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Original Article

Optimal sites and angles for the insertion of orthodontic mini-implants at infrazygomatic crest: a cone beam computed tomography (CBCT)-based study

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Abstract: Background and Objectives: Both cortical and overall bone thicknesses of the infrazygomatic crest (IZC) were measured to determine the optimal areas for mini-implants into the IZC. The impact of insertion sites, heights and angles, sex and age on bone thickness were evaluated. Materials and Methods: In this study, cone beam computed tomography (CBCT) images of 32 patients were included. The cortical bone thickness (CBT) and overall bone thicknesses (OBT) of IZC were measured at different insertion sites between the maxillary first and second molars (site 61, 62, 63, 67, 71, 72 and 73), different heights (0 to 12 mm from alveolar bone crest) and different angles (0 to 90 degrees from the reference line). Results: OBT was the thickest at site 63, followed by site 73. For each site, the insertion height where OBT was the thickest decreased with the increase of angle. CBT and OBT were significantly influenced by sex and age. The percentage of root contact was significantly influenced by insertion heights and angles, not by sites. The recommended regions in the IZC for mini-implants were mapped. Conclusions: Both CBT and OBT in the infrazygomatic crest were influenced by insertion sites, heights, and angles. Sex and age had an impact on CBT and OBT. The optimal insertion heights and angles were 12 mm to 18 mm from the occlusal plane, and 40 to 70 degrees for mini-implants at IZC.

Keywords: Infrazygomatic crest, mini-implant, orthodontic, maxillary sinus, bone thickness

Introduction

Orthodontic mini-implantation has been widely adopted as a stable skeletal anchorage in orthodontic practice [1-3]. It has been revealed that various anatomic sites are suitable for the insertion of orthodontic mini-implants, e.g., interradicular area, palatal region, and infrazygomatic crest [4, 5]. Particularly, the infrazygomatic crest (IZC), a bony ridge running along the curvature between the alveolar and zygomatic processes of the maxilla, is generally accepted as a suitable site for mini-implants to achieve various orthodontic tooth movements, e.g., anterior retraction and intrusion, posterior intrusion, and the whole maxillary dentition distalization [6-8]. Root injury will occur if the distance between the surface of the roots and mini-implants is less than 1 mm [9]. Therefore, the localization where orthodontic miniscrews are inserted ought to be precise to avoid injury to the dental root. Moreover, the anatomical structure of the IZC varies in the population, which makes it necessary to assess the distribution of different types of the IZC for better miniscrew insertion [10]. Thus, accurate insertion of IZC mini-implants is vital for clinical success.

For the stability of IZC mini-implants, both the cortical and overall bone thickness of the IZC are significant factors associated with initial stability and success [11, 12]. Moreover, it is generally accepted that the site and angle of miniscrew insertion have a great impact on primary stability [13, 14]. Hence, confirming suitable site and angle of miniscrews where preferable cortical and overall bone thickness can be acquired is crucial for IZC mini-implants. The influences of height, angle, and coronal plane on the stability of miniscrews have been evaluated in several studies [13-16]. However, few studies have taken all the three aforementioned factors into consideration to pinpoint the precise location for mini-implant insertion. Also, the effect of sex and age on IZC miniscrews placement has not been recognized. The objectives of this study were to determine the optimal sites for the insertion of IZC mini-implants by measuring the cortical and overall bone thickness at different heights, angles, and coronal planes and to examine the influence of gender and age on the insertion sites of IZC mini-implants.

Materials and methods

Participants

The study was approved by the ethical committee of West China Hospital of Stomatology, Sichuan University (WCHSIRB-CT-2020-397). A total of 32 untreated orthodontic patients (16 males, 16 females) were included in the study and their cone-beam computed tomography scans retrieved. Sample size was calculated based on the comparisons among different insertion angles, insertion sites, insertion heights and between genders. For the comparison among insertion angles, the sample size was calculated to be 16 based on the difference in means of 3.6 and the standard deviation of 2.3 from a previous study by Liou et al., [17] with a type I error of 0.05 and a power level of 80%. Similarly, sample sizes were estimated to be 8, 28, and 14 for comparisons among insertion sites and insertion heights and between genders respectively based on previous studies [16, 18]. Then, a sample size of 28 was chosen and, after a drop-out rate of 10% was considered, the final sample size for this study was 32.

