In recent years the frequency of and esthetic demand for implant restorations in the esthetic zone has increased. Recent literature has revealed numerous consistent trends which may aid the clinician in achieving predictable esthetics. Maintaining generous facial bone by judicious placement as well as by using implants with diameters of less than 4 mm appears to be beneficial. Avoiding adjacent implants in the esthetic zone while maintaining an implant to tooth distance of between 2 mm and 4 mm seems to aid in bone and soft tissue maintenance. Abutment connections in which the abutment is narrower than the implant offer distinct advantages, most notably increased bone heights. Also, provisional restoration, especially early in treatment provides long-term esthetic benefits. (J Prosthet Dent 2012;108:259-267)

Esthetic considerations related to bone and soft tissue maintenance and development around dental implants: Report of the Committee on Research in Fixed Prosthodontics of the American Academy of Fixed Prosthodontics

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In recent years the frequency of and esthetic demand for implant restorations in the esthetic zone has increased. Recent literature has revealed numerous consistent trends which may aid the clinician in achieving predictable esthetics. Maintaining generous facial bone by judicious placement as well as by using implants with diameters of less than 4 mm appears to be beneficial. Avoiding adjacent implants in the esthetic zone while maintaining an implant to tooth distance of between 2 mm and 4 mm seems to aid in bone and soft tissue maintenance. Abutment connections in which the abutment is narrower than the implant offer distinct advantages, most notably increased bone heights. Also, provisional restoration, especially early in treatment provides long-term esthetic benefits. (J Prosthet Dent 2012;108:259-267)
tion sites, thinning of the buccal and lingual walls occurs within the first few weeks with an associated decrease in buccal wall height. In a study on dogs, Qahash et al concluded that buccal bone width strongly influenced alveolar ridge resorption and recommended a buccal bone width of 2 mm or greater following implant placement. Thicknesses of 1.5 to 2.0 mm on both the buccal and lingual surfaces have been associated with high success rates. It is also reasonable to assume that initial implant stability, often stated as a prime factor for implant success, can only be enhanced when substantial facial and lingual walls remain after osteotomy site preparation. A narrower implant also allows the surgeon to avoid bony defects more easily or to traverse them with less thread exposure. In these instances, the implant could still be placed with excellent stability and perhaps augmented with a minor graft or guided tissue procedure as opposed to separate graft and implant placement procedures. In addition, a narrower implant may allow placement to be shifted slightly lingually, while still providing relatively anatomic lingual contours in the final restoration. Given this, the use of a standard or slightly narrow diameter implant of 3.75 mm or less to prevent perforation or thinning of the buccal bone and associated attached tissue loss or implant exposure has been suggested.

Preserving interproximal bone and associated soft tissue is obviously also central to achieving optimum esthetics. Crestal bone loss adjacent to the implant has been long observed and even expected in clinical practice. Rigid criteria for determining implant success have even included an expectation of initial bone loss up to 1 mm with continued yearly bone loss of up to 0.2 mm per year. Many clinicians and authors have observed bone loss progressing to the first thread of the implant and then slowing. Recent implant and prosthetic component design as well as clinical technique have focused on preventing or reducing this crestal loss.

Abutment connection

The nature and location of the abutment to implant connection and its effect on crestal bone loss and inflammation have been frequently discussed. Some studies have shown that the mere presence of this mechanical junction, in addition to poor oral hygiene, has led to increased inflammation of the marginal tissues. Hermann et al in a study of submerged and nonsubmerged implants in dogs observed that bone loss and remodeling always occur apical to the abutment/implant interface. Piattelli et al evaluated bone loss in regard to the location of the implant/abutment junction. They found that bone resorption occurred when the junction was placed below the bone crest and that less bone loss occurred when the junction was placed supracrestally. Hammerle et al found similar results while studying a rough/smooth implant abutment connection placed at the alveolar crest rather than at 1 mm below the crest, with the subcrestally placed implants displaying significantly greater bone loss. It should be noted that in both of these studies the implant/abutment connection extended to the outer circumference of the implant. Wang et al found no difference in bone loss between crestally and subcrestally placed implants for both external hexagon and Morse taper abutment connections. Conversely, Todescan et al and Welander et al in dog studies found that subcrestal placement of the implant/abutment junction led to less bone loss and a tendency toward thicker epithelium and connective tissue than crestal or supercrestal placement. In addition multiple authors have shown that eliminating the microgap by incorporating a 1-piece implant/abutment design decreased inflammatory response.

