REVIEW ARTICLE

Implant Site Development—Part I

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Abstract

This three part review evaluates the different techniques of improving the implant site in order to restore the lost alveolar bone, to allow for successful implant placement and subsequent prosthetic reconstruction. In this study anatomy and physiology of the maxillary sinus, preoperative evaluation of the alveolar ridge, maxillary and mandibular procedures, grafting procedures and postoperative complications are discussed. It was concluded bone augmentation allows clinicians to reconstruct alveolar bone deficiencies, preserve alveolar dimensions and replaces missing teeth with dental implants in a prosthetically driven position with natural appearance and function. The predictable outcome of these procedures depends on several biologic principles that must be followed. Diagnosis, treatment planning, careful execution of the surgical treatment, postoperative follow-up, and appropriate implant loading are all important factors in achieving success.

Keywords: Bone augmentation, block grafts, particulate materials, protective barriers, splitting of alveolar ridge, direct or indirect sinus grafting or elevation, repositioning of alveolar nerve and distraction osteogenesis.

INTRODUCTION

Endosseous dental implants are currently the most innovative and exciting treatment modality in dentistry. They are being used for variety of indications, and most of the various techniques in use are evidence-based and predictable. To satisfy the ideal goals of implant dentistry, the hard and soft tissues need to present ideal volumes and quality. However, in many cases, the intended implant site is compromised because of low bone density in the case of highly cancellous bone, or low vascularity, in the case of primarily cortical bone or insufficient quantity of bone (in terms of width or height of the alveolar ridge). In addition the placement of maxillary anterior implants is even more critical for ideal esthetics, phonetics and function Lack of sufficient alveolar ridge height is often related to proximity of the implant site to other anatomical structures (i.e. the maxillary sinus or the mandibular canal).

In these situations separate preparatory procedures may be required to augment the available volume of bone before placement of implant, which may result in extramorbidity, longer treatment time, greater risk of complications and higher costs. Surgical procedure that have been developed to deal with problems of insufficient alveolar ridge width or height include ridge augmentation with block grafts or particulate materials and protective barriers, splitting of alveolar ridge, direct or indirect sinus grafting or elevation, repositioning of alveolar nerve bundle and distraction osteogenesis. Alternatively, orthodontic procedures have been used to extrude and eventually extract "hopeless" teeth or to move salvageable teeth into adjacent edentulous sites. Ultimately, this approach leads to regeneration of lost bone and enables implant placement in the vacated site.

QUALITY OF AVAILABLE BONE

Available bone describes the external architecture or volume of edentulous area considered for implants. In addition bone has an internal structure described in terms of quality or density, which reflects the strength of bone. Density of alveolar bone is a determining factor in treatment planning, implant design, surgical approach, healing time and initial progressive bone loading during prosthetic reconstruction.

BONE CLASSIFICATION SCHEMES RELATED TO IMPLANT DENTISTRY[1]

Linkow in 1970, Classified Bone Density into Three Categories

Class I bone structure: This ideal bone type consists of evenly spaced trabeculae with small cancelled spaces.

Class II bone structure: The bone has slightly larger cancellated spaces with less uniformity of the osseous pattern.

Class III bone structure: Large marrow-filled spaces exist between bone trabeculae. *Linkow stated* that class III bone results in a loose-fitting implant; class II bone was satisfactory for implants; and class I bone was a very satisfactory foundation for implant prosthesis.

Lekholm and Zarb 1985 Listed Four Bone Qualities Found in the Anterior Region of the Jaw Bone[2] (Fig. 1A)

Quality 1: Composed of homogeneous compact bone.

Quality 2: Thick layer of compact bone surrounding a core of dense trabecular bone.

Quality 3: Thin layer of cortical bone surrounding dense trabecular bone of favorable strength.

Quality 4: Thin layer of cortical bone surrounding a core of low-density trabecular bone.

Misch Bone Density Classification[3] 1988

Misch extended four bone density groups independent of the regions of the jaw, based on macroscopic cortical and trabecular bone characteristics.

Bone   Density

D1   Dense cortical bone.

D2   Thick dense to porous cortical bone on crest and coarse trabecular bone width.

