3D Cortical Bone Anatomy of the Mandibular Buccal Shelf: a CBCT study to define sites for extra-alveolar bone screws to treat Class III malocclusion

Abstract

Objective: *Assess the feasibility of a proposed bone screw site in the mandibular buccal shelf (MBS) region, relative to the orientation of the skeletal platform and quantity of the available cortical bone, for either perpendicular or angled bone screws.*

Materials and Methods*: CBCT images were obtained retrospectively for 12 Asian patients treated with bilateral MBS bone screws (n=24) for Class III skeletal malocclusion. None of the subjects had periodontal or buccal-lingual alignment problems. Cortical bone thickness adjacent to the first and second molars was measured on the mesial, midpoint and distal surfaces. Seven progressive sites were measured in frontal cuts of the CBCT image from the mesial of the first molar to the distal of the second molar. The angle was measured between a line that was the best fit of the MBS surface and the axial inclination of the adjacent molar. Cortical bone thickness was measured perpendicular and at a 30° angle along the surface of the MBS at 3, 5 and 7 mm apical to the alveolar crest of the molars.*

Results*: There was a statistically significant increase (t-test P<.0001) for cortical bone thickness for a 30° angled insertion, compared to a perpendicular measurement. The increase in cortical bone thickness for an angled insertion ranged from 0.56-1.24 mm. The median for cortical bone thickness at the 30° inclination ranged from 2.92-4.10 mm for all sites.*

Discussion*: Boxplots of the data indicated that the optimal location for a MBS bone screw is 5-7 mm below the alveolar bone crest, at approximately the plane between the mandibular first and second molars. At the recommended insertion angle of 30° cortical bone thickness lateral to the interproximal area between the molars ranged from 3.54-4.05 mm. This is a sufficient site for routinely achieving primary stability with MBS bone screws.*

Conclusion*: The MBS lateral to the first and second molars is an appropriate site for extra-alveolar (E-A) temporary anchorage devices (TADs) that are inserted at ~30° The most ideal skeletal location for the bone screw is about 5-7 mm below the alveolar crest. (Int J Orthod Implantol 2016;41:74-82)*

Key words:

Mandibular buccal shelf, miniscrews, CBCT, Skeletal anchorage, Cortical bone engagement, Extra-Alveolar orthodontic anchorage

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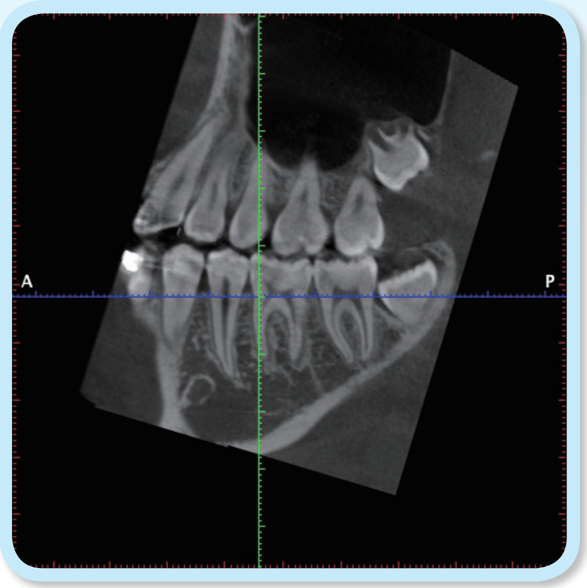
Introduction

There are numerous case reports[1-3] indicating miniscrews in the mandibular buccal shelf (*MBS*) region are a reliable form of extra-alveolar (*E-A*) anchorage for retracting the entire mandibular arch to conservatively correct severe skeletal and dental malocclusions, without extractions or orthognathic surgery.[4-7] Miniscrew temporary anchorage devices (*TADs*) are retained by mechanical conformation of bone at the implant interface rather than by osseointegration.[8] Primary stability of the TAD is the critical factor for clinical success.[9] A systematic review and meta-analysis indicates that there is a positive association between primary stability and cortical bone thickness.[10] Inaba[11] and Park et al.[12] suggest placing the TAD at an angle to the bone surface in order to increase bone contact. To serve as anchorage to reliably retract the entire mandibular arch, a MBS bone screws should be placed lateral to the molar roots and as perpendicular to the occlusal plane as possible.[4]