Eligible patients fulfilled the following selection criteria: (1) full permanent dentition; (2) absence of craniofacial developmental malformation; (3) no history of maxillofacial surgery and temporomandibular arthrosis; (4) absence of bone metabolic disease or systemic disease; (5) distance between maxillary sinus and alveolar ridge crest no less than 10 millimeters; (6) no dental defect or implants in the maxillary buccal dentition. Included participants were further divided into four subgroups according to sex (16 males and 16 females) and age (16 adolescents (14.4±1.4 years old) and 16 adults (25.1±5.5 years old)), resulting in eight male adolescents, eight female adolescents, eight male adults and eight female adults. Their height, weight and BMI were 1.67±0.09 m, 57.69±11.03 kg and 20.43±2.47 kg/m^2, respectively.

Cone beam computed tomography (CBCT) examinations

Cone beam computed tomography (CBCT) data examinations were implemented using a three-dimensional volume scanner (MCT-1, J Morita Mfg Corp, Kyoto, Kyoto-fu, Japan) based on a cone-beam technique. The following settings were required: 85 kV (anterior posterior-latero lateral), 5.0 mA (anterior posterior), and 5.0 mA (latero lateral); exposure time, 17.5 seconds; and slice thickness, 0.5 mm.

Measurements

As displayed in **Figure 1**, measurements were performed at the following anatomic locations on both sides: three sections (mesiobuccal cusp, buccal groove, distobuccal cusp) of both first and second molars, and the coronal section between the first and second molar. This resulted in seven sites that were marked as 61, 62, 63, 67, 71, 72, and 73. As displayed in **Figures 1**, **2**, at each of the seven sites, different heights (0 mm, 1 mm, ..., 12 mm from alveolar bone crest) and different angles (0, 10, ..., 90 degrees) from the reference line (connecting the mesiobuccal cusp of bilaterally first molars) were subject to measurements.

Both overall bone thickness (OBT) and cortical bone thickness (CBT) were measured. As shown in **Figure 2**, the examination of OBT was made between the buccal border of the alveolar bone and the lingual one, the maxillary sinus floor, the paranasal sinus when the dental root would not be contacted. On the condition that the dental root was contacted, OBT would be interpreted as the distance between the buccal aspect of the alveolar bone and the buccal one of dental root. The measurement of CBT was taken as between the external and internal aspect of the buccal cortex. All measurement

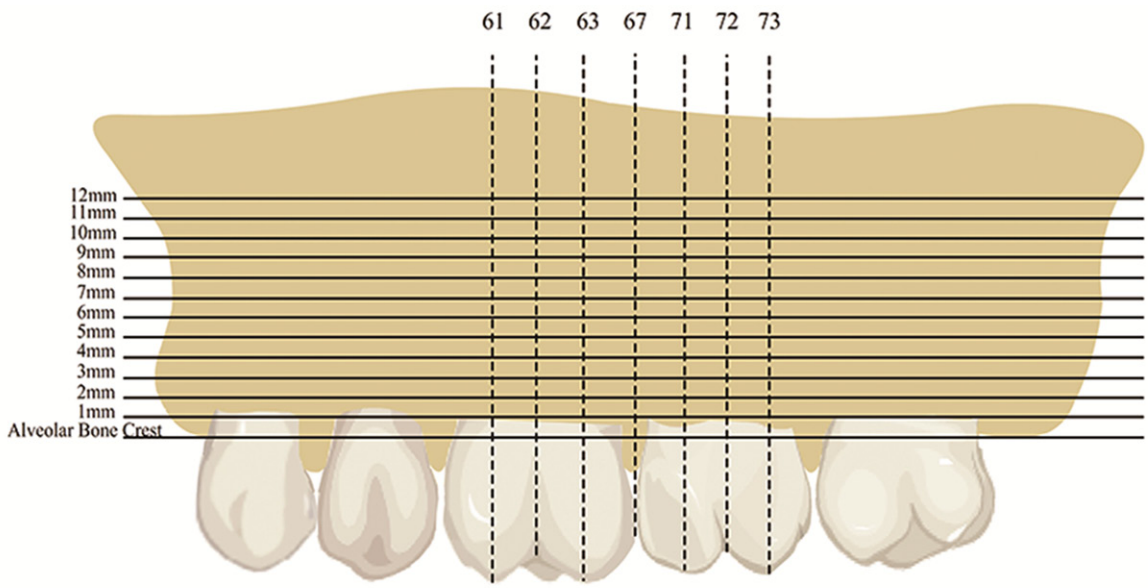


Figure 1. Anatomic locations and sites for measurements. Measurements of cortical bone thickness (CBT) and overall bone thickness (OBT) were performed at different heights (0 to 12 mm) and at different sites (61, 62, 63, 67, 71, 72, 73).