D3   Thin porous cortical bone on crest and fine trabecular bone within.

D4   Fine trabecular bone.

D5   Immature, nonmineralized bone.

These four macroscopic differences of bone may be arranged from the most dense to the least dense, as first described by Frost.

BONE DENSITY–TACTILE SENSE[4]

Drilling and placing implants into:

D1 bone: It is similar to drilling in oak or maple wood.

D2 bone: It is similar to drilling in white pine or spruce.

D3 bone: It is similar to drilling into balsa wood.

D4 bone: It is similar to drilling into Styrofoam.

BONE DENSITY- LOCATION

D1 bone: It is never observed in maxilla. In mandible observed 8% of time, twice as often in anterior.

As the bone is reduced in volume from to C-h, the D1 bone in anterior mandible is increased to 25% and D3 bone is reduced to 10%.

D2 bone: It is most commonly seen in mandible. 2/3rd of anterior mandible is D2. Posterior mandible has D2 bone in 50% of patients Maxilla has D2 less often than mandible 25% of patients have D2 and is more likely in partially edentulous anterior premolar region than in completely edentulous posterior region. Single tooth partially edentulous have D2 bone.

D3 bone: It is very common in maxilla. 50% of patients have D3 bone in maxilla. Anterior maxilla has D3 in 65% of cases. 50% of patients have posterior maxilla with D3. 50% of posterior mandible and 25% of anterior have D3.

D4 bone: It is the softest bone found in posterior maxilla (40%) in the molar region or after a sinus graft augmentation.

Anterior maxilla has D4 in <10% of time after onlay iliac crest bone graft. Mandible presents D4 in < 30% of cases.

The bone density may be different near crest than the apical region (Fig. 1B). The most critical region is the crestal 7-10 mm of bone which determines the treatment protocol.

BONE STRENGTH AND DENSITY

Bone density is directly related to the strength of bone before microfracture. A tenfold difference in bone strength may be observed from D1 to D4 bone. D2 bone exhibited a 47% to 68% greater ultimate compressive strength, compared with D3 bone.
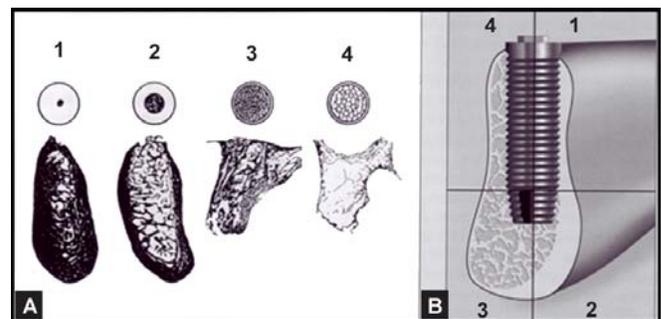
Figs 1A and B: (A) The four bone qualities defined by Lekholm and Zarb, along with typical examples of human undecalcified thin ground sections of the maxillae. (B) Different areas of a single implant site may be characterized by different types of bone

QUANTITY OF AVAILABLE BONE

The alveolar bone reacts to dental extraction by remodeling its structures, removing bone at its outer surfaces and depositing bone in the empty sockets. The various factors affecting alveolar bone resorption can be classified as mechanical, biological and anatomical. Five general groups of diverse jaw shapes encountered after extractions are as follows (Figs 2 and 3).

The various atrophic presentations generally determine the choice or modality of various implant systems. In a multimodal approach a combination of systems is recommended. Often bone augmentation is chosen to convert an atrophic ridge to a ridge that is adequate to receive root form implants. While subperiosteals and plate/blade form implants have been successfully used in the past, their utilization has decreased due to nonavailability of manufacturers and courses that teach such modalities. Another way to circumvent augmentation is the utilization of angled implants.

TOOTH-RELATED CONSIDERATIONS

The maxillary lateral incisor crown is more slender than the central incisor and may lean more medially. The labial surface is more convex than is the central incisor; frequently, the root is bent distally or distolingually near the apex.