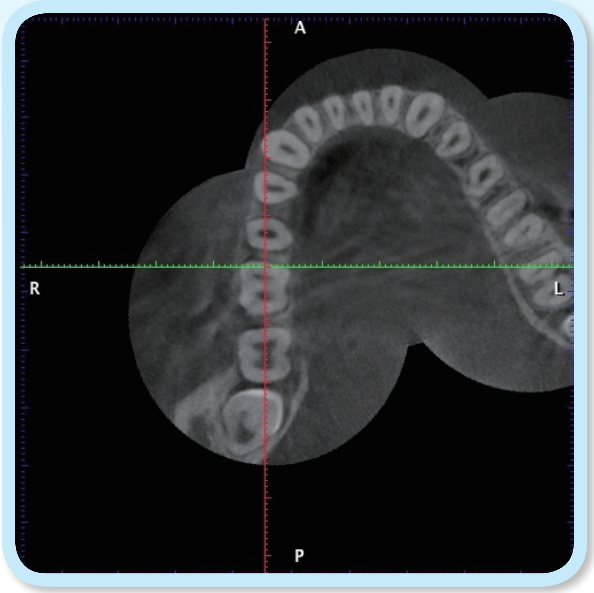
The purpose of this study was to use measurements from cone-beam computed tomography (*CBCT*) scans to quantify the skeletal anatomy of the mandibular buccal shelf region in 12 Class III patients. The study quantified the MBS relative to: 1. its angle (*slope*), 2. the cortical bone thickness measured perpendicular to the surface, and 3. the amount of cortical bone engagement at a TAD interface when the screw was installed lateral to the molar roots, and approximately perpendicular to the occlusal plane (*~30º angle to the bone surface*).

Materials and Methods

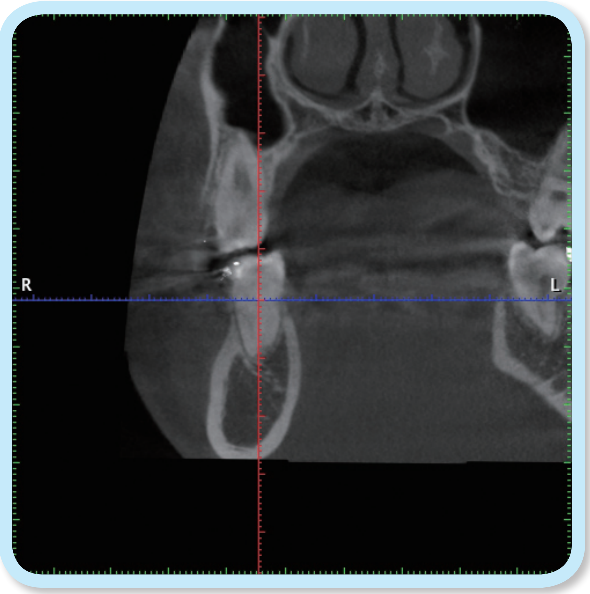
Patients with CBCT scans were retrospectively collected from the Beethoven Orthodontic Center in Hsinchu City, Taiwan, for a 19 month period ending in December 2015. Inclusion criteria were: 1. Class III malocclusion, 2. Asian heritage, 3. healthy periodontium, 4. no molar buccal-lingual alignment problems, and 5. MBS TADs were used to retract the entire mandibular arch. The inclusive sample of all patients with CBCT scans, who fit the inclusion criteria, was 12 subjects for a total of 24 MBS bone screw sites. The three-dimensional CBCT images selected for measurement were perpendicular to the sagittal plane (*Fig. 1*). To illustrate the post-



■ *Fig. 1:*
The axial plane (blue) was aligned at the mean mandibular alveolar crest level in the sagittal view.