Finne et al followed 152 1-piece implants in 87 participants for up to 2 years and reported a 97.9% success rate, minimal bone loss, and an excellent soft tissue response. While, biologically, 1-piece designs are promising, the lack of restorative flexibility seems to be a challenge.

It is well established that a stable internal abutment connection is biomechanically advantageous for long term prosthetic success. Currently there are multiple internal configurations, including various internal hexagons, an internal triangulated or cloverleaf design, and conical connections (Fig. 2). In addition, there are many variations of the previously mentioned connections as well as systems which combine elements of more than one design. Recently, some...
definite advantages of the conical connection have surfaced. Tesmer et al. have shown a decreased tendency for bacterial colonization given the intimate fit afforded by the conical connection. Biomechanical complications, such as screw loosening or component fracture, also seem to occur less with the conical connection, theoretically because of decreased micromovement at the implant/abutment junction. Schwarz noted that the conical Morse taper has virtually eliminated abutment screw loosening and fracture. In a finite element analysis study comparing multiple systems and examining stress transmission to the crestal bone during multiple loading conditions, the conical Morse taper connection with platform switch demonstrated the most favorable stress transmission during all nonaxial loading simulations.

In addition to the specific configuration of internal fit, the intimacy of fit and, therefore, the movement of the abutment relative to the implant may also affect stress transmission as well as tissue health and subsequent crestal bone loss. In fact, connection stability may have a more important role than the presence of a microgap with regard to inflammation and bone loss. Hermann et al. showed that welded 2-piece implants displayed less bone loss than conventionally joined 2-piece implant/abutment connections regardless of the size of the microgap. King et al. in a follow-up study, also concluded that stability or lack of movement at the abutment/implant junction was more important than microgap size. They compared welded 1-piece connections to 2-piece connections, while varying the microgaps for each group between 10 and 100 µm and found that the size of the microgap had no significant effect on bone loss, while the nonwelded groups consistently showed higher levels of bone loss. Heijdenrijk et al. compared 2-piece abutment/implant connections with the connections placed above and below the tissues to a 1-piece system and found no association between the presence of a microgap and inflammation.

Platform switching

Locating the abutment/implant connection internally or away from the bone/tissue to implant interface has also been attempted. This concept, which involves an abutment of decreased diameter relative to the implant, is sometimes referred to as platform switching. While many consider platform switching to be a new concept, it has been incorporated into various systems for over 20 years. Platform switching moves the abutment-implant interface inward, away from the outer circumference of the implant (Fig. 3). This has been reported to decrease crestal bone loss, preserve tissue height, and promote soft tissue health.

Whether this advantage is gained mechanically or biologically is debatable. Some theorize that this configuration shifts the inflammatory infiltrate inward, encouraging soft tissue and/or bone to biologically seal off the outer circumference of the implant from the oral environment. Becker et al. found no histological advantage to a 0.3-mm platform switch with respect to bone remodeling in a dog study over 24 weeks, suggesting that the advantage may be a consequence of a physical barrier. Other authors have reported a more favorable stress distribution within the bone for platform switched connections.

Hurzeler et al. showed significantly less bone loss 1 year after restoration placement for 14 platform switched implant single crowns than for 8 similarly restored implants that did not incorporate a platform switch. In a pair of clinical studies in-