The maxillary permanent canine is at the corner of the dental arch, and its anatomy reflects the beginning transition from anterior to posterior tooth forms. The root of the canine
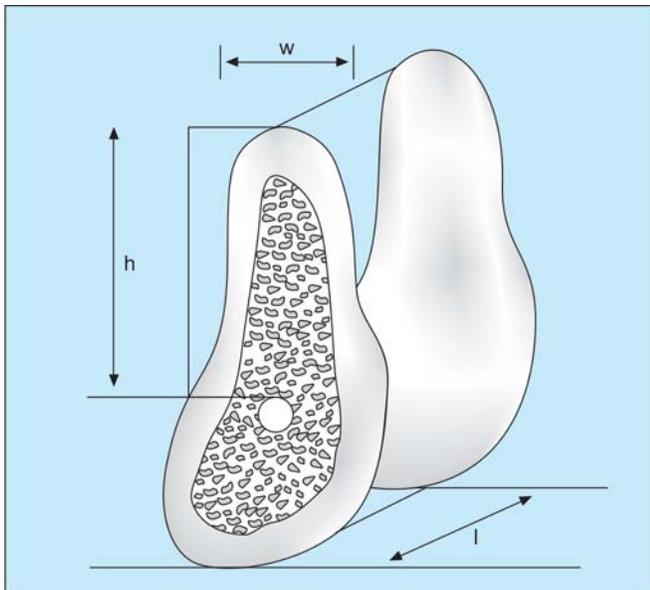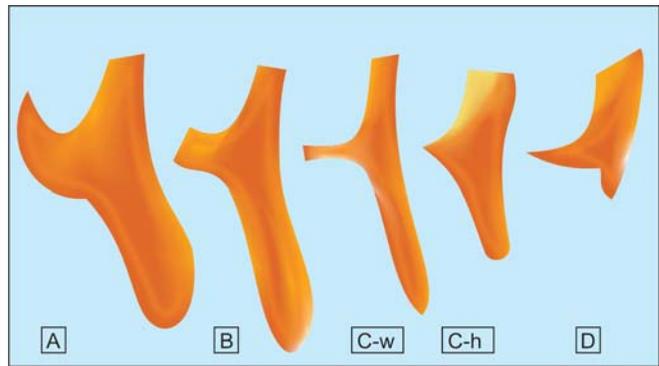

A: most of the alveolar ridge is present;
B: moderate residual ridge resorption has occurred;
C-w: advanced residual ridge resorption has occurred, only basal bone remains
C-h: some resorption of the basal bone has occurred;
D: extreme resorption of the basal bone has taken place.

Fig. 3: Misch CE, contemporary implant dentistry (2nd ed). Classification of available bone (Divisions A, B, C and D) h = height; w = width

is the longest and strongest in the human dentition. For an acceptable esthetic outcome, the clinician should keep the crown height and length proportions of implant-supported restorations similar to those of the natural teeth also, the anatomical location of maxillary canines in relation to ipsilateral and contralateral dental arches creates additional challenges for implant placement and for manipulation of the gingiva around implant-supported restorations. Relationship of lips to teeth and gingiva.

In the average smile, the lip is positioned to show 75 to 100 percent of the maxillary central incisor and the interproximal gingiva. A high smile line reveals the total cervical-incisal length of the maxillary anterior teeth and a contiguous band of gingiva

A low smile line displays less than 75 percent of the anterior teeth.

ANATOMY AND MORPHOLOGY OF SOFT TISSUES

Periodontal Biotypes

The soft-tissue phenotype (that is, shape and thickness) contouring a crown can be defined as the "periodontal biotype." Researchers have described two periodontal biotypes: the thick-flat biotype and the thin-scalloped biotype. Different biotypes have a tendency to respond differently to inflammation and surgical injury. In a patient with a thin-scalloped periodontium, the surgical and restorative intervention involved in esthetic implant therapy may result

Fig. 2: (From Misch CE, CID 2nd ed). Bone quantity measured by width (w), height (h), length (l)

in some degree of soft-tissue recession (Fig. 4). Also, the thin maxillary buccal plate is predisposed to defect formation secondary to remodeling and resorption of bone after extractions and/or implant therapy. On the other hand, the thick-flat periodontium resists recession and reacts to surgical and restorative therapy with pocket formation (Fig. 5). This type of tissue is predisposed to forming notches and scars that can jeopardize the final esthetic and functional results. Researchers have evaluated the peri-implant biotype and categorized it as thick or thin, similar to periodontal biotype.[4]

