Three-Dimensional Bone and Soft Tissue Requirements for Optimizing Esthetic Results in Compromised Cases with Multiple Implants

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Achieving an esthetic outcome in tooth replacement and implant treatment requires a proper tooth shape and stable surrounding soft tissue profiles. Bone augmentation is considered vital to support the esthetic soft tissue profile around definitive restorations. To prevent recession of the peri-implant soft tissue in cases with multiple implants, buccal bone augmentation of more than 2 mm from the implant platform is necessary to overcome the normal pattern of bone remodeling. Drawing an imaginary horizontal line spanning the space between the remaining healthy interproximal bone peaks is the most reliable vertical augmentation target to create esthetic papillae around an implant prosthesis. Provided that the adjacent bone peaks are at an ideal height and the bone is augmented vertically up to this line, the accepted general guideline of 2 to 3 mm of interproximal vertical bone augmentation from ideally placed implant platforms will invariably also be achieved. In addition, placing pontics in strategic positions to avoid consecutively placed implants has been suggested to facilitate vertical bone height preservation after bone augmentation. Even with esthetically successful results, there have been very few long-term studies on compromised cases with multiple implants. This will become more and more critical over time and must be remedied. (Int J Periodontics Restorative Dent 2010;30:503–511.)

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Dental implant treatment should always be performed with esthetics in mind[1]; this requires proper tooth shape and stable surrounding soft tissue profiles. In single-tooth implants, interdental papillae are restored predictably by maintaining the health of the adjacent periodontium.[2] Alternatively, in cases with multiple implants, the peri-implant soft tissue is guided and shaped by the restoration and supported by the bone foundation. Restoring soft tissue esthetics in cases with multiple implants remains a great challenge,[3] since bone remodeling and resorption occur at the implant-abutment junction and peri-implant soft tissue does not share the natural tooth's attachment apparatus and blood supply.[4] In this article, the concepts behind achieving esthetic and functional implant restorations and the necessary three-dimensional peri-implant hard and soft tissue management required to realize these goals are discussed.

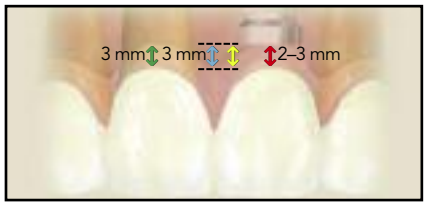

Fig 1 *Relationship between the natural morphology and implant position. Midbone crest to interproximal bone crest* (blue) *= 3 mm; free gingival margin to midbone crest* (green) *= 3 mm; free gingival margin to implant platform* (red) *= 2 to 3 mm; implant platform to interproximal bone crest* (yellow) *= 2 to 3 mm.*

Three-dimensional bone augmentation

Horizontal parameters

It has been found that between 1.3 and 1.4 mm of horizontal bone resorption[5] and 1.5 to 2.0 mm of vertical bone resorption[6] occur at the implant-abutment junction. This could result in total soft tissue volume loss, gingival recession, and subsequent esthetic problems in the labial and interproximal areas. To maintain esthetic results and prevent future soft tissue recession, Grunder et al[7] recommended augmenting the labial bone foundation beyond the implant platform by at least 2 to 4 mm to adequately compensate for the natural bone remodeling that occurs following restoration and loading.

The routine procedures involved in implant site osteotomy and placement are traumatic to the hard tissue. In a worst-case scenario, if alveolar bone thickness is not adequate, implant placement could lead to the total loss of bone, especially on the labial aspect of the ridge.[8] In cases with multiple implants, supporting the ideal crown form and soft tissue profile requires at least 2 mm of labial bone foundation from the implant platform. To support the ideal crown form and soft tissue profile, the implant platform is usually placed 1 to 2 mm lingual to the future gingival margin.[9] Therefore, the bone should be more buccal than the future gingival margin (> 2 mm). This should establish maintainable facial bone support for the stability of the labial soft tissue profile.

Additionally, after bone augmentation, the mucogingival junction often moves in a coronal direction, and the soft tissue thickness over the barrier membrane is reduced because of the compromised blood supply to the area.[10]

Berglundh and Lindhe[11] reported that when peri-implant soft tissue thickness was reduced intentionally to less than 2 mm in dogs, bone resorption occurred around the implant to reestablish a 3-mm peri-implant soft tissue thickness. Kan et al[12] found that a thick biotype maintained better peri-implant soft tissue height at all measuring points on the labial and interproximal surfaces. Jung et al[13] reported that mucosal thickness is a crucial factor in terms of the discoloration caused by different restorative materials.

