Implant Designs for the Spectrum of Esthetic and Functional Requirements

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ABSTRACT

In recent years, attention has shifted from merely achieving successful osseointegration of dental implants to achieving proper esthetics that mimic natural dentition. Original implant designs were primarily developed for the treatment of fully edentulous patients where esthetics was not a major objective of the therapeutic outcome. During the initial years of the development of osseointegrated implants, greater emphasis was placed on achieving successful osseointegration. As the number of patients undergoing implant therapy, as well as the number of clinical indications for dental implants, is rapidly expanding, the therapeutic armamentarium also has to expand. The most important requirement for achieving predictable esthetic results is careful consideration of the biology of the interaction between the implant-prosthesis complex with the implant site. Only those implant-supported restorations that achieve harmony with the surrounding hard and soft tissues can be expected to have an optimal esthetic outcome will endure.

The explosion in implant dentistry has been accompanied by an increase in the number of dental implant manufacturers and the dental implant designs available. Today a variety of dental implants are available with many more in development. Many of the implants have incorporated novel design features to respond to the variety of esthetic and functional requirements (**Table 1**). The term "root form" was designated at the 1988 National Institutes of Health consensus development conference to endosseous implants which are variations of a cylinder and are inserted vertically into the alveolar process.[1] Root form endosseous implants vary in design including the implant body shape, the prosthetic interface (platform), the presence or absence of threads, as well as other design features.[2,3] Root form dental implants can be categorized into threaded and non-threaded (press-fit). Implant shapes

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Table 1

Implant Design Features

Implant aspects	Implant Design features				
Body	Cylindrical (parallel-walled)	Tapered	Stepped		
Insertion mechanism	Threaded	Press fit			
Prosthetic interface (Platform)	Flat	Scalloped	Anatomic		
Implant –abutment connection	External connection	Internal connection	One piece		
Surface characteristics	Machined	Subtractive textured surface (acid etched, blasted)	Additive textured (HA coated, sintered)		
Additional design features	Microthreads	Ridges	Grooves	Flutes	Vents

include parallel-walled, tapered or stepped contour and can be hollow or solid, The design of apical ends of implants include flat, round or pointed. A variety of other design features have been incorporated in dental implants primarily to increase their stability and to reduce compressive forces during insertion. These features include grooves, vents, microthreads, ridges, flutes, and indentations, as well as perforations.

A systematic comparison of various implant systems is lacking in the literature. Many of the manufacturers' claims, as intuitive as they may be, have not been substantiated with rigorous research. Therefore, the selection of a particular implant system may in part rely on the availability of preliminary data and in part based on the experience and preferences of the clinician.

Implant Restoration in the Esthetic Zone

In the esthetic zone, where the requirements are more demanding, a variety of biologic and anatomic factors have to be taken into account in treatment planning patients. Becker, et al. have analyzed the alveolar bone morphology on dry skulls to define three distinct anatomic morphotypes.[4] These included flat, scalloped and pronounced scalloped anatomic profiles according to alveolar bone anatomy (**Figure 1**). It was suggested that tooth extraction in patients with thick-flat anatomic profiles merely may lead to subtle changes in hard and soft tissues. However, marked hard and soft tissue defects may result after extraction in patients with thin-scalloped profiles. These changes may result in significant deformities of bone height and width, which pose esthetic challenges for restoration. Therefore, in order to replace teeth with different anatomic hard and soft tissue morphotypes, different implant designs may be required. The conventional cylindrical implants with a flat platform are appropriate for flat anatomic profiles. However, replacement of teeth in patients with scalloped profiles of hard and soft tissues may require specialized implant designs.

In treating patients with scalloped profiles, there is significant distance between the crest of the papilla and the mid-facial zenith gingival height of contour. Therefore, preserving and maintaining the papilla is a challenge to the clinician and requires an in-depth understanding of the anatomy and biology of the hard and soft tissues. Tarnow et al.

Figures 1a-c. Anatomic morphotypes. Soft tissue and bone anatomic morphotypes include flat, scalloped or pronounced scalloped.

Figure 1b.