Biological Width Concept and Dental Implants

The physiological dentogingival junction of natural teeth includes the length of the epithelial attachment, the length of the connective-tissue attachment and the depth of the sulcus. This also is known as "the biological width." The mean value of the biological width around a natural tooth is

Fig. 4: Thin biotype (note the grayish hue of the healing abutment showing through the thin gingival)

Fig. 5: Thick biotype—Implant, abutment and PFM crown on 21 site is well-masked by the thick biotype

2.73 mm. The implant-epithelium junction is similar to that in the natural dentition, except that it is shorter and thinner than the tooth-epithelium junction.[5]

Because of the absence of a cementum layer around an implant, most connective-tissue fibers in supracrestal region are oriented in a direction parallel to the implant surface. Furthermore, investigators have observed the presence of an avascular zone, 50 to 100 micrometers wide, of dense circular connective-tissue fibers that are in direct contact with the implant post at the supracrestal area. The biological width around implants can have significant influence on the character of soft tissues and depends on a variety of characteristics that include implant design, presence of adjacent teeth and quality of soft tissue. For example, one-piece implant designs have been implicated in more closely mimicking the biological width around natural teeth. Similarly, platform switching (as in controlling the dimension of the abutment) during the period of osseointegration affects biological width by altering the position of the microgap and controlling circumferential bone loss around dental implants. In addition, a scalloped implant platform is available that follows the osseous structure of the maxillary anterior teeth and may prevent interproximal crestal bone resorption during healing. These results may have important implications when dealing with esthetic implant-borne restorations, considering that long-term esthetic survival depends on soft-tissue dimensions that remain healthy and vertically constant over time.

Anatomical Basis for Optimal Implant Positioning

The extent of alveolar bone resorption that follows tooth extraction depends on a number of factors, including existing periodontal disease, trauma, time after the extraction and the quality of alveolar bone. The reduction in width of the maxillary alveolar ridge after tooth extraction is greater than the loss in height. Severity of resorption also depends on whether the patient is wearing a removable denture. A transformation from skeletal Class I or II to a class III relation between maxillary and mandibular jaws routinely can be seen in totally edentulous patients and can affect the maxillary esthetic result owing to implant angulation in the upper jaw. Guided bone regeneration (GBR) procedures are performed routinely before or during dental implant placement to increase the width and the height of the alveolar ridge.

Particulate bone graft materials in the presence or absence of resorbable or nonresorbable membrane can be used to augment bone, whereas bone blocks fixed with mini screws and a barrier membrane may be indicated in areas with more extensive bone defects. Creating alveolar bone height usually is more challenging than creating alveolar bone width, and it almost always requires placement of a bone block. This can be obtained from the chin, the mandibular ramus, the rib or the hip of the patient, or it can be purchased from a tissue bank. Although controversial, it has been suggested that vertical bone length should be able to support at least a 10 mm implant with a crown-to-root ratio of 1:1. One of the main requirements for a GBR surgical approach is the availability of keratinized tissue to cover the wound and to allow biomaterial stability. Scar tissue often makes wound coverage difficult, and onlay- or inlay-type soft-tissue grafts may be required to cover bone graft material.

Soft-tissue Support for Papilla Reconstruction and Preservation

The bony support between a tooth and an implant or between two implants has been shown to be an important criterion in creating or preserving the papilla.[6] For example, when the measurement from the interproximal coronal contact point to the crest of bone is 5 mm or less, the papilla is present almost 100 percent of the time. When the distance is 6 mm or greater, the papilla is present 50 percent of the time or less. Tarnow[7] and colleagues reported a mean papillary height between two adjacent implants as 3.4 mm. One difficulty in maintaining or reforming a papilla between two Implants is that the biological width around an implant usually is located apical to the implant abutment connection. In the esthetic zone, the distance from alveolar crest to the adjacent tooth cementoenamel junction should be 3 to 5 mm to achieve ideal implant localization and appropriate space for the peri-implant sulcus to form. This location places the biological width subcrestally, whereas in a natural tooth, biological width always forms supracrestally. Hence the location of bone level of natural tooth adjacent to an implant will determine if the papilla can be created or lost (Figs 6A to D).