[Image A, Conical internal abutment connection; B, Internal hexagon abutment connection.]
volving implants placed immediately into extraction sites, Canullo et al.\textsuperscript{63,64} showed generally less bone loss than previously described in the literature after a mean follow-up of 22 months. Also they noted significantly less buccal tissue recession and greater papilla height in an experimental platform switched group than in a nonplatform switched group. The treatment protocol for both groups included immediate provisional restoration and placement of the definitive restoration 2 months following implant placement. Vela-Nebot et al.\textsuperscript{77} also reported dramatically less bone loss when using implant systems incorporating a narrower diameter of restorative components relative to implant diameter. A comprehensive literature review of 10 studies and 1239 implants by Atieh et al.\textsuperscript{67} showed strong evidence of less bone loss around the platform switched implants, although there was no difference in overall implant survival. The authors also noted that a more favorable bone response was seen when the platform switch was 0.4 mm or greater. Wagenberg and Froum\textsuperscript{68} followed 94 platform switched connections over 11 years and found that approximately 75% showed no radiographic bone loss with 88% displaying 0.8 mm or less bone loss. Conversely a 2 year study by Crespi et al.,\textsuperscript{78} which compared external hexagon regular platform implants to platform switched implants placed in fresh extraction sites and immediately loaded, showed no difference in bone loss.

In an attempt to mimic platform switching, some implant manufactures offer implant designs in which the coronal portion of the implant flares to accommodate an abutment that is roughly the same diameter as the implant body but narrower than the flared neck.\textsuperscript{54} Using this concept, it has been stated that a residual ridge width of at least 6.3 mm is necessary to accommodate the flared design.\textsuperscript{78} For example, Cocchetto et al.\textsuperscript{80} followed 15 implants with a 5.8 mm diameter receiving a 4.1 mm abutment healing cap and showed an average bone loss of only 0.3 mm at 18 months. However, this study required a minimum bone width of 8 mm for inclusion. Because bone width of this dimension is exceptional in the esthetic zone, this design may have limited application. Neck diameters of this dimension will most likely necessitate removal of the same critical coronal bone that the clinician is trying to preserve. Also the resulting distance from the implant to the adjacent tooth will be minimal at best, preventing the establishment of a desirable interproximal distance. Therefore, given the above, a parallel walled implant of standard or slightly narrow diameter with reduced diameter restorative components seems preferable.

A distinct advantage of the implant/abutment diameter difference is the ability to place the implant subcrestally, encouraging bone and soft tissue at the superior edge of the implant circumference to remain and even grow to or over the edge of the implant and remain there undisturbed by restorative components.\textsuperscript{59,60,81,82} Novaes et al.\textsuperscript{59,60} found this to be true, while noting greater papilla fill and less bone loss for subcrestal placement than for crestal placement in 2 dog studies of platform switched implants. They also concluded that the presence of a microgap did not adversely affect tissue health. Weng et al.\textsuperscript{81} compared a platform switched, Morse taper design placed subcrestally to an external hexagon design. They demonstrated bony overgrowth only in the former. Veis et al.\textsuperscript{82} compared 193 regular platform implants to 89 platform switched implants and found that the platform switched design resulted in less bone loss only when placed subcrestally. Conversely, Cochran et al.\textsuperscript{83} found slightly more bone loss for platform switched implants placed 1 mm subcrestally than for those placed crestally or 1 mm supracrestally.

Tenenbaum et al.\textsuperscript{84} showed a greater number and greater length of connective tissue fibers around implants which incorporated a nonflared neck with reduced diameter abutments than other designs. Attached tissue thickness of greater than 2 mm has been associated with a decreased tendency for buccal bone loss and tissue recession around platform switched implants.\textsuperscript{85-87} This effect was even more dramatic when implants were placed supracrestally. Interestingly, when the mucosa was considered thin (less than 2 mm), the authors found no advantage with regard to bone level for the platform switched design.\textsuperscript{88} Subcrestal placement leads to other esthetic advantages. The distance from the top of the implant to the emergence of the restoration is maximized, allowing adequate vertical length for the development of anatomic con-
tours and proper emergence profiles. Priest\textsuperscript{63} recommended providing at least 3 mm from the implant margin to the zenith of the facial margins of adjacent teeth, while noting that provisional restoration is essential in developing optimum esthetics. This is especially critical when soft tissue thickness is minimal.