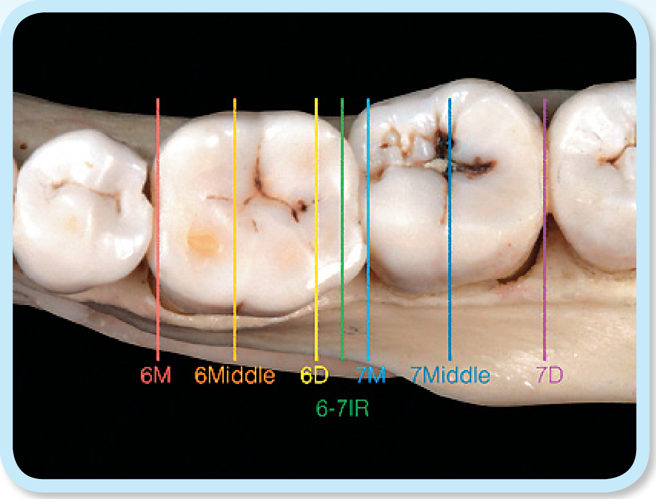


■ *Fig. 2:*
The sagittal plane (red) was aligned by bisecting the mandibular first and second molars symmetrically in the axial view.

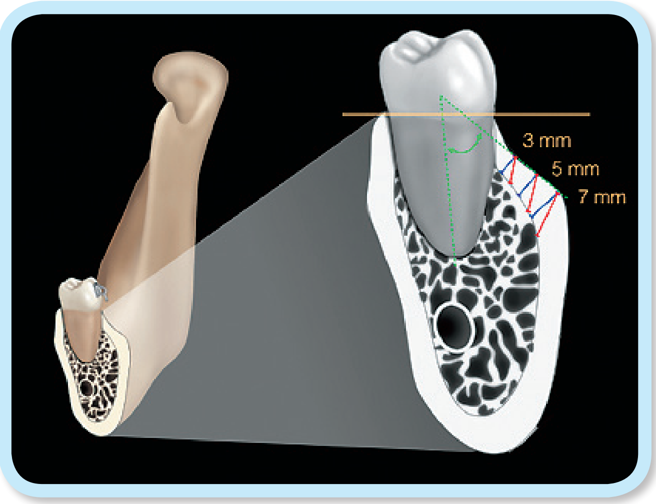


■ *Fig. 3:*
Measurements were performed on slices in the frontal plane inferior to the blue line.

operative position of a TAD in the area studied, the axial (*Fig. 2*) and frontal (*Fig. 3*) views are shown for a patient, who required a follow-up CBCT after TAD placement to ensure that a buccally oriented screw was lateral to the molar roots. As shown in Figure 4, the planes selected for bone measurement in the first molar (6) region were: 1. mesial (*6M*), 2. middle of the crown through the furcation area (*6Middle*), 3. through the crown at the posterior plane distal to the root (*6D*), 4. interradicular bone between the molars (*6-7IR*), 5. mesial plane of the second molar (*7M*), 6. middle of the second molar (*7Middle*), and 7. distal of the second molar (*7D*). The planes are color coded (*Fig. 4*) to correspond to the subsequent bone measurement data, collected in the frontal plane (*Fig. 3*).



■ *Fig. 4:*
The CBCT views measured corresponded to seven coronal sections from the mesial of the first molar to the distal of the second molar. Each plane is color coded to correspond to the Boxplot data. See text for details.



■ *Fig. 5:*
The angle (green curved arrow) of the MBS was measured relative to the axial inclination of the adjacent molar (green lines). Bone thickness measurements were performed at 3, 5 and 7 mm from the alveolar crest. The width of the cortex was assessed perpendicular (blue lines) and at a 30° angle to the bone surface (red lines).

The angle (*green double-headed arrow*) measured was formed by the cortical outline of the MBS (*green lines*) relative to the axial inclination of the respective molar (*Fig. 5*). The cortical bone thickness was measured perpendicular (*blue lines*) and at a 30 degree angle (*red lines*) as shown at 3, 5 and 7 mm from the alveolar bone crest.