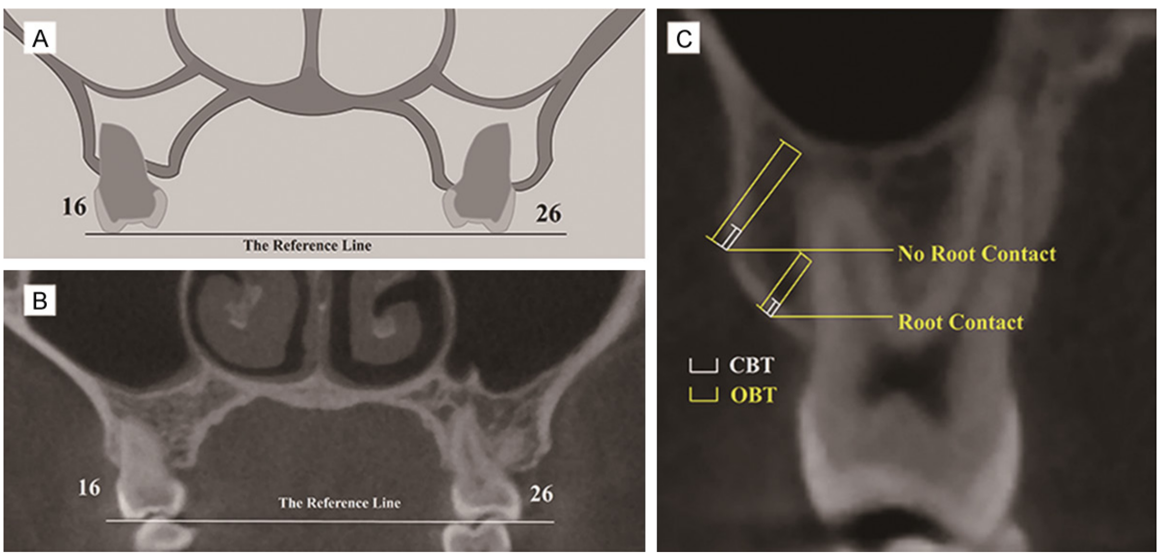


Figure 2. Reference lines and methods for measurements. A, B. The reference line was defined as the line connecting the mesiobuccal cusp of bilaterally first molars. C. The definition of cortical bone thickness (CBT) and overall bone thickness (OBT) in the condition of root contact and no root contact.

work was conducted in INFINITT PACS (INFINITT Healthcare Co., Ltd, Seoul, Korea). The measurements were performed by two investigators independently.

Statistical analyses

Both the intra-rater reliability and inter-rater reliability were analyzed through intraclass correlation (ICC) test. Moreover, the intra-rater and inter-rater differences of the measurements were compared through Student's paired t-test. The correlation between height or BMI and CBT or OBT was estimated through correlation analysis. The differences of IZC shape among seven different insertion sites (site 61, 62, 63, 67, 71, 72, 73) were analyzed through Chi-square test. The influences of insertion site, insertion height

Table 1. Distribution of the infrazygomatic crest shape among seven sites

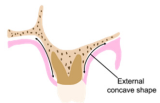
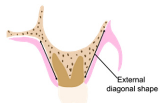
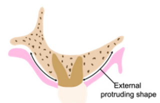
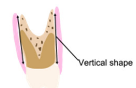
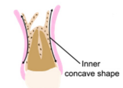
	External concave shape	External diagonal shape	External convex shape	Vertical shape	Inner concave shape	Inner diagonal shape
Shape						
61	50	6	3	0	4	1
62	47	15	2	0	0	0
63	36	17	2	9	0	0
67	12	26	1	25	0	0
71	7	19	1	36	0	1
72	2	17	0	40	0	5
73	1	18	0	36	0	9
Total	155	118	9	146	4	16

Table 2. Comparison of CBT and OBT in males and females, adolescents and adults

Outcome	Gender				P	Age				P
	Males		Females			Adolescents		Adults		
	Mean (mm)	SD	Mean (mm)	SD		Mean (mm)	SD	Mean (mm)	SD	
CBT	1.12	1.01	1.50	1.54	<0.001	1.07	1.01	1.55	1.53	<0.001
OBT	4.86	4.72	4.75	4.65	0.01	4.39	4.38	5.22	4.93	<0.001

and insertion angle on OBT, CBT and root contact were analyzed through three-way ANOVA. All the statistical analyses were conducted in SPSS 25.0 and GraphPad 7.0, and a *p*-value <0.05 was considered significant.

