The Role of Implant Position on Long-Term Success

Chuan-Yi Su,* Jia-Hui Fu,† and Hom-Lay Wang‡

Focused Clinical Question: In the past, implants were placed where the bone was. This mode of treatment often led to implant-related complications, such as peri-implant soft-tissue recession, esthetic challenges, and fractured implants and/or associated suprastructures. Therefore, advances in soft-tissue and bone augmentation techniques have enabled implants to be placed in an ideal three-dimensional position, thus ensuring adequate peri-implant soft tissue and bone thickness for a stable and successful long-term treatment outcome. The present report aims to answer the question: What are the clinical guidelines for implant placement to achieve long-term success?

Summary: In the maxillary anterior region where esthetics is of paramount importance, 2 mm of buccal bone anterior to the implant is preferred. This ensures stability of the buccal bone plate, minimizing peri-implant mucosal recession. To achieve an esthetic emergence profile, the implant platform is generally placed 3 to 4 mm apical to the cemento-enamel junction (CEJ) of the adjacent teeth and 1.5 to 2 mm away from the adjacent roots. In the posterior region, a minimum of 1 mm of buccal bone around the implant ensures stability of the buccal plate. Generally, implants with a polished collar are preferred because the collar can be placed supracrestally to compensate for any vertical ridge deficiency and yet not compromise the esthetics of the restoration. The implant is placed 1.5 to 3 mm apical to the CEJ of the adjacent teeth and 3 to 4 mm away from adjacent roots to create a smooth transition from implant platform to occlusal plane.

Conclusion: Ideal three-dimensional implant positioning ensures a long-term stable esthetic and functional treatment outcome. *Clin Adv Periodontics* 2014;4:187-193.

Key Words: Bone regeneration; bone substitute; complications; dental implants; survival rate.

Background

Multiple studies have proved that long-term (≥10 years) implant survival and success rates are in the high 90th percentile.[1-3] Despite the high survival and success rates, common implant complications include technical complications (e.g., screw fracture),[4] biologic complications (e.g., loss of peri-implant marginal bone,[4] osseointegration), and esthetic complications (e.g., midfacial mucosal recession).[5] Literature proposed that poor oral hygiene, history of periodontitis, and cigarette smoking are the main risk indicators for peri-implant disease.[6] However, the three-dimensional (3D) position of implants in the dental arch appeared to play an important role, yet not many studies related the success of dental implants to their 3D position. It has been proposed that implants should be placed in a prosthetically driven position, so that axial occlusal forces are exerted on the implant-supported restoration and fixture, thereby minimizing biomechanical complications and peri-implant marginal bone loss.[7]

Buser et al.[8] recommended that dental implants in the esthetic zone (e.g., anterior maxilla) should be placed in "comfort" zones so that an esthetic implant-supported restoration is achieved. The authors proposed that implants should be placed 1.5 mm away from the adjacent roots, 1 mm apical to the cemento-enamel junction (CEJ) of the contralateral tooth, and 1 mm palatal to the emergence of adjacent teeth.[8] Bashutski and Wang[9] proposed that at least 2 mm of buccal bone should lie anterior to the implant fixture. The implant platform should be 1.5 to 3 mm apical to the CEJ of adjacent teeth, with 1.5 mm between implant and root or 3 mm between implants.[9] The present report aims to discuss guidelines on implant positioning in the anterior and posterior regions so that an esthetic and functional implant-supported restoration that is stable over time can be achieved.

Decision Process

Figure 1 illustrates the guidelines to keep in mind when placing implants in the anterior and posterior regions.

Bucco-Palatal Position

To minimize hard- and soft-tissue loss over time, the authors of the present study proposed that a minimum of 2 mm of buccal bone thickness should lie buccal to the implant platform in the anterior region (Fig. 2a). To achieve this, the implant fixture is directed at the cingulum level of the adjacent teeth. In the posterior region, where esthetics is not of prime importance, having 1 mm of buccal bone thickness is acceptable, and the implant fixture is directed at the central groove of the adjacent posterior teeth. Bone remodeling of 2 to 2.5 mm will occur at sites undergoing immediate implant placement.[10] As such, it is important to compensate for this loss of buccal bone thickness. For

* *Private practice, Kaohsiung, Taiwan.*

† *Discipline of Periodontics, Faculty of Dentistry, National University of Singapore, Singapore.*