Results

Conflicting results have been reported for age and gender effects on cortical bone thickness,[13] so there was no attempt to test these variables with the current relatively small sample (*n=12*). Since all comparative measurements were consistent in a preliminary analysis, the 24 MBS sites were plotted together (*n=24*). Boxplot 1 (*Fig. 6*) shows the angle of the MBS to the long axis of the molars progressively increased between the planes mesial to the first molar and distal to the second molar. Consistent median angles were noted for 6-7IR (*39.1°*) and 7M (*40.2°*), but there was an abrupt increase to 55.2° at 7Middle. The statistical details for Boxplot 1 are presented in the legend to Figure 6.

Boxplot 2 (*Fig. 7*) shows the comparison of perpendicular to 30° angled bone thickness measurements at 3 mm from alveolar crest for all sampling sites. A consistent increase for angled measurements was noted for all sites and the differences were significantly different (*t-test, ***P<.0001*). The 30° insertion angle for the TAD resulted in 0.56-1.24 mm more cortical bone engagement at the interface. The median thickness

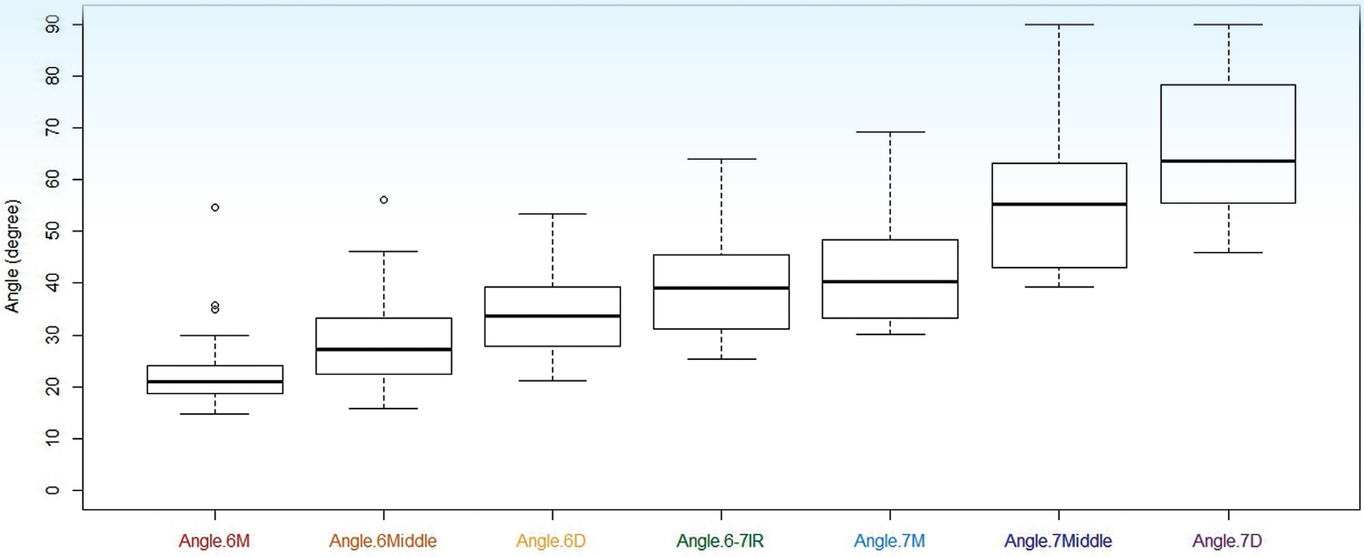


Fig. 6:

Boxplot 1 illustrates the increasing angle (flattening) of the MBS to the long axis of the molars as the buccal shelf extends posteriorly. See text for details.