Results

Through paired-t test, no significant difference was found between the repeated measurements for both two observers (both P>0.05). Additionally, the ICC test revealed that the intra-rater reliability of two observers were good (ICCs were 0.94 and 0.83 for each of the two investigators, respectively). For the reliability between two observers, paired-t test showed the data were similar (both P>0.05), and the ICC test for inter-rater reliability was indicative of good reliability (ICC = 0.88).

Chi-square test found the distribution of the infrazygomatic crest shape was significantly different among the seven insertion sites (P<0.001). As displayed in **Table 1**, the external concave shape is the most frequent shape at the three sites (site 62, 62, 63) of the maxillary first molar, and the percentages were 78.12%, 73.44%, and 56.25% respectively. However, the external diagonal shape is the most common at the site (site 67) between the maxillary first and second molar and the percentage was 40.63%. When it comes to the three sites (site 71, 72, 73) of the maxillary second molar, the vertical shape occurs most frequently and the percentages were 56.25%, 62.50%, and 56.25% respectively.

As shown in **Table 2**, CBT was significantly higher among females than among males (P<0.001), while males had significantly wider OBT than females (P<0.05). Both CBT and OBT were significantly higher among adults than among adolescents (both P<0.001). Through correlation analysis, no significant correlation was found between BMI with either CBT or OBT (P>0.05). Height was not correlated with either CBT or OBT (P>0.05).

For CBT, none of the seven insertion sites were significantly different from the other ones through Tukey's post-hoc test (all P>0.05). On average, OBT was the highest at the site of the maxillary first molar distobuccal cusp (site 63) (5.7±5.2) and the second highest at the site of the maxillary second molar distobuccal cusp (site 73) (5.4±4.7). However, the site of the

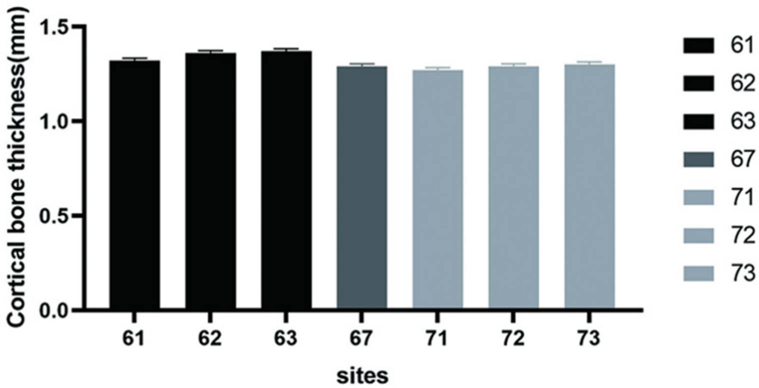


Figure 3. Comparisons of cortical bone thickness (CBT) among seven sites.

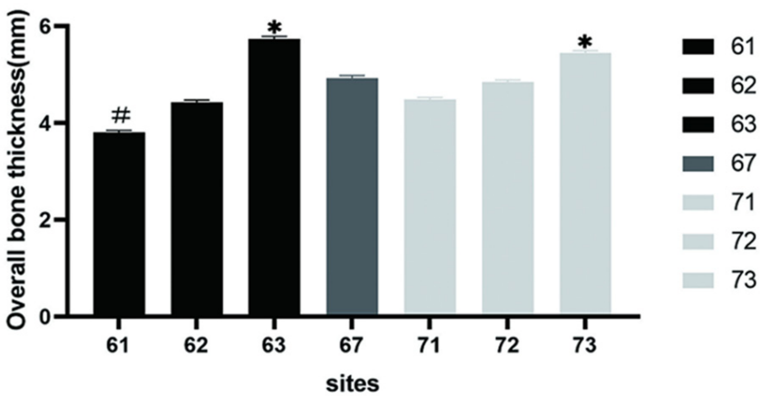


Figure 4. Comparisons of overall bone thickness (OBT) among seven sites.

maxillary first molar mesiobuccal cusp (61) obtained the least favorable width of OBT (3.80±4.3) (**Figures 3**, **4**). Tukey's post-hoc test found that the above three insertion sites of OBT (site 61, 63 and 73) were significantly different from the others (all P<0.001).