‡ *Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.*

Submitted September 10, 2012; accepted for publication December 28, 2012

doi: 10.1902/cap.2013.120100

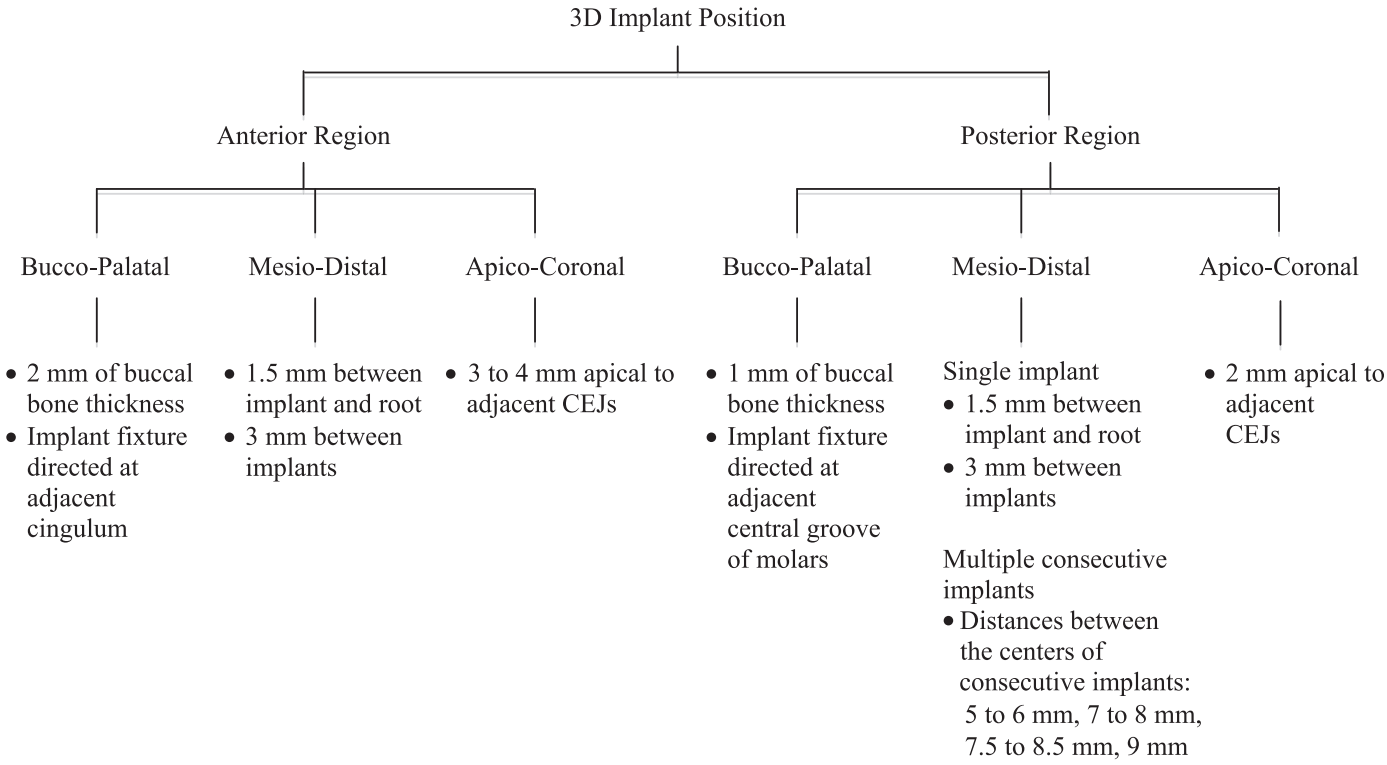

FIGURE 1 Proposed guidelines for implant placement in the anterior and posterior regions.

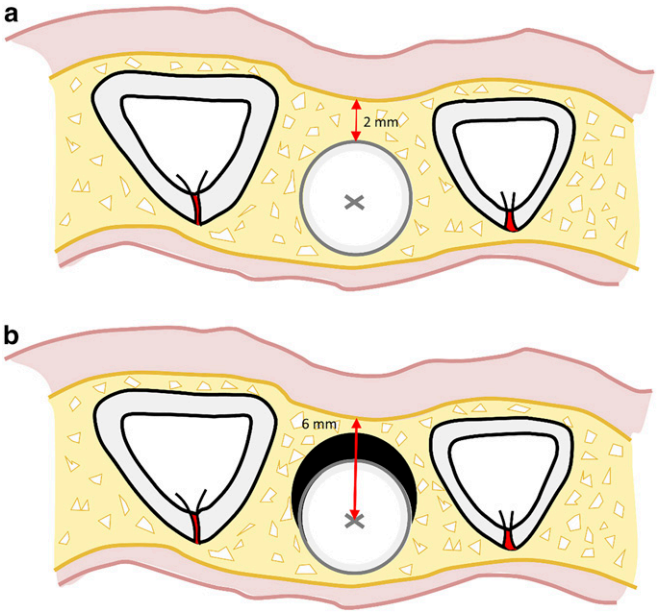

FIGURE 2 Schematic diagrams of bucco-palatal implant positions. **2a** Bucco-palatal position of an implant placed in a healed site in the maxillary anterior region. The center of the implant fixture should be directed at the level of the cingulum of adjacent teeth, leaving a minimum of 2 mm of buccal bone thickness. **2b** Bucco-palatal position of an implant placed in an extraction site in the maxillary anterior region. The center of the implant fixture should be directed at the level of the cingulum of adjacent teeth, leaving a distance of 6 mm from the buccal bone to the center of the implant, thus compensating for potential buccal bone resorption as the site heals. (Illustrations courtesy of Mr. Wee-Wah Tok).