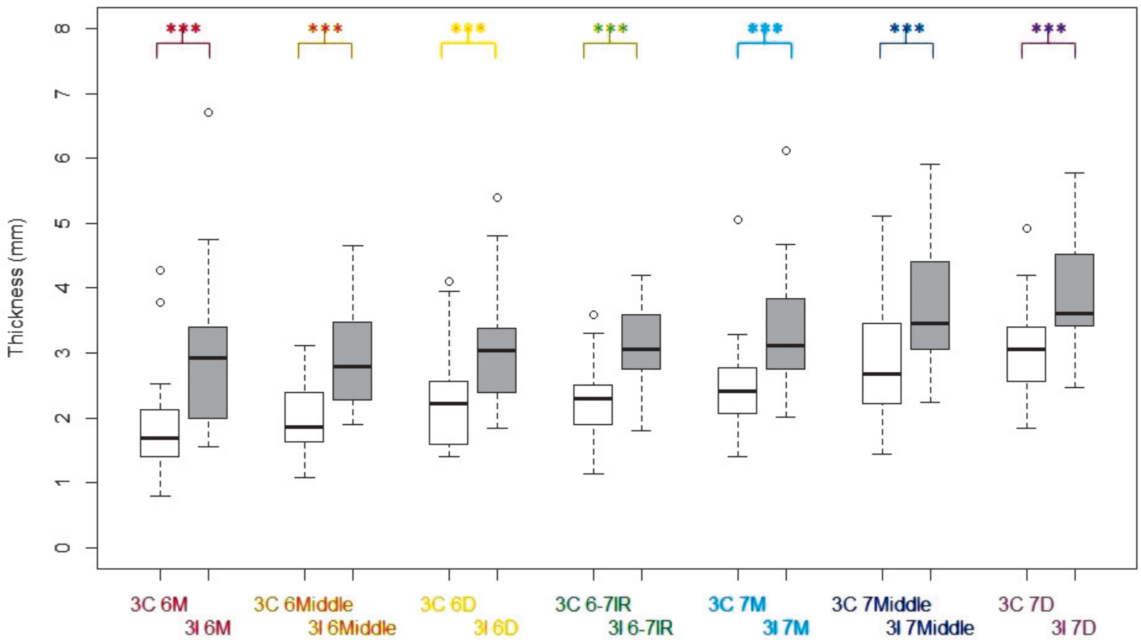


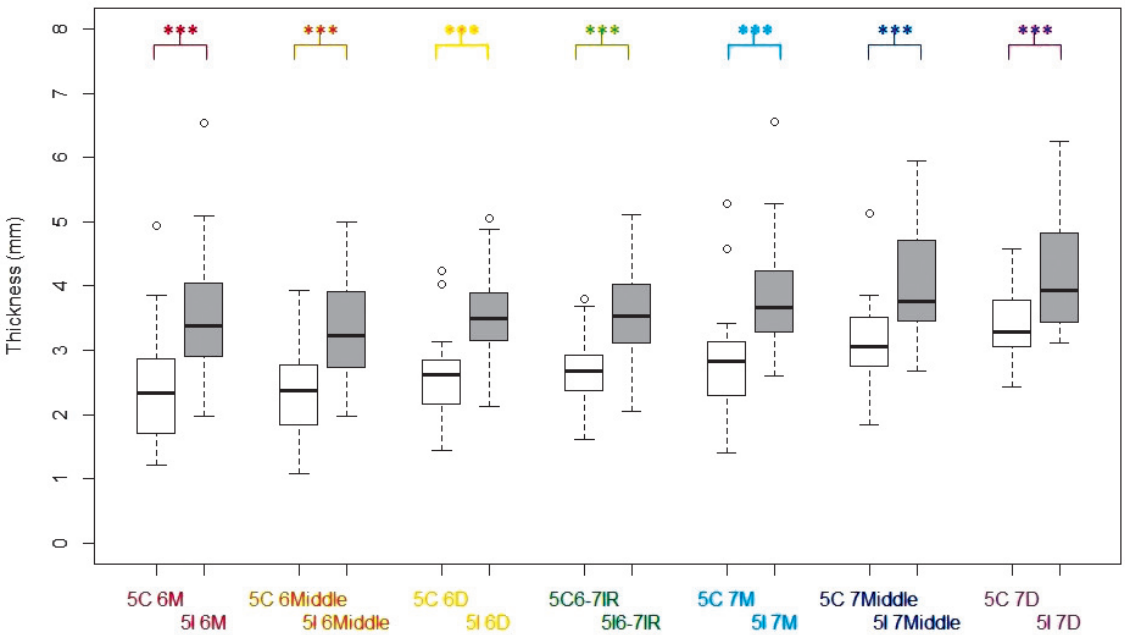
Fig. 7:

*Boxplot 2 compares the cortical bone thickness, when measured perpendicularly (white box) and at a 30° angle (grey box) to the axial inclination of the molars. The bold horizontal line is the median for all specimens measured (n=24). The bottom and top of each box are the 25th (Q1) and 75th (Q3) percentiles, respectively. Relative to the interquartile range (IQR) the variation bars (whiskers) are the minimum and maximum data within the range of Q1-1.5 IQR and Q3+1.5 IQR (IQR=Q3-Q1). The angled bone thickness measurement was significantly increased for all sites (P<0.001***).*

for the 3C 6-7IR and 3I 6-7IR sites were 2.30 and 3.05 mm, respectively. Similar measurements at the 3C 7M and 3I 7M sites were 2.41 and 3.12 mm.

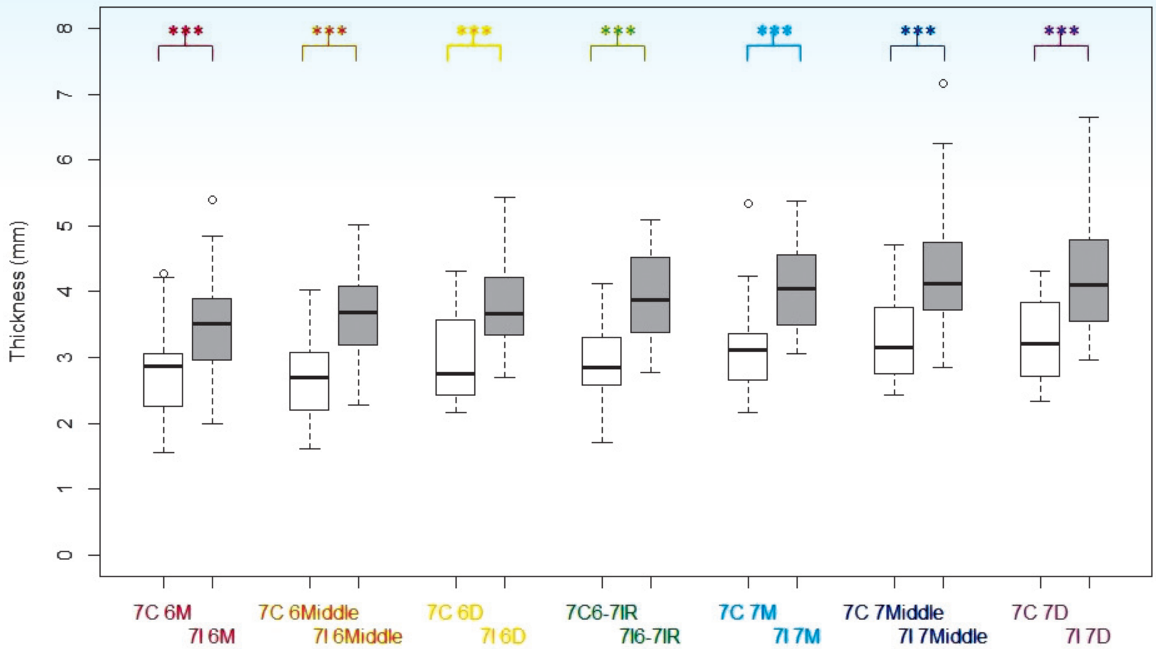
Boxplot 3 (*Fig. 8*) reveals a similar pattern for the same comparative measurements at 5 mm from alveolar crest (*t-test, ***P<.0001*). Again the angled insertion angle resulted in 0.66-1.04 mm more cortical bone engagement. The median thickness for the 5C 6-7IR and 5I 6-7IR sites were 2.69 and 3.54 mm, respectively. The median thickness of 5C 7M and 5I 7M sites were 2.83 and 3.67 mm.