Three-way ANOVA test revealed that insertion sites (P<0.001), insertion heights (P<0.001) and insertion angles (P<0.001) were all the significant influencing factors for CBT and OBT. As displayed in **Figure 5**, there was a significant difference in CBT among different insertion heights (all P<0.001) in 0 to 90 degrees, while CBT was significantly influenced by insertion sites only in 40, 50, and 70 degrees (P>0.05). As shown in **Figure 6**, for each insertion site, the insertion height where OBT was the thickest decreased with the increase of insertion angle. As displayed in **Figure 7**, the percentage of root contact was significantly influenced by insertion heights and angles (all P<0.001), but there was no significant difference among different insertion sites (P>0.05).

As displayed in **Figure 8**, the yellow and grey areas were identified as insertion positions where the OBT was greater than 5 mm and the percentage of root contact was less than 10%. The seven dotted lines were interpreted as the connecting line between different locations where the minimum insertion angle was 10, 20, 30, 40, 50, 60, 70, or 80 degrees respectively to meet the above conditions. The yellow region was the recommended insertion positions for mini-screws plantation, while the grey regions were not optimal enough for mini-implants. The mean of the distance between alveolar bone crest and occlusal plane among seven sites (site 61, 62, 63, 67, 71, 72, 73) was 9 mm. Moreover, among the seven sites, the insertion site passing the distobuccal cusps of first molars (site 63) is the most ideal site. As displayed in **Figure 9**, for the insertion site of 63, the recommended insertion heights were 12 mm to 18 mm from the occlusal plane, with insertion angles being 40 to 70 degrees.

Discussion

In this study, both cortical bone thickness (CBT) and overall bone thicknesses (OBT) were assessed so that the optimal positions for mini-screws insertion in the infrazygomatic crest (IZC) could be determined. Insertion sites, heights and angles were all important influencing factors for CBT and OBT. Sex and age had an impact on CBT and OBT. However, BMI and heights had no correlation with CBT or OBT.

This study demonstrated that the most frequent IZC shapes of three sites of the first molar (site 61, 62, 63) and the second molar (site 71, 72, 73) were the external concave shape and the vertical shape, respectively. For

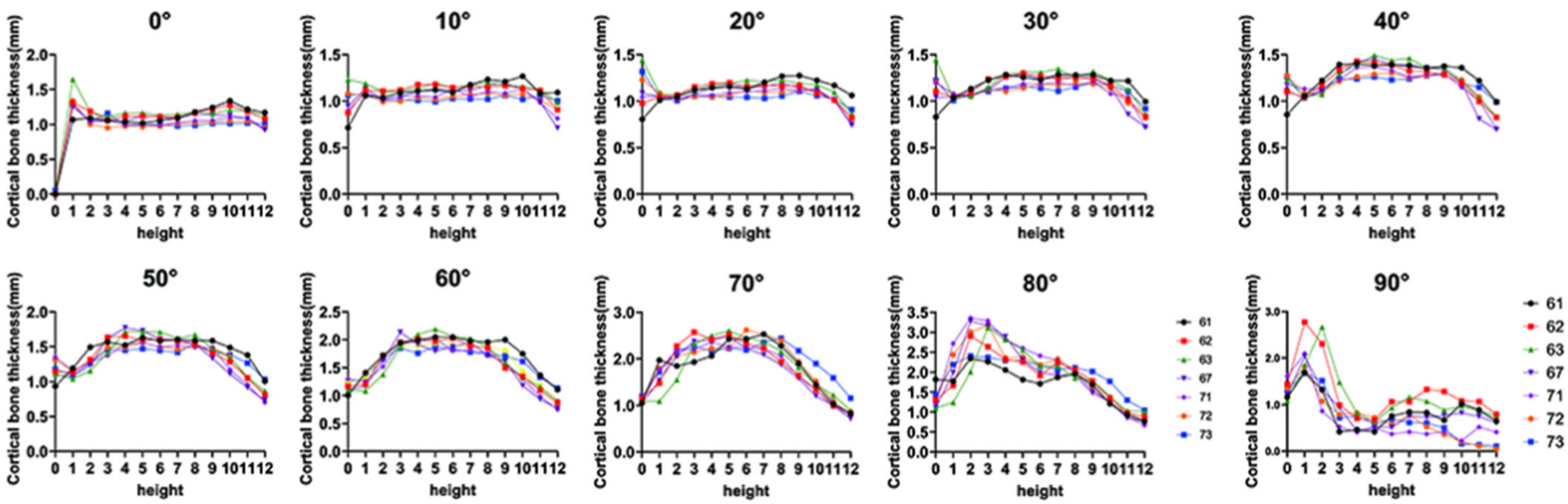


Figure 5. Comparison of thickness of cortical bone thickness (CBT) at different sites, heights and angles.