example, the center of a 4-mm-diameter implant should be 6 mm palatal to the buccal bone flange so that 2 mm of buccal bone thickness remains after bone remodeling is completed (Fig. 2b). Conversely, in delayed implant placement, the center of a 4-mm-diameter implant should be 4 mm palatal to the buccal bone flange.

Mesio-Distal Position

It was proposed that a safe distance of 1.5 mm between implant and root or 3 mm between implants was needed to maintain the peri-implant bone.[11] Having adequate implant–tooth or interimplant distance maintains the bone support that preserves the papillary tissues needed for an esthetic restoration.[12] In the anterior region, a single implant has to be centered mesio-distally in the edentulous space, allowing a distance of 1.5 mm between the implant and the adjacent roots. For example, if the implant has a diameter of 4 mm, a minimum mesio-distal ridge width of 7 mm is needed (Fig. 3a). In the posterior region (e.g., restoring a molar), a 5- or 6-mm-diameter implant is commonly used. In addition to accommodation for the implant–root distance, more space is needed for the emergence profile of the restoration. Therefore, a single implant of 5-mm diameter needs a minimum mesio-distal ridge width of 11 mm, with 3 mm between implant and adjacent root (Fig. 3b). When placing multiple implants in the posterior region (e.g., 4- and 5-mm-diameter implants for restoring premolars and molars, respectively), the clinician has to consider space distribution between the implants. The center of the first 4-mm-diameter implant should be 5 to 6 mm away from the adjacent tooth CEJ; the center of the