Figure 1c.

have performed a systematic analysis of inter-implant papillary heights and have demonstrated that the mean height of papillary tissue between two adjacent implants is 3.4 mm.[5] In many patients with a scalloped profile, the height of papillary tissue is greater than 3.4 mm. Therefore, when placing two adjacent implants in the esthetic zone, clinicians should consider this distance and plan their treatment accordingly. In sites with pre-existing crestal bone loss, augmentation of the bone height prior to implant placement in anticipation of the final location of the bone crest is required for optimal esthetic outcome. In many cases, the crestal bone loss has to be overbuilt, in an effort to end up within the 3.4 mm, which is the estimated location of papilla.

In order to preserve and maintain the interproximal papilla, it will be required to preserve and maintain the underlying bone. This is of particular importance in the esthetic zone, where interproximal bone loss between adjacent implants/teeth may lead to the loss of papillary height. The papilla between two adjacent implants is affected by the design of the coronal portion of the implant, as well as the location and contour of the implant-abutment interface. Another important factor in preserving the papilla around implants has to do with the distance between an implant and its adjacent tooth/implant. Tarnow et al. have demonstrated increased crestal bone loss when two adjacent implants were placed with less than 3 mm distance between.[5-7] These investigators have recommended that when multiple implants are planned in the esthetic zone, a minimum of 3 mm of distance to be allowed between them at the implant-abutment level.

The morphology and dimensions of natural roots have been compared to those of conventional cylindrical implants, demonstrating a significant discrepancy.[8] Recently, Gallucci et al. examined the dimensions and characteristics of the cementoenamel junction of maxillary anterior teeth and compared the natural CEJ to current implant designs.[9] These investigators found tooth-implant biologic width discrepancies ranging from 4 mm to 6 mm. Therefore, it is clear that cylindrical, conventional implant designs exhibit significant discrepancies with the dimensions of natural teeth. These authors concluded that the existing implant design featuring a flat platform should be reconsidered in view of natural CEJ contour to improve biologic considerations and related esthetics.

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A comprehensive review of implant design is beyond the scope of this article. The present review will discuss a few of the novel alternative implant designs, which may have utility in more demanding clinical applications, with special emphasis on the esthetic zone.

Tapered Implants

One of the indications for tapered implants has been in soft quality bone. The survival rate of dental implants in soft quality bone has been demonstrated to be lower than that of implants inserted in dense bone. Therefore, tapered implants were developed in an attempt to increase primary stability of implants.

Although increased primary stability has been demonstrated with some designs of tapered implants, the success rate of tapered and cylindrical implants were in one study demonstrated to be equally high (>96 percent).[10,11]

Another indication for the tapered design is proximity to anatomic structures. In alveolar ridges with concavities or proximity to other anatomic structures in the apical third of implant site, tapered implants are less likely to produce a dehiscence or impinge on those anatomic structures than cylindrical implants.

In the clinical case illustrated in **Figure 2**, a 65-year-old female presented with a severely carious tooth No. 9. Clinical evaluation of the soft tissue morphotype revealed a flat topography. Analysis of the osseous topography revealed the presence of concavity of the alveolar process near the apical area of the tooth.

Due to the flat morphotype, an implant with a flat platform was selected and the presence of apical concavity necessitated selection of a tapered implant body design. Following atraumatic extraction, a tapered implant with an internal prosthetic connection (Sterios Replace Select Tapered, Nobel Biocare) was placed.

The current recommendation for this type of implant placement requires slightly more palatal location. The implant was placed with the platform nearly 2 mm apical to the gingival margin. When properly placed the implant does not need to be submerged too far apically. The definitive abutment was connected followed by immediate provisional placement.

Figure 2a.

Figure 2b.

Figure 2c.

Figure 2d.

Figures 2a-d. Clinical case utilizing the tapered implant. A 65-year old female presented with a severely carious tooth No. 9. Clinical evaluation of the soft tissue morphotype revealed a flat topography. Analysis of the osseous topography revealed the presence of concavity of the alveolar process near the apical area of the tooth. Due to the flat morphotype, an implant with a flat platform was selected and the presence of apical concavity necessitated selection of a tapered implant body design. Atraumatic extraction, showing preservation of the hard and soft tissues in the extraction site. Placement of a tapered implant with an internal prosthetic connection (Sterios Replace Select Tapered), using a minimally invasive approach. The implant platform was placed only 2 mm apical to the gingival margin, thus avoiding impingement of the biologic width.