It would therefore appear that soft tissue augmentation is advisable after bone augmentation, not only because of the gain in keratinized tissue and soft tissue thickness, but also to maintain the regenerated bone and tissue color for optimal esthetics.

Vertical parameters

In natural teeth, crestal bone height typically follows the cementoenamel junction, approximately 3 mm apical to the proximal surfaces in relation to the facial.[14] The biologic width at the facial aspect is approximately 3 mm.[15] To allow for adequate prosthetic space, implants should be placed 2 to 3 mm apical to the free gingival margin at the facial aspect.[16] An ideally placed implant platform would then be 2 to 3 mm apical to the interproximal height of bone because of the flat nature of the typical implant platform (Fig 1). Hence, in cases with single and multiple implants, the vertical bone height in the proximal area is suggested to be 2 to 3 mm coronal to the implant platform, which is the ideal position.

For multiple implants, papillae are created by a combination of prosthetic components and adequate vertical bone support. To create esthetic papillae around an implant prosthesis, the most reliable vertical augmentation target is achieved by drawing an imaginary horizontal line spanning the space between the remaining healthy interproximal bone peaks. Provided that the adjacent bone peaks are at an ideal height and the bone is augmented vertically up to this line, the accepted general

Fig 2 (left) *The maxillary right central incisor and left central incisor, lateral incisor, and canine were lost because of infection, resulting in significant vertical and horizontal tissue loss.*

Fig 3 (right) *Periapical radiograph showing the degree of vertical bone loss. Because of limited space, the four lost teeth were to be replaced with three crowns.*

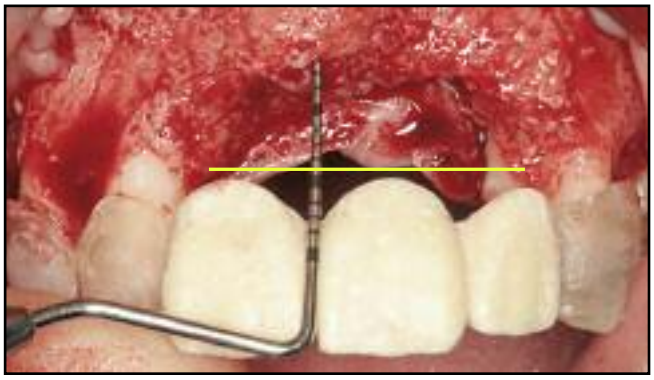

Fig 4 *Nine millimeters of bone augmentation was necessary to reconstruct a bone ridge up to the imagined horizontal line connecting the adjacent bone peaks* (yellow).

Fig 5 *Three implants (Prevail 4/3 × 13 mm, Biomet 3i) were placed in their ideal positions, maintaining interimplant distances of more than 3 mm.*

guideline of 2 to 3 mm of interproximal vertical bone augmentation from ideally placed implant platforms will invariably also be achieved.

Unfortunately, some degree of resorption will always be experienced clinically. Dahlin et al[17] found that using a combination of 3-mm abutments, bovine hydroxyapatite, and membranes to augment interproximal bone and optimize the papillae appearance ultimately preserved an esthetic result at 5 years, even after the unavoidable ridge resorption (Figs 2 to 10).

When there is significant attachment loss present, restoring the bone level on adjacent teeth through orthodontic extrusion may be required prior to vertical bone augmentation.[18]

Fig 6 *Autogenous bone particles mixed with Bio-Oss (Geistlich) and soaked in recombinant human platelet-derived growth factor were held in place by titanium mesh. The three implants acted as a support for the graft and mesh. A cross-linked collagen membrane was used as a barrier.*

Fig 7 *The implants were completely covered with regenerated tissue 7 months later. However, an additional 2 to 3 mm of vertical augmentation was necessary to achieve an esthetic outcome.*

Fig 8 *Vertical augmentation was accompanied by a 4-mm buccal horizontal augmentation and a 3-mm lingual horizontal augmentation.*

Fig 9 *Secondary guided bone regeneration was performed to reconstruct the optimal interproximal height of bone. Three healing abutments were used to support the titanium mesh.*