**Provisional Restoration**

As in conventional restorative and fixed prostodontics, provisional restorations are an invaluable esthetic and diagnostic tool. Provisional restoration of implants is often neglected probably because provisional components are often time consuming and cumbersome. Also many provisional components do not readily accommodate angle correction. Attached gingiva can be sculpted and molded by means of the provisional restoration to help create the illusion of interdental papillae as well as contributing to more stable, predictable overall esthetics and providing increased function.\textsuperscript{69-92} Providing anatomic fixed provisional restorations also avoids the introduction of dramatically different restorative contours at the time of final restoration placement, decreasing the likelihood of postplacement recession.\textsuperscript{63,93} Lai et al\textsuperscript{94} and Gallucci et al\textsuperscript{95} showed that dramatic soft tissue changes, both in dimension as well as health, occur following the initial establishment of anatomic contours. Although bone response was similar to delayed provisional restoration, Block et al\textsuperscript{93} found an average increase in tissue height of 1 mm for immediately provisionally restored implants following their placement in fresh extraction sites. Establishing these contours immediately, either at placement or during second stage uncovering has been shown to be especially effective.\textsuperscript{63,79,93,95} DeRouck et al\textsuperscript{93} compared the postrestoration soft tissue contours of 24 immediately provisionally restored implants to 25 restored with a conventional 2-stage approach. They found 2.5 to 3 times less midfacial recession and better predictability of papilla heights in the immediately provisionally restored group.

The use of definitive stock abutments placed intraorally by the clinician as opposed to laboratory prepared custom abutments would seem to offer distinct advantages in the esthetic zone. Provisional restoration is simplified, allowing the establishment of a proximal contact point early in the restorative phase to initiate papilla formation. The use of cumbersome, interim, partial removable dental prostheses is also obviated. Most of all this technique eliminates the multiple switching of various components during the restorative phase. Although such evidence in the literature could not be found, it is this authors’ opinion that the techniques afforded by this type of abutment offer distinct biologic and clinical advantages.

**Parameters influencing papillary tissue development**

The possibility of papilla fill is greatly enhanced when interproximal bone is preserved, creating a reasonable opportunity to provide a desirable distance of 5 mm or less from the proximal contact to the interseptal bone as described in the literature for natural teeth as well as recently for implants immediately adjacent to natural teeth.\textsuperscript{96-99} Lops et al\textsuperscript{98} and Gastaldo et al\textsuperscript{99} recommend 3 to 4 mm and 3 to 5 mm, respectively, between proximal contacts and bone crest when the implant is adjacent to a natural tooth. However, papilla fill was observed, in some instances, where the bone to contact distance was as great as 9 mm, suggesting, not surprisingly, that multiple factors influence soft tissue response.\textsuperscript{97} Palmer et al\textsuperscript{90} also found, in a study of 46 participants with platform switched implants, that papilla fill was observed when the proximal contact to bone distance exceeded 4 to 5 mm. It should be noted that both of these studies involved implants adjacent to natural teeth. In addition, Kwon et al\textsuperscript{66} observed that in the tooth-implant-tooth clinical scenario, the critical distance is that from the proximal contact to the bone level adjacent to the natural tooth, termed tooth side bone level. In this study of 17 implants and 37 papillae, they found virtually complete papilla fill when the average bone to contact distance was 4.88 mm or less and a lack of papilla fill when this distance exceeded 6 mm.

The situation becomes much more challenging when adjacent implants are present. In a dog study of platform-switched implants, de Oliveira et al\textsuperscript{100} found that a 5 mm bone to proximal contact distance proved to be the critical factor for papilla development between implants, regardless of interimplant distances, which varied between 1 and 3 mm. Other investigators have observed that to achieve papilla fill between implants, a proximal contact to bone crest distance of 3 mm or less is desirable, while a distance of 3 to 5 mm can provide papilla fill between an implant and a natural tooth.\textsuperscript{98}