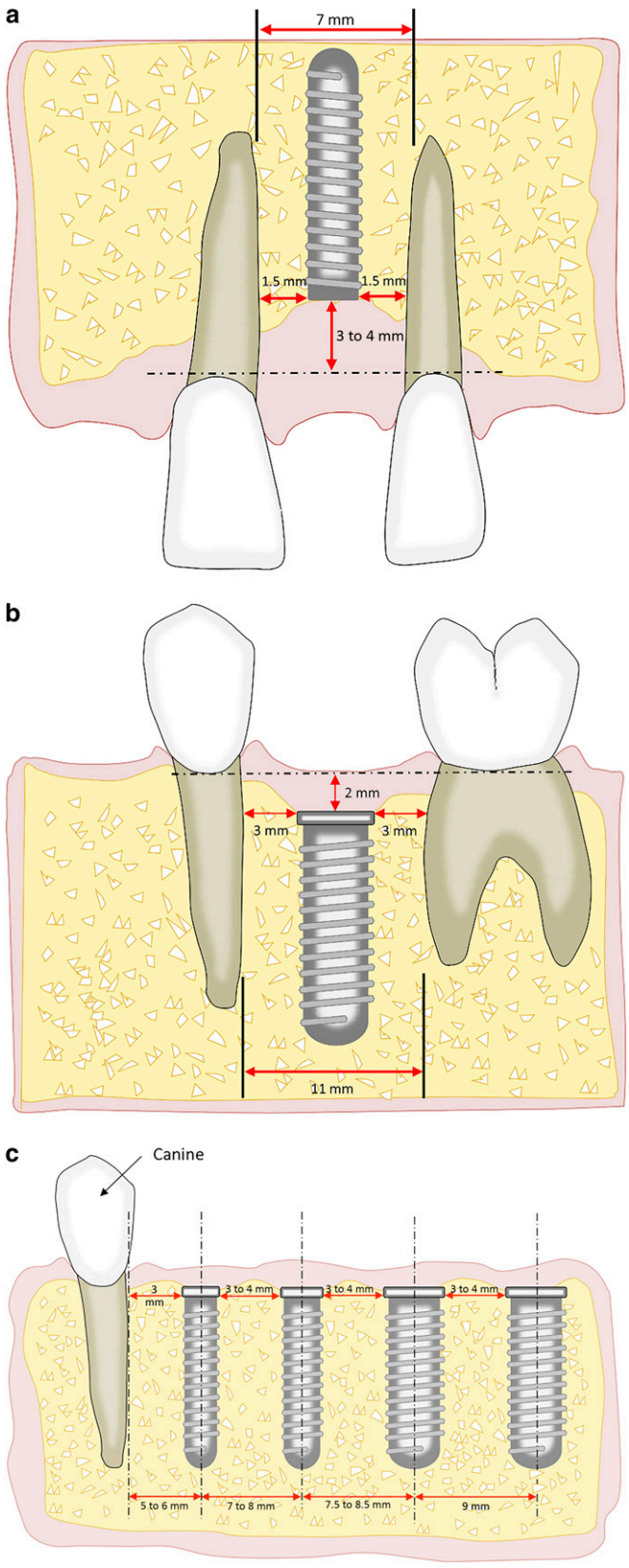

FIGURE 3 Schematic diagrams of mesio-distal and apico-coronal implant positions. **3a** Mesio-distal and apico-coronal position of a single implant in the maxillary anterior region. **3b** Mesio-distal and apico-coronal position of a single implant in the mandibular posterior region. **3c** Mesio-distal positions of consecutive implants in the mandibular posterior region. (Illustrations courtesy of Mr. Wee-Wah Tok).

subsequent 4-mm-diameter implant should be 7 to 8 mm away from the center of the anterior implant. The center of the subsequent 5-mm-diameter implants should be 7.5 to 8.5 mm away from the center of the anterior implant, and the final implant should be 9 mm away from the anterior implant (Fig. 3c).

Apico-Coronal Position

In the esthetic zone, it is suggested that the implant platform be placed 3 to 4 mm apical to the adjacent or proposed CEJ so that an esthetic emergence profile can be fabricated (Fig. 3a). In addition, a bone-level implant is preferred over an implant with a polished collar to minimize esthetic complications, such as exposure of the polished collar. In the posterior region, the implant platform is placed 2 mm apical to the adjacent or proposed CEJ (Fig. 3b). An implant with a polished collar is preferred because it makes it easier to maintain oral hygiene. Also, in sites with vertical bone loss and where esthetics is not a main concern, placement of the polished collar above the bone would aid in maintaining the bone height and crown-to-implant ratio (Fig. 4).

Clinical Scenarios

Case 1

This case presentation illustrates the importance of having implants placed in the correct 3D position to minimize postplacement implant complications (Fig. 5).

A 55-year-old Chinese male with a history of chronic periodontitis and no contributory medical history or drug allergies, presented at a dental clinic in Kaohsuing, Taiwan, in June 1991. He was interested in seeking implant therapy

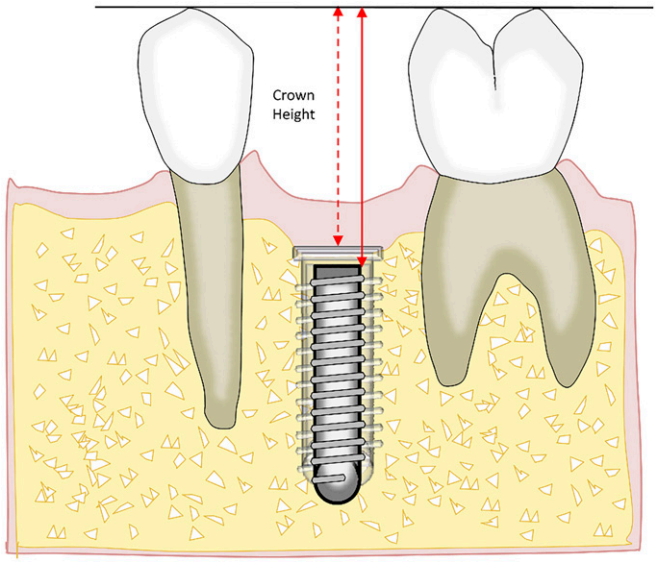

FIGURE 4 Schematic diagram showing the redistribution of crown-to-implant ratios with change in apico-coronal implant position. An implant with a polished collar (transparent implant image) could be placed supracrestally, thus giving rise to a more ideal crown-to-implant ratio. Comparatively, notice the increase in crown-to-implant ratio when a bone-level implant (opaque implant image) is used. (Illustration courtesy of Mr. Wee-Wah Tok).