The localization of the alveolar crest is important not only for partially edentulous patients but also for those who are totally edentulous. Depending on the type of restoration (fixed bridge, hybrid or bar/ball attachment-supported overdenture) adequate vertical space should be available for different restorative parts to be placed. Thus, alveolar bone height reduction may be required before implant placement can take place (Figs 7A and B).

Mesial-distal Position of Implant in Bone

A minimum of 1.25 mm of clearance is required between the implant fixture and adjacent teeth for proper osseointegration and decreased risk of damage to adjacent natural teeth (Fig. 8). However, an average crestal bone loss of 1.04 mm has been reported when inter implant space is 3 mm or less compared with 0.45 mm crestal bone loss when this distance is greater than 3 mm.[8] When calculating the mesial-distal distance to select the appropriate implant diameter, one also has to consider the space required for the fabrication of contact points between crowns. Thus, a minimum of 1.5 to 2 mm of clearance from the adjacent tooth is recommended to obtain optimum esthetics with appropriate space for prosthetic devices related to various implant designs and also for peri-implant tissue health.

Buccolingual Positioning of Implant in Bone

Two factors play an important role in clinical decisions regarding buccolingual positioning of an implant: bone thickness with adequate blood supply and the appropriate implant angulation for the proper emergence profile. An implant should be surrounded with bone at least 1 mm thick on both the buccal and lingual aspects. When a mean facial bone thickness of 1.8 mm or larger remains after site preparation, the potential for bone loss decreases significantly and bone apposition is more likely to occur (Figs 9A and B). In addition, the implant body should be aligned with adjacent teeth as well as with the dentition in the opposing arch. One researcher has recommended that the implant be oriented 5 degrees palatally and closer to the palatal cortical aspect to minimize buccal angulation and to open up space for screw retention If an implant must be placed palatally, for each millimeter of palatal inclination, the implant should be placed an additional millimeter apically to correct angulations. If the buccolingual dimension of the maxillary arch is compromised, GBR should be considered to allow implant placement at the appropriate buccal or lingual position.[4]

Fig. 6A: Preoperative

Fig. 6B:

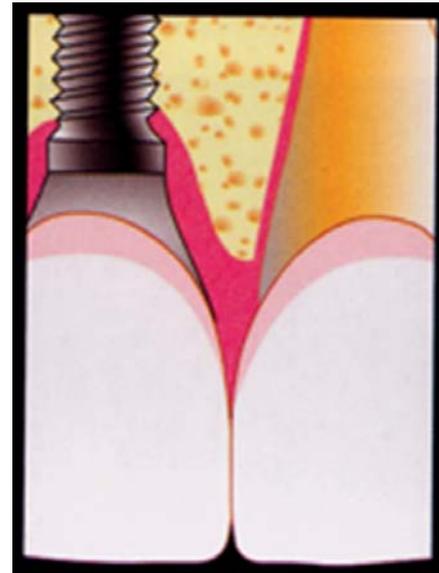**Fig. 6C:** Postoperative

Fig. 6D:

Figs 6A to D: Distance from alveolar crest to adjacent tooth cementoenamel junction (CEJ). (A) Initial presentation. Notice buccal concavity and papilla covering interproximal area. (B) Implant location after guided bone regeneration. Implant was placed 3 millimeters apically to the adjacent tooth CEJ without reducing alveolar bone height. (C) Final restoration with ideal implant localization and accurate space for peri-implant sulcus to form. (D) Relationship of bone levels between implant and natural tooth

Trajectory of the Implant-Emergence Profile

The emergence profile of a dental implant depends on both implant body angulation and the existing status of the periodontal tissues. The clinical parameters that have been reported earlier should be considered for an optimal emergence of the implant restoration. In regard to implant angulation, implant bodies should be placed at angles less than 25 degrees since esthetic needs cannot be fulfilled easily with implants placed with wider angles. The clinician should carefully evaluate the soft-tissue characteristics-including the amount of keratinized tissue, biotype and papilla form-before performing implant surgery. It is important to remember that soft-tissue augmentation is not possible without hard-tissue support therefore, a ridge deficiency at the implant site should be within 3 mm of its optimal contour