Boxplot 4 (*Fig. 9*) shows the same trends for measurements made 7 mm from alveolar crest. The cortical bone thickness increased gradually from the anterior to posterior planes for both the perpendicular and 30° inclinations (*t-test, ***P<.0001*). For the angled measurements there was 0.65-1.04 mm more cortical bone engagement across all sites. The median thickness of 7C 6-7IR and 7I 6-7IR sites were 2.85 and 3.88 mm, respectively. The same relationship for the 7C 7M and 7I 7M sites were 3.12 and 4.05 mm.



■ *Fig. 8:*

*Boxplot 3 shows the comparison of cortical bone thickness at 5 mm from the alveolar crest, between perpendicular (white box) and 30 degree angle (grey box) methods, at all seven sampling sites. The angled measurements were consistently greater at all sites (P<0.001***).*



■ *Fig. 9:*

*Boxplot 4 compares cortical bone thickness at 7 mm from the alveolar crest, between perpendicular (white box) and 30 degree angle (grey box) methods, at all seven sampling sites. The angled measurements were consistently greater at all sites (P<0.001***).*

Disussion

Angulation and bone thickness measurements from CBCT cuts documented that the MBS in Class III patients becomes progressively flatter from anterior to posterior. Figure 6 shows that the most consistent, relatively flat relationship was noted lateral to the interproximal area between the first and second molars (*6-7IR and 7M*). This site is the optimal location for an E-A bone screw that is also extra-radicular. The angulation of the MBS at the optimal TAD site is ~38 degrees (*Fig. 6*) which indicates that the bone screw should have the same angulation to the surface of the MBS to approximate the axial inclination of the molar. The latter is an important objective to avoid blocking the path of tooth movement when retracting the entire lower arch to conservatively treat Class III malocclusion.

Another factor favoring a superiorly angled insertion angle for a TAD is increased bone contact at its interface to achieve enhanced mechanical interlocking.[9-11] Under ideal conditions the TAD angulation should be as close to the axial inclination of the adjacent molar as possible.

Inaba et al. suggest that the initial stability of miniscrews increases due to the extended bone contact when inserting at an inclined angle.[11] Miniscrews are generally inserted at approximately 30 degrees to the line perpendicular to the bone contact. The present measurements at a 30° angle for sites 3-7 mm from the alveolar crest documented that angulating the TAD consistently increased bone contact from 0.56-1.23 mm, which was ~25-30% increase at all sites. This is an important consideration because even a 0.5 mm difference in cortical bone thickness (*contact*) can have a major impact on the success rate.[14]

The median for bone interface contract for an inclined TAD was 2.92-4.10 mm, and even the minimal value for the inclined cortical bone thickness measurement was 1.56 mm at 3I 6M. At least 1 mm of buccal cortical bone thickness is necessary to achieve primary stability.[15,16] The abundant cortical bone in the MBS, up to 4 mm of bone thickness for an inclined miniscrew, is reflected in the high success rate for E-A TADs (*~ 93%*).[17]

Inserting MBS miniscrews at a 30° angle can be problematic. Pilot holes and changing the orientation of the TAD as it is screwed in have been suggested to consistently achieve a vertical orientation of the bone screw. However, pilot holes are also difficult to drill at an inclined angle, and rotating screws as they are inserted into dense cortical bone risks factoring the screw and/or creating a bone defect. Stainless-steel miniscrews with high flexibility and resistance to fracture are indicated for the MBS.[17] There are other factors which should be considered, including the mucogingival junction and the buccal impingement of the cheek. Chang et al.[17] recommend a relatively vertical orientation for the bone screw, and found that penetrating moveable alveolar mucosa was not a problem, if the TADS had 5 mm of soft tissue clearance.