Figure 2e.

Figure 2f.

Figures 2e-h. The definitive abutment was connected, showing facial and occlusal views. Radiograph of the implant and abutment, showing 2 mm of distance between implant platform. Fabrication of the provisional restoration. Marginal adaptation of the provisional to the abutment, as well as contours and high polish near the cervical area are critical factors for immediate restoration of implants.

Figure 2g.

Figure 2h.

Figure 2i. Provisional cemented. It is also critical to assure absence of any cement extending beyond the margin.

Figure 3a. Clinical case utilizing the scalloped implant. Sixteen-year-old female, who was congenitally missing tooth No. 10, underwent orthodontic therapy to open the space for tooth No. 10.

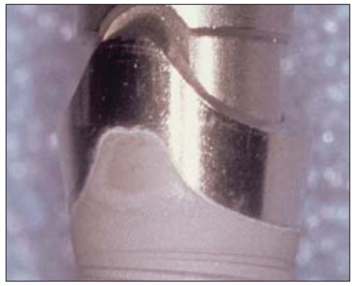

Figure 3b. The platform of the scalloped implant. The platform has a facial leve, which is more apical than the interproximal area to follow the anatomic contour of the alveolar bone crest in the anterior area.

Figure 3c. A scalloped implant was placed.

Figure 3d. Clinical view of the abutment.

Figure 3e. Radiograph of the abutment.

Figure 3f. Clinical view of the provisional.

Scalloped Implant

In an attempt to address the problem of tooth replacement in sites where the alveolar morphotype is scalloped, modifications to the implant platform have been introduced. The scalloped implants feature a platform which is raised in the interproximal areas and is lowest in the mid-facial and mid-lingual areas. The rationale in the design of the scalloped design is to more closely follow the contour of the CEJ. This has been proposed to assist in preserving the interdental bony peaks that support the soft tissue, thereby maintaining inter-implant papillae.[12] The scalloped implant, which is treaded in design provides two positional opportunities per rotation, to allow proper positioning of the interproximal height of contours. A clinical case utilizing the scalloped implant is presented in **Figure 3**. The case illustrates a 16-year-old female, who was congenitally missing tooth No. 10 and had undergone orthodontic therapy to open the space for the tooth. A scalloped implant was placed followed by abutment connection and provisional restoration.

Anatomic Implant

Another alternative implant design has been the development of the anatomic implant system. This is an implant system that has been in development with the underlying rationale to more closely mimic the dimensions and form of natural dentition.

The problem with cylindrical implants with a flat platform is the discrepancy between their shape and that of natural teeth (**Figure 4**). In restoring implants with a cylindrical flat platform, the prosthesis has to compensate for this discrepancy by incorporating contours that span the transition from the implant to the cervical region. The region of the prosthesis spanning the implant platform to the cervical area of the prosthesis has been termed "the transition zone." The contour of the transition zone will dictate the emergence profile of the prosthesis.

In situations where the discrepancy between the implant platform and the prosthesis is great, prostheses with unfavorable transition zone contours may have to be fabricated, such as one with a "ridge lap" contour. Some surgeons have attempted to compensate

Figure 4a. Comparison of the conventional threaded parallel-walled implant with anatomic implant. Conventional implant with flat platform exhibits significant discrepancy in its size and shape with that of the boney crest and the CEJ of the tooth it is replacing.

Figure 4b. Comparison of the cross-section of a conventional implant with a maxillary central incisor, showing significant discrepancy. Superimposition of an anatomic implant over the longitudinal section of a maxillary central incisor.

Figure 4c. The platform of the anatomic implants follows the rise of the CEJ in the interproximal area. The facial level is more apical than the interproximal area.

Figures 4d-f. Cross-section of different anatomic implants, showing maxillary incisor, mandibular incisor, and posterior canine implants.