Fig 10 *An interpositional subepithelial connective tissue graft was performed to correct the displaced mucogingival junction and to acquire optimal soft tissue thickness.*

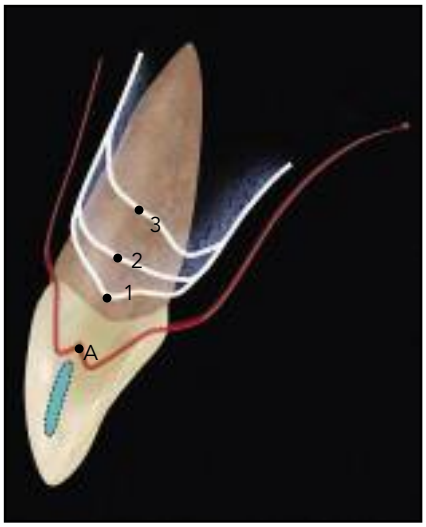

Fig 11 *Classification of the interproximal height of bone. Class 1: Optimal prognosis for achieving soft tissue esthetics (2 mm from the cementoenamel juntion [CEJ] in conventional restorative dentistry or 4 to 5 mm from the apical extent of the future contact point [A] in implant therapy). Class 2: Guarded prognosis; restorative intervention may be required to position the contact point apically (4 mm from the CEJ in conventional restorative dentistry or 6 to 7 mm from point A in implant therapy). Class 3: Poor prognosis (greater than 5 mm from the CEJ in conventional restorative dentistry or greater than 7 mm from point A in implant therapy) (reprinted from Salama et al[20] with permission).*

Table 1 Classification of predicted height of interdental papillae[21]

Class	Restorative environment	Proximity limitations (mm)	Vertical soft tissue limitations (mm)
1	Tooth-tooth	1.0	5.0
2	Tooth-pontic	NA	6.5
3	Pontic-pontic	NA	6.0
4	Tooth-implant	1.5	4.5
5	Implant-pontic	NA	5.5
6	Implant-implant	3.0	3.5

NA = not applicable.

Strategic pontic placement

If implants are placed at a distance of less than 3 mm, the bone height between them will be reduced as bone remodeling occurs, and the related papilla height between them will also be reduced. Scarano et al[19] measured the distance necessary to diminish bone resorption between implants. They reported that maintaining a 5-mm interimplant distance resulted in no significant bone resorption, but as the interimplant distance decreased, the amount of bone resorption increased accordingly.

Salama et al[20] reported the three classifications of interproximal bone support (Fig 11) and the classification of predicting the height of interdental papillae in six different fixed restorative environments (Table 1).[21] Implant-to-implant papillae showed the lowest vertical height, while implant-to-pontic papillae maintained a comparatively superior vertical height. Salama et al concluded that in multiple tooth replacement, the distance between the interproximal height of bone and the proximal crown contact point may vary from 3.5 to 6.5 mm, depending on the type of restoration selected.

Fig 12 *Final treatment outcome. This patient had a high smile line, so establishing a truly esthetic soft tissue frame necessitated the creation of natural tissue over the entire restoration area.*

Fig 13 *A natural-looking keratinized soft tissue frame was achieved using a subepithelial connective tissue graft.*

Tarnow et al[22] measured the height of interimplant papillae and reported the mean papillae height between two implants was 3.4 mm, with 3- and 4-mm-high papillae representing 72.8% of the total sites evaluated.

To create adequate papillae form between adjacent implants, the ideally augmented interproximal bone height should be 3.5 mm from the projected final restorative contact area, although this is impossible to maintain clinically.

In cases with multiple implants, it is suggested that placing a pontic in a strategic position is better than placing adjoining implants, since this would minimize the loss of vertical bone height resulting from crestal bone remodeling and facilitate greater soft tissue height in the proximal area.[21,23]

Even if papillae heights between varied restorative environments are different, the clinician can merely aim to achieve the vertical bone augmentation standard of a solid bone frame connecting the two adjacent bone peaks. Therefore, in a clinical reality, the papillae must be adjusted using manipulation of the subgingival contour of the abutment and the crown. The crown contour can also be modified supragingivally to create acceptable embrasure spaces (Figs 12 to 14).

Platform switching,[24–26] Laser-Lok microchannels,[27] one-piece implants, and reducing the numbers of abutment try-ins[28] has also been postulated to reduce bone resorption at the implant-abutment junction and maintain long-term soft tissue stability.