Fig. 7A: Excessive alveolar bone—Contraindicated for overdentures

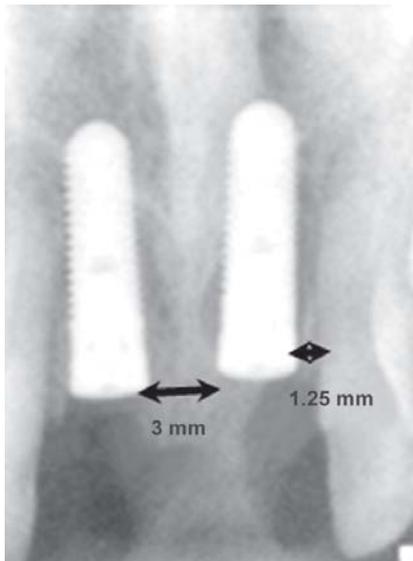**Fig. 7B:** Alveolectomy to accomodate overdenture attachments


Fig. 8: Calculation of mesial-distal distance to select appropriate implant diameter. (A) A minimum of 1.5 to 2 millimeters of clearance (d and b) is required between implant and adjacent tooth for proper osseointegration and decreased risk of damage to adjacent teeth. (B) A minimum of 3 to 4 mm clearance (a) is required between two adjacent implants to decrease crestal bone loss. This space also is important for the fabrication of contact points between crowns
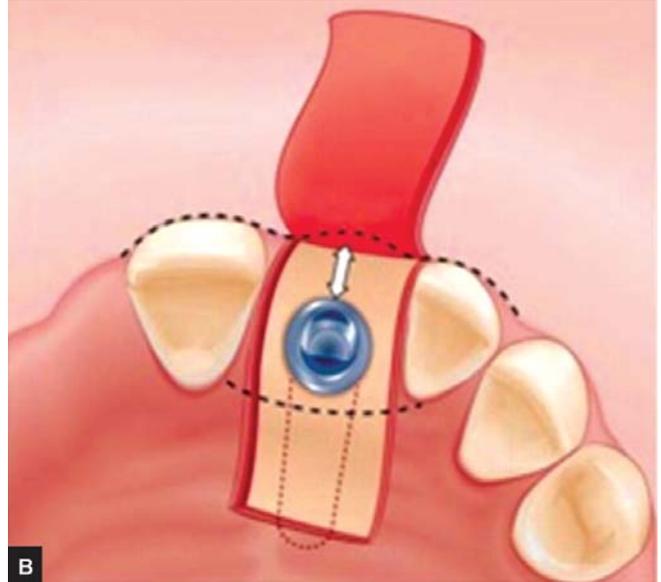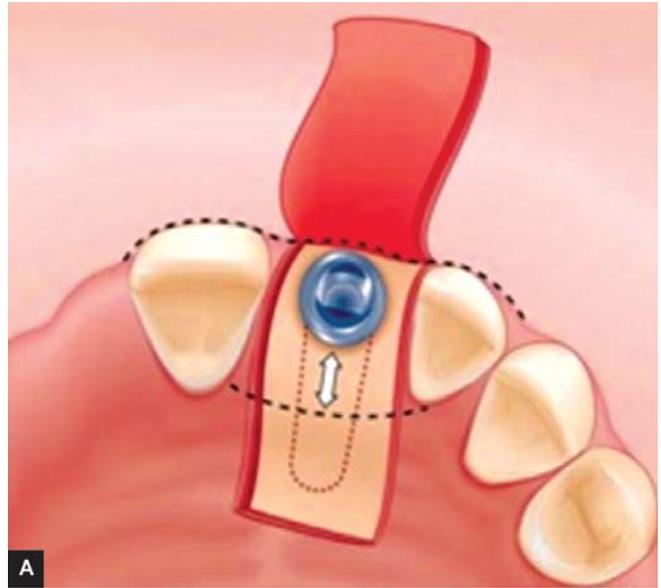
Figs 9A and B: Buccolingual positioning of the implant. Bone thickness with adequate blood supply and appropriate implant angulation for the proper emergence profile. (A) Implant placed too far to the buccal aspect, leaving thin buccal bone and a poor emergence profile. (B) Implant placed too far to the lingual aspect, leaving a more than ideal space on the buccal aspect and jeopardizing the occlusal space