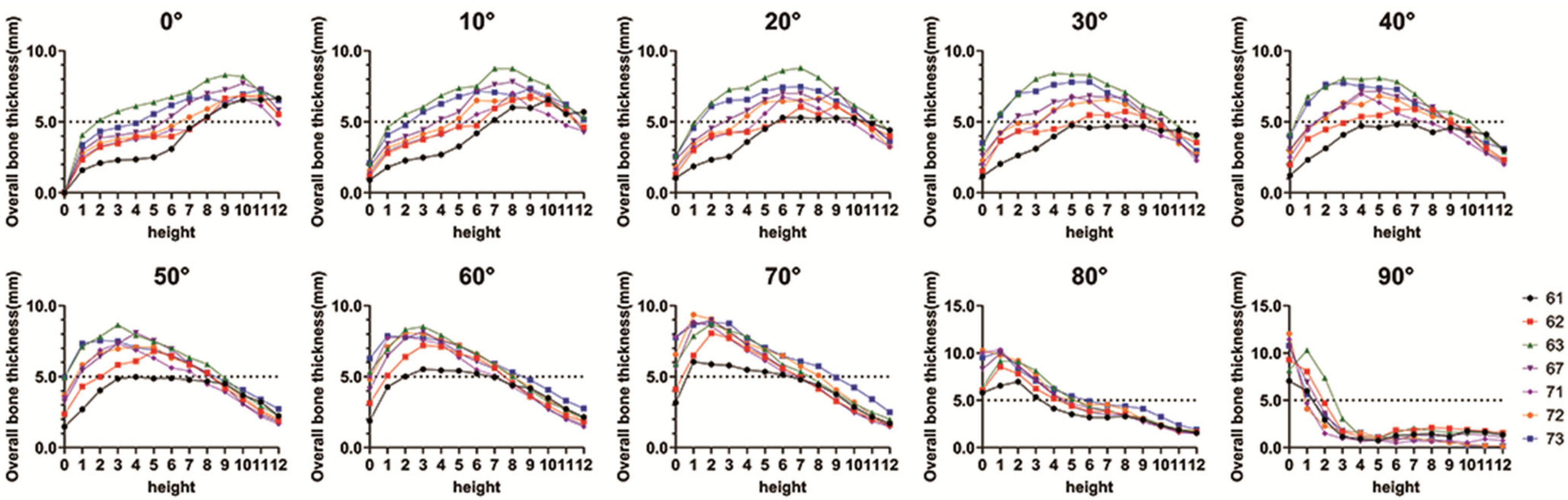


Figure 6. Comparison of thickness of overall bone thickness (OBT) at different sites, heights and angles.