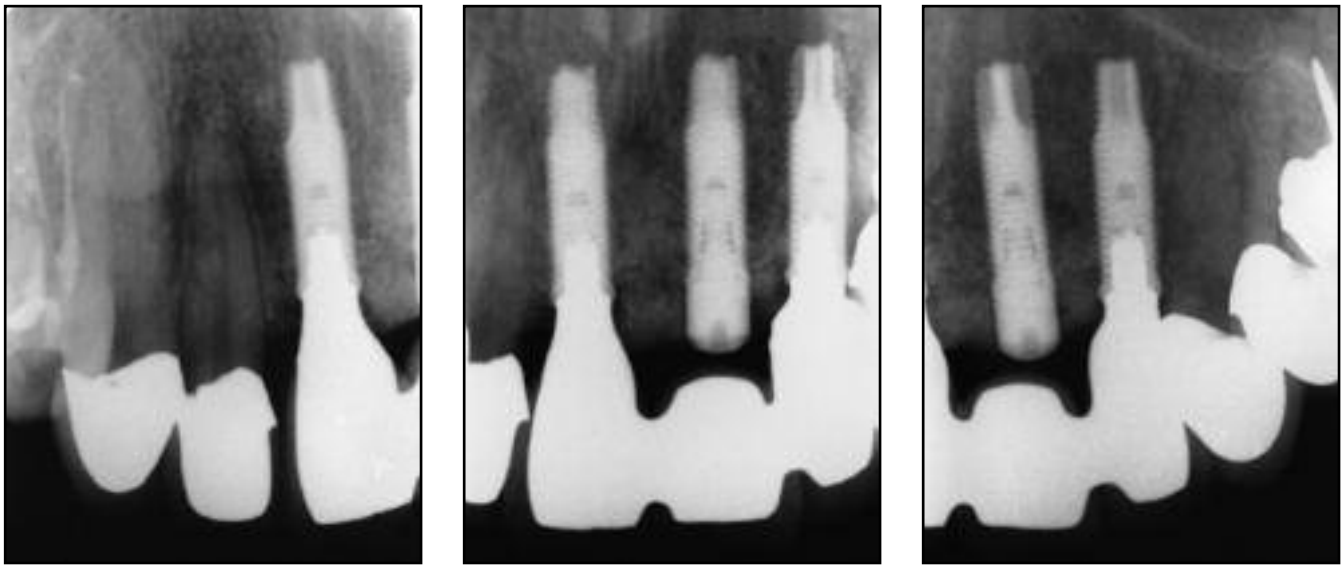

Fig 14 *Periapical radiograph taken 2 years after the implants became functional. Regenerated tissue height was preserved by using a strategically placed pontic instead of all three neighboring implants. Platform switching seems to have had a positive effect on the bone preservation around the functioning implants.*

Using the same procedures and concept, very similar results have been achieved in multiple patients.[29]

Conclusion

To achieve an esthetic outcome in cases with multiple implants, augmentation of the vertical and horizontal bone foundation and the gingival tissue is critical to overcome the bone remodeling that occurs at the implant platform level. Selecting better prosthetic environments (avoiding adjacent implants), reducing the number of times that abutments need to be removed and reinserted, as well as using one-piece implants, micro - grooves, and platform switching, may all eventually provide assistance in maintaining bone and soft tissue height around implants. Soft tissue augmentation is often necessary simultaneous to or after bone augmentation, not only for gaining adequate keratinized tissue and soft tissue thickness, but also in maintaining regenerated bone and esthetic contours of the definitive restoration. Even with successful results, we must keep in mind that there have been very few long-term studies regarding the esthetic results of compromised multiple implants. This is a factor that will become more and more critical over time and must be remedied.

