the missing tooth and to provide a means to consistently orient the guide intraorally. A radiopaque material such as barium sulfate is mixed with acrylic/composite resin and used to fill in the missing tooth in the stent.

Alternatively, the radiopaque mix can be utilized to form a denture "tooth" and then oriented with an occlusal index of clear autopolymerizing acrylic resin. Either way, a channel is drilled through the center of the radiopaque "tooth" indicating the ideal implant position and angulation (**FIGURE 6**). An alternate method of fabricating the surgical guide is to fill the tooth mold with regular acrylic/composite resin. The channel is prepared similar to the first method but is filled with gutta percha as a radiopaque marker. In addition, the buccal surface of the tooth is lined with tin foil. The radiopaque tin foil appears as an outline in the

TABLE 1

Implant Pretreatment Evaluation

Patient _____ Date _____

Chief Concern _____

Significant Medical History / Meds / Allergies _____

Edentulous region _____ (tooth number to be replaced)

Smoking	☐ No	☐ Yes	_____ (quantity)
Alcohol	☐ No	☐ Yes	_____ (quantity)
Parafunctional habits			
Bruxing/Clenching	☐ No	☐ Yes	_____ (frequency)
Smile line	☐ Low	☐ Average	☐ High
Occlusal scheme	☐ Anterior guidance	☐ Group function	☐ Posterior interferences
Adjacent tooth/crown form	☐ Square (contact area)	☐ Ovoid	☐ Triangular (contact point)
Hard tissue			
Horizontal deficiency	☐ No	☐ Yes	_____ (quantity)
Vertical deficiency	☐ No	☐ Yes	_____ (quantity)
Soft tissue			
Gingival biotype	☐ Thick/fibrous	☐ Average	☐ Thin
Gingival contour	☐ Flat	☐ Average	☐ Scalloped
Presence of attached tissue	☐ Yes	☐ No	
Presence of keratinized tissue	☐ Yes	☐ No	
Radiographic exam			
Adjacent root angulation	☐ Divergent	☐ Parallel	☐ Convergent
Mesial-distal space at crest		_____ mm	(≥7 mm ; <7 mm)
Mesial-distal space at apical end/root tip		_____ mm	(≥5 mm ; <5 mm)

Distance from adjacent crestal bone to contact point (mesial to space) _____ mm

Distance from adjacent crestal bone to contact point (distal to space) _____ mm

(<5 mm ; between 5-7 mm ; >7 mm)

Overall prognosis ☐ Good ☐ Fair ☐ Guarded

scans indicating the buccal contour of the tooth and its relation to the residual ridge.

These guides are relatively inexpensive to fabricate in comparison to the overall treatment cost and are critical not only to assess and plan the proposed implant position but to accurately relate the radiographic image to the actual site at the time of surgery. Following their use as a radiographic guide, the guides are sterilized for use as surgical templates. They should be free from debris, loose particles, or burs that may dislodge and contaminate the surgical site.

A number of software packages allow CT data to be utilized for computer-aided implant surgical planning by means of virtual surgeries on modeled 3-D images. Some of these programs incorporate the ability to generate surgical guides via CAD/CAM technology. These guides are made with computer-machined channels that limit the site preparation to the precise implant angulation, bodily position, and depth determined during the software planning phase. While these technologies may promise greater potential precision in implant placement, at this time, there may be some added costs to these types of guides particularly for the single-tooth application in comparison with manually produced guides.

Occlusion

It is important to understand what factors may affect the anticipated load the implant restoration must resist. Implants generally perform better in axial load as opposed to lateral loads.[17] In the anterior maxilla, lateral loads are unavoidable due to the vertical and horizontal overlap of the anterior teeth. The relationship of the opposing dentition plays a vital role in the long-term success of the restored implant. The amount of interarch space (crown-height space) available should also be noted as it may impact treatment planning decisions.[18,19] Dentitions with good stable bilateral simultaneous contacts in centric relation or maximum intercuspal position would allow a light centric contact on the implant restoration with minimal risk of implant overload.

The type of occlusal scheme the patient presents with should be noted. Favorable occlusal schemes would include those that have good, immediate anterior guidance.[20] This could help avoid excessive lateral loads on a posterior implant, for example. Ideally, the implant restoration should not change the existing occlusal scheme.

Patients who exhibit parafunctional habits are not contraindicated from having an implant restoration. Although no controlled definitive clinical outcomes studies exist, some practitioners have suggested that occlusion has to be carefully analyzed and the restoration adjusted to have narrower occlusal tables to minimize implant overload or fracture.[21,22] If space permits, like in the molar regions, some practitioners have placed two smaller diameter implants for a single-tooth restoration to increase the bone/implant interface in an attempt to achieve more favorable stress distribution and resistance to overloading.[22] **FIGURE 7** illustrates the various loading protocols for an implant replacing a single missing tooth.

Summary

The initial steps of a new patient evaluation and factors to consider for treatment planning a single-tooth implant restoration have been presented. ■■■■

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