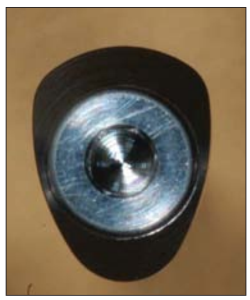

Figure 4e.

Figure 4f.

Figure 5a. Clinical case utilizing the anatomic implant. Missing tooth No. 5.

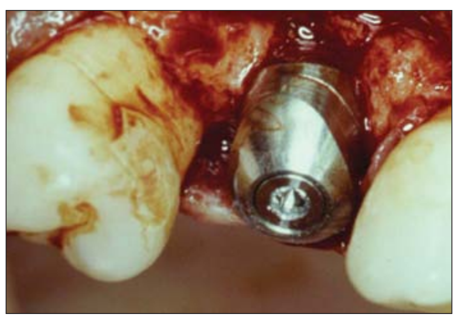

Figure 5b. Surgical placement of an anatomic implant.

Figure 5c. Healing abutment.

Figures 5d-f. Radiograph of the restored implant. Restoration of the implant in 1996 and followup six years later showing stable peri-implant tissues.

Figure 5e.

Figure 5f.

Figure 6b.

Figures 6a and b. Clinical case utilizing the one-piece implant. Preoperative clinical view and radiograph of missing mandibular central incisor.

Figure 6d.

Figures 6c and d. Clinical and radiographic views following placement of a 3.0 mm one-piece narrow diameter implant, using a minimally invasive approach.

Figure 6e. Immediate fabrication of a provisional restoration with no occlusal contacts.

for this unfavorable discrepancy by placing the implant more apically. In the short term, this will allow the restorative dentist more space to gradualize the contour in the transition zone. However, in the long run, implants placed too far apically will exhibit more crestal bone loss and there is the possibility of either recession or pocket formation with accompanied risk of abscess formation. The initial attempt to incorporate the 3-D geometry of root morphology into implant components was anatomically-configured abutments.[13] The anatomic implant is the next step in the progression toward implant components which mimic natural teeth. This system features three implant designs for different regions of the mouth (**Figures 4d-f**). The maxillary and mandibular incisor designs are triangular in cross section. The posterior design is oval in cross section. These implants also have a sloped inclination with the facial margin more apically located than the lingual margin. The anatomic implant, which is press-fit in design offers complete flexibility of vertical, as well as rotational positioning during insertion.

The clinical case in **Figure 5** is a 54-year-old female missing tooth No. 5. A posterior anatomic implant was placed. Restoration and follow up illustrate stability of the peri-implant tissues during the six-year follow-up.

One-piece implants

There are a number of animal studies that have analyzed the response of hard and soft tissues to the presence of the implant-abutment interface. These studies have suggested that the one-piece non-submerged implants have a more favorable hard and soft tissue response, since the biologic width dimensions are more similar to natural teeth.[14,15] In comparison, two-piece implants have been shown to induce more crestal bone resorption, presumably because a biologic width establishes between the bone and the implant-abutment interface. This has been used as a rationale for development of one-piece implants.

Another advantage of one-piece implants is the ability to fabricate fixtures with very narrow diameters, such as the implant with 3.0 mm diameter. Implants with very narrow diameters have application for the mandibular anterior, maxillary incisor or other situations with limited space. The limitation of one-piece implants is the fact that the orientation of implant and abutment portions of the implant are in one line. This limits the ability to change the orientation of the prosthetic portion, compared to two-piece implant designs, where angled abutments can be utilized.

The clinical case illustrated in **Figure 6** is a 48-year-old male with a missing mandibular central incisor. There available space for the missing tooth was only 7 mm. This space was merely adequate for a very narrow implant of 3 mm in diameter. Accordingly, one-piece narrow diameter implants (Nobel Direct) were placed and immediately provisionalized.

Conclusion

The increased application of dental implants has been accompanied by a surge in the availability of an array of different implants, some with novel design features. Manufacturers of dental implants have proposed that the introduced design features offer improvements over previous dental implant designs. Much research will be required to substantiate all of the claims. However, the availability of the multitude of implant designs has provided clinicians with more choices to select the appropriate implant type for a given clinical situation. CDA

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