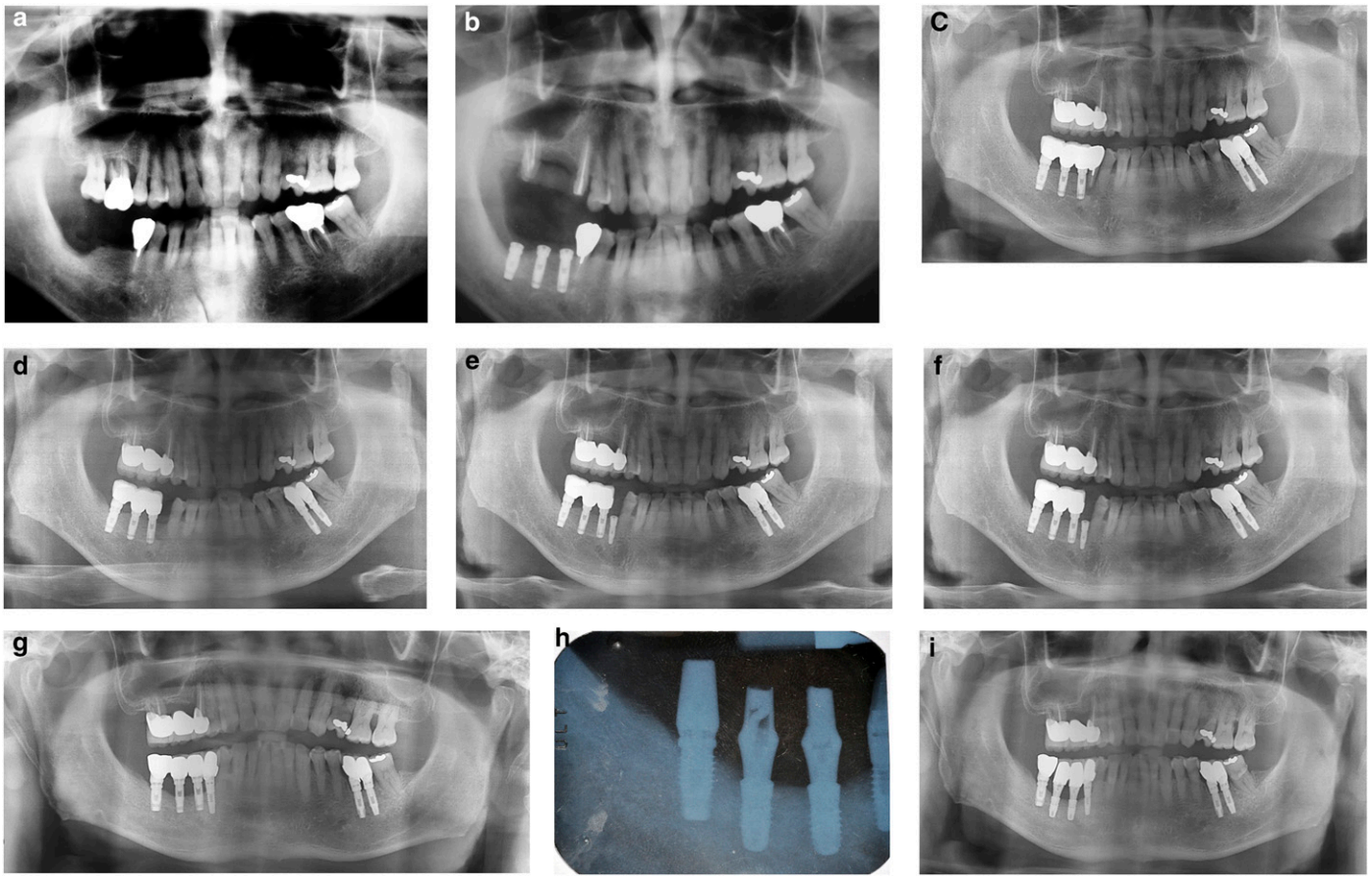

FIGURE 5 Case 1. Presentation of peri-implant bone loss due to incorrect apico-coronal implant position. **5a** Baseline radiograph of the edentulous mandibular posterior right region. **5b** Radiograph showing adequate mesio-distal implant positioning from tooth sites #29 through #32. **5c** Radiograph of the installed implant-supported fixed prosthesis replacing teeth #30 through #32. **5d** Radiograph showing stable marginal bone levels around the implants in tooth sites #30 through #32 after 6 months of functional loading. **5e** Radiograph of a bone-level implant placed at tooth site #29, 6 months after the tooth was extracted. The implant at tooth site #29 was placed ≈2 mm deeper than the implant at tooth site #30. **5f** Radiograph showing significant marginal bone loss around implant in tooth site #30. **5g** Radiograph showing significant marginal bone loss around implants in tooth sites #30 and #31, 18 months after the implant at tooth site #29 was placed. **5h** Radiograph of two shorter implants placed at the same apico-coronal level to replace the affected implants at tooth sites #30 and #31. **5i** Radiograph showing stable marginal bone level around all four implants after 2 years of functional loading.