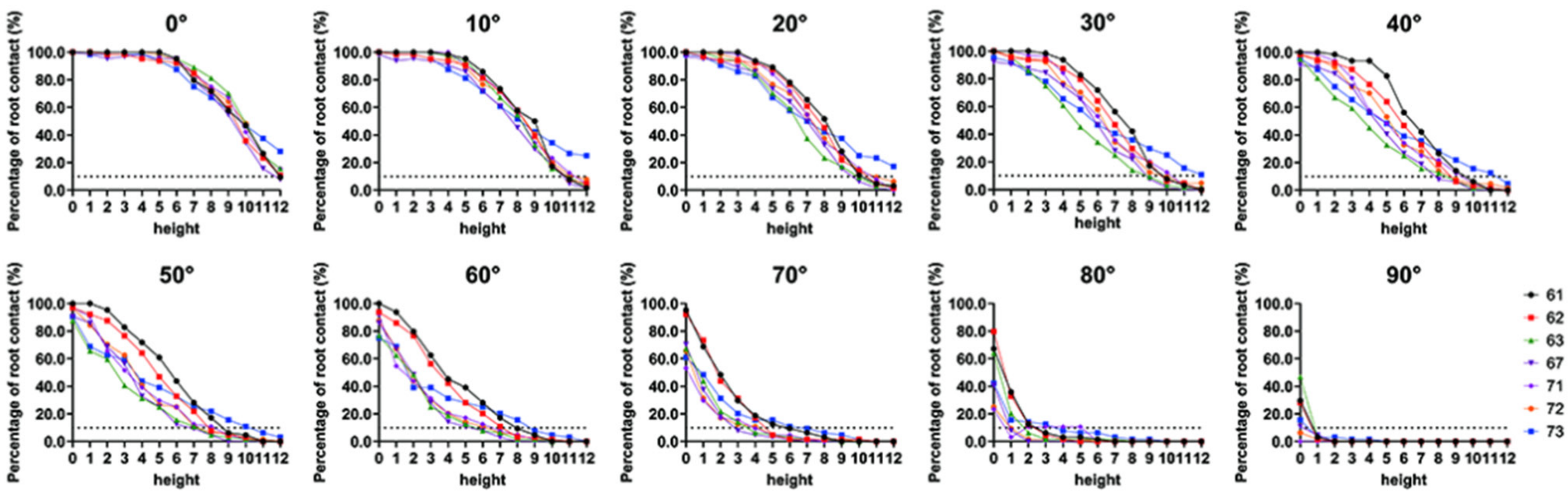


Figure 7. Comparison of the percentage of root contact at different sites, heights and angles.

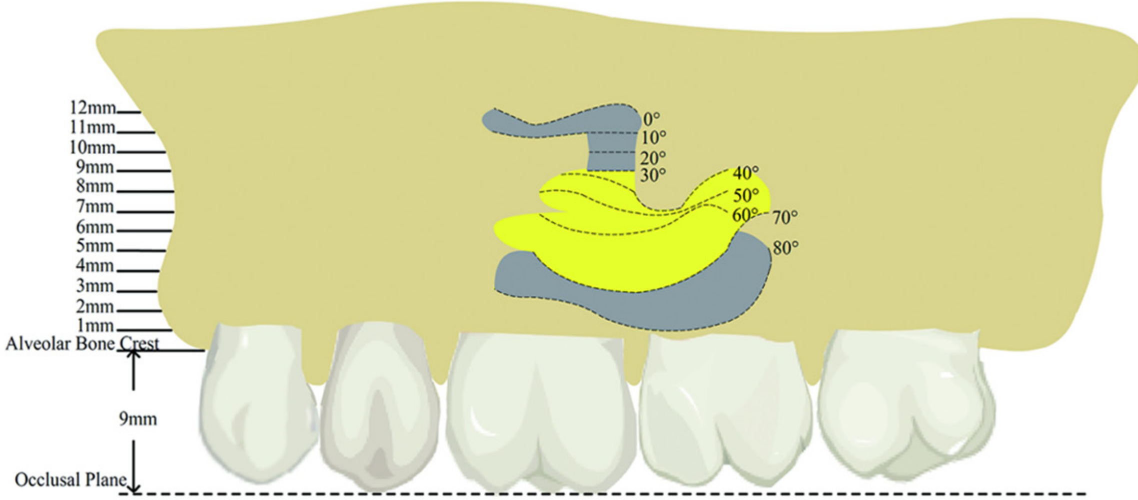


Figure 8. Recommended anatomic sites for the insertion of mini-implants at infrazygomatic crest (sagittal view) (optimal area: yellow; suboptimal area: grey).

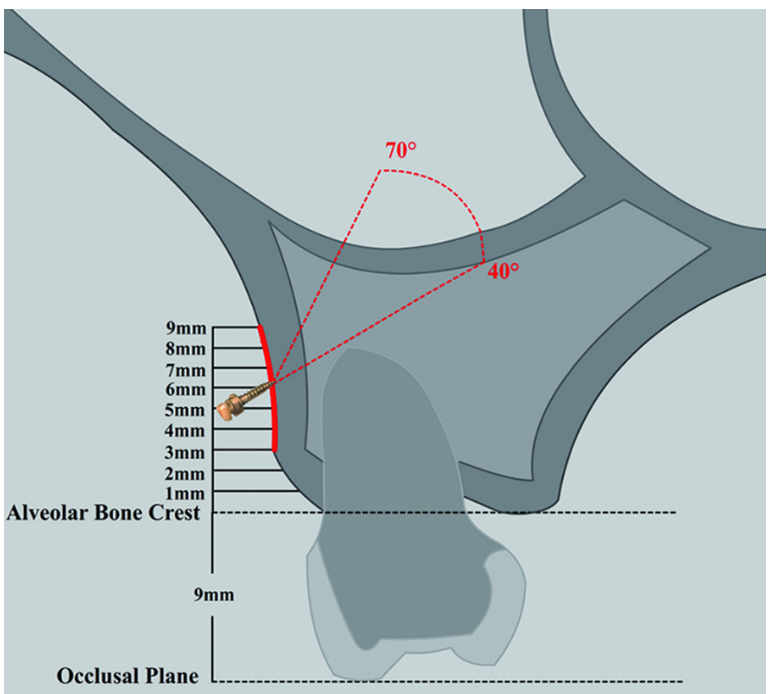


Figure 9. Recommended heights and angles at the insertion site of 63 (coronal view).