The present data (*Figs. 6-9*) was plotted with the Boxplot method because it is a convenient way of comparing groups of data according to their quartiles.[18] Collectively the boxplots indicate that the optimal position for a MBS bone screw is 5-7 mm from alveolar crest and the TAD should be inserted lateral to the first and second molar interproximal area (*6-7IR and 7M*). The median for inclined cortical bone thickness at the recommended sites ranged from 3.54 to 4.05 mm, which is more than sufficient for primary stability.[15-17]

Conclusion

The mandibular buccal shelf is an appropriate skeletal site for extra-alveolar bone screws to retract molars for nonextraction treatment of mandibular crowding. They are also suitable anchorage for retracting the entire lower arch to conservatively correct Class III malocclusion. The optimal position for the TAD is lateral to the contact of the lower first and second molars, approximately 5-7 mm below the alveolar crest, and inserted at an orientation of about 30° to the bone surface.

Reference

1. Huang S, Chang CH, Roberts WE. A severe skeletal Class III open bite malocclusion treated with non-surgical approach. Int J Orthod Implantol 2011;24:28-39.
2. Su B, Chang CH, Roberts WE. Conservative management of a severe Class III open bite malocclusion. Int J Orthod Implantol 2013;30:40-60.
3. Shih YH, Lin JJ, Roberts WE. Conservative correction of severe class III open bite: 3 force vectors to reverse the dysplasia by retracting and rotating the entire lower arch. Int J Orthod Implantol 2015;38:4-15.
4. Lin JJ. Treatment of severe Class III with buccal shelf miniscrews. News & Trends in Orthodontics 2010;18:4-13.
5. Chang CH, Roberts WE. Orthodontics. Taipei: Yong Chieh; 2012.
6. Lin JJ, Liaw JL, Chang CH, Roberts WE. Orthodontics: Class III correction. Taipei: Yong Chieh; 2013.
7. Park HS, Lee SK, Kwon OW. Group distal movement of teeth using microscrew implant anchorage. Angle Orthod 2005;75(4):602-9.
8. Crismani AG, Bertl MH, Celar AG, Bantleon H-P, Burstone CJ. Miniscrews in orthodontic treatment: review and analysis of published clinical trials. Am J Orthod Dentofacial Orthop 2010;137(1):108-13.
9. Wilmes B, Rademacher C, Olthoff G, Drescher D. Parameters Affecting Primary Stability of Orthodontic Mini-implants. J Orofac Orthop / Fortschritte der Kieferorthopädie 2006;67(3):162-74.
10. Marquezan M, Mattos CT, Sant'nna EF, de Souza MMG, Maia LC. Does cortical thickness influence the primary stability of miniscrews?: A systematic review and meta-analysis. Angle Orthod 2014;84(6):1093-103.
11. Inaba M. Evaluation of primary stability of inclined orthodontic mini-implants. J Oral Sci 2009;51(3):347-53.
12. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. Am J Orthod Dentofac Orthop 2006;130(1):18-25.
13. Holmes PB, Wolf BJ, Zhou J. A CBCT atlas of buccal cortical bone thickness in interradicular spaces. Angle Orthod 2015;85(6):911-919. No. 150311070540000.
14. Motoyoshi M, Matsuoka M, Shimizu N. Application of orthodontic mini-implants in adolescents. Int J Oral Maxillofac Surg 2007;36(8):695-9.
15. Motoyoshi M, Inaba M, Ono a., Ueno S, Shimizu N. The effect of cortical bone thickness on the stability of orthodontic mini-implants and on the stress distribution in surrounding bone. Int J Oral Maxillofac Surg 2009;38:13-8.
16. Motoyoshi M, Yoshida T, Ono A, Shimizu N. Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implants. Int J Oral Maxillofac Implants 22(5):779-84.
17. Chang CH, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf miniscrews placed in movable mucosa or attached gingiva. Angle Orthod 2015;85(6):905-910. No. 150120092518005.
18. Frigge M, Hoaglin DC, Iglewicz B. Some implications of the boxplot. American Statistician 1989;43(1):50-54.