As previously mentioned, interimplant distance and tooth-to-implant distance have been shown to play a role and possibly interact with bone to proximal contact distance. In a more recent study involving the same type of implants, de Oliveira et al\textsuperscript{102} reported increased bone remodeling when interimplant distance was 1 mm or less than in groups with 2 to 3 mm interimplant distance. In the natural dentition, Martegani et al\textsuperscript{103} found that papilla loss increased dramatically when interradicular distances were 2.4 mm or less and that this factor had both an independent and combined effect with proximal contact distance. Degidi et al\textsuperscript{104} examined 152 implants and 99 interimplant sites and found that optimum interimplant distance for papilla development was greater than 2 mm but less than 4 mm. They also found that optimum bone to contact height should be 3 to 4 mm and that papilla height decreased dramatically when this distance exceeded 6 mm. Tarnow et al\textsuperscript{105}...
also concluded that less interproximal bone loss occurs as interimplant distance increases, while recommending a minimum of 3 mm, lending further support to their earlier mentioned recommendation of using standard to narrow diameter implants in the esthetic zone. Garber et al.105 have recommended in order to maintain interproximal bone height and the accompanying papilla, that the implant should be placed at least 1.5 mm from adjacent teeth and 3 mm from adjacent implants. Traini et al.106 also recommend a minimum of 3 mm interimplant distance to provide optimum alveolar bone health. They observed a more desirable orientation of collagen fibers and significantly increased marrow spaces for interimplant distances of 3 mm in a histological dog study of 48 implants, sacrificed 24 months after implant placement. In a similar follow-up study, they observed that an interimplant distance of 3 mm allowed for an increase in the development of blood vessels.107

While it is difficult to isolate clinical variables scientifically, the literature seems to indicate that the risk to interproximal bone increases for tooth-to-implant distances less than 3 mm.108 Conversely, in a 5-year study of interproximal bone changes between implants, Chang et al.109 found that interimplant distance played a minor role in final bone levels and that the coronal height of bone to implant contact was a better predictor. Lee et al.110 found that both interimplant distance and bone to implant contact level had minimal effect on papilla height and that the width of keratinized tissue exerted a greater influence. However, the literature is fairly consistent in showing that the maintenance of proximal bone height and associated papilla height seems to be more difficult between adjacent implants than in the tooth-implant situation.111-113 In a retrospective study evaluating previously mentioned variables, Kourkouta et al.112 followed 35 implants in 15 participants and found bone crest and papilla heights to be 4.6 mm and 2 mm lower, respectively, for the implant-implant clinical situation than for the tooth-implant situation. They also found only 1 mm of missing papilla height when the interimplant distance was 3 mm and that immediate provisional restoration reduced papilla loss from 2 mm to 1 mm. It is also noteworthy that, in this study, 87.5% of participants were pleased with their esthetic result even with a papilla height discrepancy of 2 mm. Because most of these changes have been found to occur within the first 6 months following placement, the advantages of early and long term provisional restoration seem clear. Tarnow et al.113 also recommended caution, while reporting mean papillary tissue heights of only 3.4 mm for 136 adjacent implant sites in 33 participants.

While 3 to 4 mm appears to be the ideal interimplant distance, the use of a platform switched design may allow more bone and soft tissue maintenance for enhanced esthetics, effectively increasing the interabutment distances for implants in close proximity.65,105 In a study of 41 pairs of platform switched implants in 37 participants, Rodriguez-Ciurana et al.105 demonstrated bone maintenance to be an average of 2.4 mm above the implant/abutment interface at interimplant distances less than 3 mm. As stated previously, Novaes et al.59,60 also found improved papilla fill for subcrestally placed platform switched implants than for those placed crestally. However, the papilla height was not influenced by interimplant distance, which varied from 1 to 3 mm.59,60 In addition to his previous mentioned recommendation of a 3 mm distance from implant to adjacent gingival margin zeniths, Priest51 similarly recommended 3 mm of interimplant distance as well as orienting the center of the implant 3 mm palatal to the future facial restorative margin. Therefore, because of the esthetic challenges detailed above, the placement of adjacent implants in the esthetic zone should be avoided whenever possible.114

SUMMARY

A review of the current literature suggests that the use of standard to narrow diameter implants, a platform switched design, and early provisional restoration should be considered when long term esthetics are paramount. Also, maintaining interimplant and tooth-to-implant distances of approximately 3 mm is desirable with regard to crestal bone maintenance and papilla development. Subcrestal placement may afford adequate space to develop restorative contours from the top of the implant to restoration emergence while avoiding facial thread exposure. This may be even more effective in combination with a platform switched design. In addition, abutment to implant connections, which are extremely intimate and allow little to no relative movement, seem to offer distinct advantages with regard to tissue health. Lastly, the use of noncustomizable abutments and abutment level restorative techniques provides for ease of provisional restoration and treatment sequencing while avoiding multiple exposures of the implant/abutment junction, although the biological advantages this may offer have yet to be investigated.

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