for the replacement of missing mandibular right posterior molars (teeth #30 through #32) (Fig. 5a). Oral informed consent to be treated was obtained from the patient. Implants with polished collars were placed in the ideal 3D positions to replace teeth #30 through #32 (Fig. 5b). Subsequently, an implant-supported splinted fixed prosthesis was installed. At 5 years reevaluation, the bone levels around implants in tooth sites #30 through #32 were maintained at the rough–smooth junction of the implant platform (Fig. 5c). However, tooth #29 had a root fracture and was extracted (Fig. 5d). Six months after the extraction, a new implant was placed to replace tooth #29. However, the implant was placed too deep, thus violating the proposed guideline that consecutive implants should be placed at the same apico-coronal level to avoid peri-implant bone loss (Fig. 5e). Six months after the implant at tooth site #29 was placed, significant peri-implant bone loss was observed around tooth site #30 (Fig. 5f). Nonetheless, a final crown was placed on the implant in tooth site #29. Eighteen months later, the patient returned to the clinic with more peri-implant bone loss at tooth sites #30 and #31 (Fig. 5g). A clinical decision was made to remove the affected implants at tooth sites #30 and #31 and then place shorter implants after 6 months of healing to minimize additional vertical ridge resorption as well as inflammation (Fig. 5h). Single cemented implant crowns were fabricated for tooth sites #29 through #32. A 2-year reevaluation radiograph showed stable peri-implant bone levels around all four implants (Fig. 5i), thereby further supporting that implants have to be placed in an ideal 3D position to minimize implant complications, such as peri-implantitis or peri-implant bone loss.

Case 2

A 52-year-old white female with a history of dental trauma affecting the maxillary right central and lateral incisors, presented to the Graduate Periodontics Clinic at the University of Michigan, Ann Arbor, Michigan, in October 2009. Written and oral informed consent to be treated was obtained from the patient prior to commencement of treatment. Both incisors were removed, and ridge preservation using allogenic bone graft was performed. Seven months later, two dental implants were placed, but the implant replacing the central incisor was placed too buccally

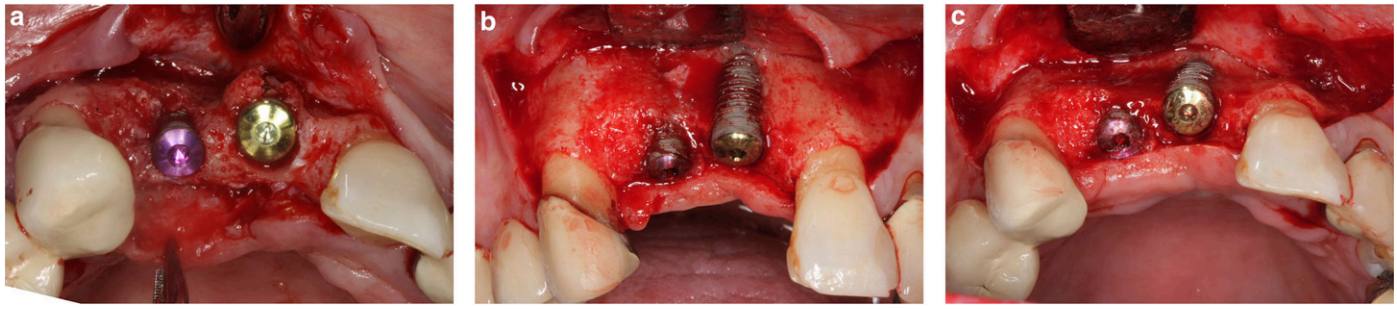

FIGURE 6 Case 2. Presentation of implant failure because of incorrect bucco-palatal implant position. **6a** Occlusal view of implant replacing the maxillary right central incisor that was placed too buccally. **6b** Buccal view of implant showing complete exposure of buccal surface. **6c** Occlusal view of implant that was placed too buccally.

(Fig. 6a). At implant uncovering, the implant replacing the central incisor was not osseointegrated and was removed (Figs. 6b and 6c). Therefore, this case presentation illustrates the complications associated with incorrect 3D implant position in the maxillary anterior region.

Discussion

The bone- and soft-tissue loss in both horizontal and vertical dimensions is an unavoidable consequence of tooth removal. This phenomenon can be attributed to the bone remodeling process, in particular the resorption of the bundle bone on the buccal surface.[13] A recent systematic review on undisturbed healing of extraction sites in humans reported 29% to 63% horizontal bone loss and 11% to 22% vertical bone loss 6 months after tooth extraction, which occurred rapidly within the first 3 to 6 months.[14] There was an associated 0.4- to 0.5-mm gain in soft-tissue thickness at the 6-month follow-up.[14] An animal model demonstrated resorption of the buccal socket wall after tooth extraction, which was even more significant at sites with immediate implant placement.[15] A retrospective study demonstrated that a minimum buccal bone thickness of 2 mm was needed to avoid peri-implant mucosal recession and bone loss.[16] Having 2 mm of buccal bone thickness would compensate for bone remodeling around the implant platform, thereby maintaining a stable buccal bone support for the overlying soft tissues.[17] A recent multivariate analysis demonstrated that midfacial mucosal recession around a dental implant was strongly associated with a buccally placed implant.[18] It was also found that placing implants more lingually in freshly extracted sockets not only minimized the exposure of the buccal implant surface,[19] but it also resulted in more bone formation on the buccal surface.[20] Therefore, to safeguard buccal bone and soft-tissue levels, it is recommended to direct the implant fixture toward the cingulum, leaving 2 mm of buccal bone thickness. In the anterior region, having the implant fixture placed palatally would allow for both a screw- or cement-retained overlying restoration.