to allow the clinician to modify the soft tissues suitably. To have ideal localization, implant placement in bone requires placement of the implant platform 3 to 4 mm from the cementoenamel junction of the adjacent tooth (Fig. 10). Furthermore, both buccal and lingual bone walls should be at least 1 to 2 mm in thickness.[9]

Hard- and Soft-tissue Remodeling During the First Year

Up to the mid-1990s, alveolar bone loss at the crest was considered to be a physiological response to healing during
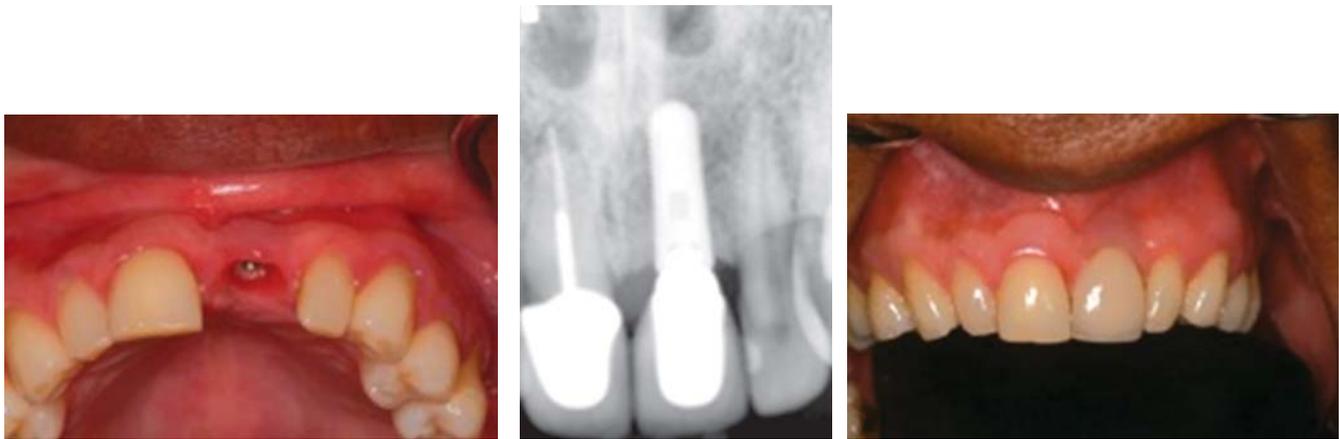
Fig. 10: Implant placement 3 mm below interproximal CEJ of adjacent teeth, radiographic and clinical views of completed restorations

the first year after dental implant placement. This was thought to occur as a result of mechanical stress caused by the implant body at alveolar crest level and was defined as "saucerization." Currently, it is accepted that this phenomenon occurs not only owing to mechanical stress created by the implant body at the crest but also owing to lack of a space for biological width and the existence of microgap at the alveolar crest level. Cochran and colleagues[5] reported that a space of approximately 3 mm in height is required for peri-implant sulcus formation around dental implants without alveolar bone loss (Fig. 10).[9] Thus, several implant designs have been modified to allow a polished collar to create biological width at the alveolar crest. The dilemma is that existence of a polished collar may create esthetic problems due to metal color showing through the gingiva. Some dental implant surgeons have recommended embedding the polished collar into alveolar bone, especially at esthetic regions.

This should not be considered as a routine practice, since bone will not integrate on a polished titanium surface and the alveolar crest will have a higher risk of resorption. Also, soft-tissue changes can occur; an additional 0.75 mm and 0.9 mm of tissue recession can occur at six months and one year, respectively, after abutment connection.[10,11]

SUMMARY

This review discusses the importance of the evaluation of hard and soft tissues prior to implant placement.

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