the site between the first and second molars (site 67), the most common one was the external diagonal shape. As the coronal plane moves distally between the first and second molars, the shape of IZC gradually becomes straight towards the vertical direction. It has been revealed that the IZC often runs from the zygomatic process to the first molars, making external concave shape most frequently encountered at the first molar region.

The CBT of females was thicker than males, while males had thicker OBT. Additionally, both CBT and OBT of adults were thicker than those of adolescents. According to some studies, the maxillary sinus floor moved upward with age increasing after 20, thus the average position of maxillary sinus floor was higher among adults than adolescents, leading to thicker OBT among adults than adolescents.

OBT at site 63 was thickest among all the insertion sites, which was consistent with the studies of Liu et al. [16]. The second thickest OBT was obtained at site 73, while OBT at site 61 was the thinnest.

The CBT was significantly different among different insertion heights when the insertion angle ranged from 0 to 90 degrees. However, the CBT was similar among different insertion sites in all insertion angles except 40, 50 and 70 degrees. As for OBT, the insertion height where OBT was the thickest decreased with the increase of insertion angle for each insertion site. Therefore, the insertion angle was recommended to be larger at lower insertion heights and the angle could be relatively smaller at greater insertion heights.

Root injury would occur with inserted mini-implants contacting the dental root, thus the root contact should be avoided [17]. The percentage of root contact was significantly influenced by insertion heights and angles, not by insertion sites. Liou et al. found that the mean bone thickness of IZC was at least 5 mm to be adequate for mini-implant insertion [17]. Thus, the recommended areas in yellow for mini-screws insertion in IZC where the mean of OBT was greater than 5 mm and the percentage of root contact was less than 10% was displayed in **Figures 8**, **9**. The grey regions, where insertion angles are required to be 70 to 90 degrees or the insertion heights need to be 9 mm to 12 mm, were less optimal for IZC mini-screw insertion. Too large insertion angles was inappropriate and greater insertion heights might cause soft tissue infection and the failure of mini-implants [19]. The ideal insertion heights for IZC mini-implants placement were 3 mm to 9 mm from alveolar bone crest. However, the occlusal plane was a more convenient reference for clinicians and the mean of the distance between alveolar bone crest and occlusal plane was 9 mm. Moreover, the insertion site passing the distobuccal cusps of first molars (63) is the most ideal site. Hence, for the insertion site of 63, the optimal insertion heights were 12 mm to 18 mm from the occlusal plane and the ideal insertion angles are 40 to 70 degrees. In the opinion of Wang et al. [20], the best insertion height for miniscrews is 13.6 mm in Chinese male patients and 12.5 mm in female patients at the vertical level from buccal cemento-enamel junction. Paul et al. [21] reported that the angles of insertion are recommended to be 50 to 60 degrees. The results of the above previous studies were basically consistent with this study, but the difference may be attributed to that those previous studies didn't include both adults and adolescents, mesiobuccal and distobuccal roots of the maxillary first and second molars, and root protection simultaneously. Therefore, this study offers evidence and clinical recommendation for the insertion of orthodontic mini-implants at IZC.

The limitation of the current study is acknowledged. The sample size of our research is limited. Owing to the lack of samples, the conclusion of comparison between adolescents and adults needs further validation and support. This result should be interpreted with caution.

Conclusions

The most frequent shapes of the infrazygomatic crest at the maxillary first and second molars were the external concave shape and vertical shape, respectively. For the site between the maxillary first and second molars, the most common one was the external diagonal shape.

CBT was significantly thicker among females than among males, while males possess significantly thicker OBT than females. Both CBT and OBT are significantly higher among adults than among adolescents.

Both the CBT and OBT in the infrazygomatic crest were significantly influenced by insertion sites, heights and angles.

The optimal insertion heights and angles were 12 mm to 18 mm from the occlusal plane and 40 to 70 degrees respectively for the insertion site of 63 for mini-implant placement in the infrazygomatic crest.

Acknowledgements

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Disclosure of conflict of interest

None.

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