Studies on interradicular distance showed that a minimum distance of 0.5 to 0.8 mm was needed to ensure the existence of healthy and functional attachment apparatus between teeth.[21,22] A clear association of increased bone loss between teeth was observed when the interradicular distance was ≤0.8 mm.[22] This could be attributable to the inability to maintain good oral hygiene in these areas, leading to rapid breakdown of a site with reduced interradicular bone volume. If this safety zone was infringed upon, circumferential peri-implant bone loss would occur, leading to exposure of roughened implant surfaces, which are hard to maintain. The accumulation of bacterial plaque makes the site susceptible to peri-implant marginal bone loss.[23] Therefore, extrapolating this scenario to dental implants, adequate distance of 1.5 mm between implant and root or 3 mm between implants maintains the peri-implant bone and thus preserves the papillary tissues.

From an animal model, it was shown that implants placed immediately in freshly extracted sockets should be ≈1 mm apical to the buccal bone crest so as to avoid the exposure of the rough implant surface.[24] In another scenario, it was observed that placement of consecutive implants at different apico-coronal levels attributable to an uneven bony plane resulted in bone remodeling to the most apical level.[9] This inevitably led to the exposure of implant threads and their rough implant surfaces, thus bringing about a domino effect whereby loss of peri-implant bone consequently led to exposure of rough implant surface, resulting in significant bacterial plaque accumulation and additional bone loss.[23] Therefore, it is suggested that osteoplasty be performed with a tungsten carbide bur to create a level bone surface. Bone-level implants are commonly placed 1 mm subcrestally and have a built-in platform switch feature that together demonstrated minimal peri-implant marginal bone loss.[25] This is exceptionally beneficial in the esthetic zone because it minimizes the risk of esthetic complications.

The soft-tissue profile is essential in creating an esthetic implant restoration. Several factors (e.g., position of implant platform and thickness of soft tissue and buccal bone) were reported as significant risk factors in causing peri-implant midfacial mucosal recession.[26] For example, a buccally positioned implant platform would increase the risk of midfacial recession by three times,[27] and a thin-tissue biotype would result in greater peri-implant mucosal recession.[28] It was reported that sites with thicker peri-implant tissue had lesser resorption of the buccal bone.[29] In addition, presence of sufficient

keratinized mucosa was thought to be beneficial in the prevention of peri-implant mucosal recession.[30] Therefore, soft-tissue grafting to increase tissue thickness of peri-implant mucosa is beneficial in preventing peri-implant mucosal recession.[31] It was thus recommended that soft-tissue grafting be performed at sites with a thin buccal plate (<2 mm) or when the implant platform was placed at the incisal position.[32]

Conclusions

Placement of dental implants in an ideal 3D position aids in maintaining hard- and soft-tissue levels over time. Associative relationships are drawn between the effect of implant positions and their long-term stability. Therefore, careful retrospective analysis of implant position and peri-implant tissue is needed to establish the relationship between implant position, suprastructures, and peri-implant tissues. ■

Acknowledgments

Figures 2, 3, and 4 are provided courtesy of Mr. Wee-Wah Tok, Lead Systems Analyst, Department of Informatics and Technology, Faculty of Dentistry, National University of Singapore. The authors report no conflicts of interest related to this study.

CORRESPONDENCE:
Dr. Hom-Lay Wang, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, 1011 N. University Ave., Ann Arbor, MI 48109-1078. E-mail: homlay@umich.edu.