Acknowledgments

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References

1. Garber DA, Belser UC. Restoration-driven implant placement with restoration-generated site development. Compend Contin Educ Dent 1995;16:796, 798–802, 804.
2. Grunder U. Stability of the mucosal topography around single-tooth implants and adjacent teeth: 1-year results. Int J Periodontics Restorative Dent 2000;20:11–17.
3. Belser UC, Schmid B, Higginbottom F, Buser D. Outcome analysis of implant restorations located in the anterior maxilla: A review of the recent literature. Int J Oral Maxillofac Implants. 2004;19(suppl): 30–42.
4. Berglundh T, Lindhe J, Jonsson K, Ericsson I. The topography of the vascular systems in the periodontal and peri-implant tissues in the dog. J Clin Periodontol 1994;21: 189–193.
5. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 2000;71:546–549.
6. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
7. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. Int J Periodontics Restorative Dent 2005;25:113–119.
8. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: Stage 1 placement through stage 2 uncovering. Ann Periodontol 2000;5:119–128.
9. Salama M, Garber D, Salama H, Cabral G. Implant placement in the esthetic zone: The use of autogenous mandibular block grafting and soft tissue augmentation—A case report. Inside Dent 2008;4(8):2–4.
10. Iasella JM, Greenwell H, Miller RL, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: A clinical and histologic study in humans. J Periodontol 2003;74: 990–999.
11. Berglundh T, Lindhe J. Dimension of the periimplant mucosa. Biological width revisited. J Clin Periodontol 1996;23:971–973.
12. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: An evaluation of maxillary anterior single implants in humans. J Periodontol 2003; 74:557–562.
13. Jung RE, Sailer I, Hämmerle CH, Attin T, Schmidlin P. In vitro color changes of soft tissues caused by restorative materials. Int J Periodontics Restorative Dent 2007;27: 251–257.
14. Spear FM. Maintenance of the interdental papilla following anterior tooth removal. Pract Periodontics Aesthet Dent 1999;11: 21–28.
15. Gargiulo A, Wentz FM, Orban B. Dimensions and relations of the dentogingival junction in humans. J Periodontol 1961;32:261–267.
16. Saadoun AP. The key to peri-implant esthetics: Hard- and soft-tissue management. Dent Implantol Update 1997;8: 41–46.
17. Dahlin C, Simion M, Hatano N. Long-term follow-up on soft and hard tissue levels following guided bone regeneration treatment in combination with a xenogeneic filling material: A 5-year prospective clinical study. Clin Implant Dent Relat Res [epub ahead of print 7 May 2009].
18. Salama H, Salama M. The role of orthodontic extrusive remodeling in the enhancement of soft and hard tissue profiles prior to implant placement: A systematic approach to the management of extraction site defects. Int J Periodontics Restorative Dent 1993;13:313–333.

19. Scarano A, Assenza B, Piattelli M, et al. Interimplant distance and crestal bone resorption: A histologic study in the canine mandible. Clin Implant Dent Relat Res 2004:6:150–156.
20. Salama H, Salama MA, Garber D, Adar P. The interproximal height of bone: A guidepost to predictable aesthetic strategies and soft tissue contours in anterior tooth replacement. Pract Periodontics Aesthet Dent 1998;10:1131–1141.
21. Salama MA, Ishikawa T, Salama H, Funato A, Garber D. The advantages of root submergence technique for pontic site development in esthetic implant therapy. Int J Periodontics Restorative Dent 2007;27: 521–527.
22. Tarnow D, Elian N, Fletcher P, et al. Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. J Periodontol 2003; 74:1785–1788.
23. Funato A, Salama MA, Ishikawa T, Garber DA, Salama H. Timing, positioning, and sequential staging in esthetic implant therapy: A four-dimensional perspective. Int J Periodontics Restorative Dent 2007;27: 313–323.
24. Cappiello M, Luongo R, Di Iorio D, Bugea C, Cocchetto R, Celletti R. Evaluation of peri-implant bone loss around platform-switched implants. Int J Periodontics Restorative Dent 2008;28:347–355.
25. Lazzara RJ, Porter SS. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. Int J Periodontics Restorative Dent 2006;26:9–17.
26. Rodríguez-Ciurana X, Vela-Nebot X, Segalà-Torres M, et al. The effect of interimplant distance on the height of the interimplant bone crest when using platform-switched implants. Int J Periodontics Restorative Dent 2009;29: 141–151.
27. Nevins M, Nevins ML, Camelo M, Boyesen JL, Kim DM. Human histologic evidence of a connective tissue attachment to a dental implant. Int J Periodontics Restorative Dent 2008;28:111–121.
28. Abrahamsson I, Berglundh T, Lindhe J. The mucosal barrier following abutment dis/reconnection. An experimental study in dogs. J Clin Periodontol 1997;24:568–572.
29. Funato A. Ishikawa T. 4D Implant Therapy: Esthetic Considerations for Soft Tissue Management. Berlin: Quintessenz, 2010.