References

1. Buser D, Janner SF, Wittneben JG, Brägger U, Ramseier CA, Salvi GE. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: A retrospective study in 303 partially edentulous patients. *Clin Implant Dent Relat Res* 2012;14:839-851.
2. Frisch E, Ziebolz D, Rinke S. Long-term results of implant-supported over-dentures retained by double crowns: A practice-based retrospective study after minimally 10 years follow-up. *Clin Oral Implants Res* 2013; 24:1281-1287.
3. Östman PO, Hellman M, Sennerby L. Ten years later. Results from a prospective single-centre clinical study on 121 oxidized (TiUnite™) Brånemark implants in 46 patients. *Clin Implant Dent Relat Res* 2012; 14:852-860.
4. Papaspyridakos P, Chen CJ, Chuang SK, Weber HP, Gallucci GO. A systematic review of biologic and technical complications with fixed implant rehabilitations for edentulous patients. *Int J Oral Maxillofac Implants* 2012;27:102-110.
5. Jemt T, Laney WR, Harris D, et al. Osseointegrated implants for single tooth replacement: A 1-year report from a multicenter prospective study. *Int J Oral Maxillofac Implants* 1991;6:29-36.
6. Heitz-Mayfield LJ. Peri-implant diseases: Diagnosis and risk indicators. *J Clin Periodontol* 2008;35(Suppl. 8):292-304.
7. Fu JH, Hsu YT, Wang HL. Identifying occlusal overload and how to deal with it to avoid marginal bone loss around implants. *Eur J Oral Implantology* 2012;5(Suppl.):S91-S103.
8. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: Anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004;19(Suppl.):43-61.
9. Bashutski JD, Wang HL. Common implant esthetic complications. *Implant Dent* 2007;16:340-348.
10. Botticelli D, Berglundh T, Lindhe J. Hard-tissue alterations following immediate implant placement in extraction sites. *J Clin Periodontol* 2004;31:820-828.
11. 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.
12. Zetu L, Wang HL. Management of inter-dental/inter-implant papilla. *J Clin Periodontol* 2005;32:831-839.
13. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005; 32:212-218.
14. Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. *Clin Oral Implants Res* 2012;23(Suppl. 5):1-21.
15. Araújo MG, Wennström JL, Lindhe J. Modeling of the buccal and lingual bone walls of fresh extraction sites following implant installation. *Clin Oral Implants Res* 2006;17:606-614.
16. 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.
17. 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.
18. Cosyn J, Sabzevar MM, De Bruyn H. Predictors of inter-proximal and midfacial recession following single implant treatment in the anterior maxilla: A multivariate analysis. *J Clin Periodontol* 2012;39:895-903.
19. Favero G, Botticelli D, Favero G, García B, Mainetti T, Lang NP. Alveolar bony crest preservation at implants installed immediately after tooth extraction: An experimental study in the dog. *Clin Oral Implants Res* 2013;24:7-12.
20. Bressan E, Sivolella S, Stellini E, Almagro Urrutia Z, Lang NP, Botticelli D. Healing of buccal dehiscence defects at implants installed immediately into extraction sockets: An experimental study in dogs. *Clin Oral Implants Res* 2013;24:270-277.
21. Heins PJ, Wieder SM. A histologic study of the width and nature of interradicular spaces in human adult pre-molars and molars. *J Dent Res* 1986;65:948-951.
22. Kim T, Miyamoto T, Nunn ME, Garcia RI, Dietrich T. Root proximity as a risk factor for progression of alveolar bone loss: The Veterans Affairs Dental Longitudinal Study. *J Periodontol* 2008;79:654-659.
23. Aljateeli M, Fu JH, Wang HL. Managing peri-implant bone loss: Current understanding. *Clin Implant Dent Relat Res* 2012;14(Suppl. 1):e109-e118.
24. Caneva M, Salata LA, de Souza SS, Baffone G, Lang NP, Botticelli D. Influence of implant positioning in extraction sockets on osseointegration: Histomorphometric analyses in dogs. *Clin Oral Implants Res* 2010; 21:43-49.
25. Buser D, Wittneben J, Bornstein MM, Grütter L, Chappuis V, Belser UC. Stability of contour augmentation and esthetic outcomes of implant-supported single crowns in the esthetic zone: 3-year results of a prospective study with early implant placement postextraction. *J Periodontol* 2011; 82:342-349.
26. Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in postextraction sites. *Int J Oral Maxillofac Implants* 2009;24(Suppl.): 186-217.
27. Evans CD, Chen ST. Esthetic outcomes of immediate implant placements. *Clin Oral Implants Res* 2008;19:73-80.
28. Kan JY, Rungcharassaeng K, Lozada JL, Zimmerman G. Facial gingival tissue stability following immediate placement and provisionalization of maxillary anterior single implants: A 2- to 8-year follow-up. *Int J Oral Maxillofac Implants* 2011;26:179-187.
29. Grunder U. Crestal ridge width changes when placing implants at the time of tooth extraction with and without soft tissue augmentation after a healing period of 6 months: Report of 24 consecutive cases. *Int J Periodontics Restorative Dent* 2011;31:9-17.
30. Chung DM, Oh TJ, Shotwell JL, Misch CE, Wang HL. Significance of keratinized mucosa in maintenance of dental implants with different surfaces. *J Periodontol* 2006;77:1410-1420.
31. Kan JY, Rungcharassaeng K, Morimoto T, Lozada J. Facial gingival tissue stability after connective tissue graft with single immediate tooth replacement in the esthetic zone: Consecutive case report. *J Oral Maxillofac Surg* 2009;67(Suppl. 11):40-48.
32. Hsu YT, Shieh CH, Wang HL. Using soft tissue graft to prevent mid-facial mucosal recession following immediate implant placement. *J Int Acad Periodontol* 2012;14:76-82.