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Original Article

Assessment of Bone Thickness at the Infra Zygomatic Crest Region for Various Orthodontic Miniscrew Implant (OMSI) Insertion Angles: A Cone-Beam Computed Tomographic Study

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Main Points

- Cone-beam computed tomography assessment provided an optimal clinical parameter for safe placement of the miniscrew at the infrazygomatic crest (IZC) bone.
- The bone thickness of the IZC ranged from 4.39 mm to 9 mm along the distobuccal root of the permanent first molar
- Adequate bone thickness (6 mm to 9 mm) at the IZC was found with a probable miniscrew insertion angle of 55°-75°.
- The best possible position for orthodontic miniscrew implantation was 13.69-16 mm from the maxillary occlusal plane along the distobuccal root of the permanent first molar.

ABSTRACT

Objective: To evaluate the infrazygomatic crest (IZC) bone and develop guidelines for the optimum placement of orthodontic miniscrew implants (OMSIs) along the distobuccal root of the permanent maxillary first molar.

Methods: Bone thickness of the IZC region of 50 young adults (25 males and 25 females) aged 18-30 years were evaluated using cone-beam computed tomography images. The infrazygomatic bone thickness along the distobuccal root of the permanent maxillary first molar was assessed at various insertion angles (40° to 75° i.r.t the maxillary occlusal plane) with an increment of 5°. Student's t-test was used to compare the IZC bone thickness and height at the orthodontic miniscrew insertion site for males and females on the right and left sides.

Results: The bone thickness of the IZC region above the distobuccal root of the permanent maxillary first molar was estimated between 4.39±0.25 mm and 9.03±0.45 mm for insertion angles from 40° to 75° to the maxillary occlusal plane. The corresponding OMSI insertion heights were 17.71±0.61 mm to 13.69±0.75 mm, respectively, above the maxillary occlusal plane. There were statistically significant gender and side-wise variations in bone thickness at the IZC area and insertion height.

Conclusion: The safe position for OMSI placement at the IZC was 13.69-16 mm from the maxillary occlusal plane with an insertion angle between 55° and 75°. These parameters provide the optimum placement of OMSIs along the distobuccal root of the permanent maxillary first molar.

Keywords: Bone thickness, cone-beam computed tomography, infrazygomatic crest, orthodontic miniscrew implant

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INTRODUCTION

Maintaining anchorage has always been a key component of the success of comprehensive orthodontic treatment.[1] Orthodontic miniscrew implants (OMSIs) are considered effective anchorage support in the orthodontic armamentarium.[2,3] Several advantageous aspects of OMSIs, such as their small size, relatively uncomplicated surgical procedure, ease of placement, patient cooperation, possibility of immediate loading, and availability of multiple sites in the maxilla and mandible, have made them a promising tool in orthodontics.[4-9] In routine orthodontic practice, inter-radicular sites are used for OMSI placement, but their placement requires careful evaluation due to limited inter-radicular bone width.[10] This increases the risk of root injury when OMSI is placed in the inter-radicular area.[11-13] In addition, it has been observed that OMSI in the inter-radicular area can limit the extent of orthodontic tooth movement, whereas this is not the case with extra-radicular placement.[14] This has led clinicians to consider other favorable alternative OMSI placement sites, such as the infrazygomatic crest (IZC), mandibular buccal shelf, and hard palate.

The IZC of the maxilla is one of the most commonly used extraradicular sites for OMSI placement. It is also considered as an anatomically reinforced bone, with the cortical bone layer thickening along the maxilla from the zygoma to the molar.[15,16] The advantage of using IZC is that it is distant from the roots and has a higher bone density than the interradicular region. This could be a critical factor in the primary stability of OMSI. For various orthodontic tooth movements, such as en-masse retraction of anterior teeth, retraction of canines, group distalization of maxillary molars, and intrusion of the maxilla teeth, the OMSI at the IZC serves as absolute anchorage support.[15]

IZC consists of the cortical bone at the zygomatic process of the maxilla. It is a bony structure that appears as a ridge and is located between the zygomatic process of the maxilla and the alveolar ridge. The apex of the mesial root of the maxillary permanent first molar normally bounded the zygomatic crest distally and inferiorly, while the medial portion of the maxillary sinus and the protruding zygomatic process bounded it superiorly (Figure 1).[16,17] The height and thickness of the IZC vary with age, i.e., in young patients, the maximum thickness of the IZC is located between the maxillary deciduous second molar and permanent first molar; while in adult patients, it is located above the permanent maxillary first molar.[18] The primary stability of OMSI is essential for its success, which depends on bone thickness. Therefore, proper positioning of the OMSI at the appropriate IZC area is crucial. Earlier studies on the subject reported safe placement of IZC screw bilaterally at approximately 11 mm from the maxillary alveolar crest

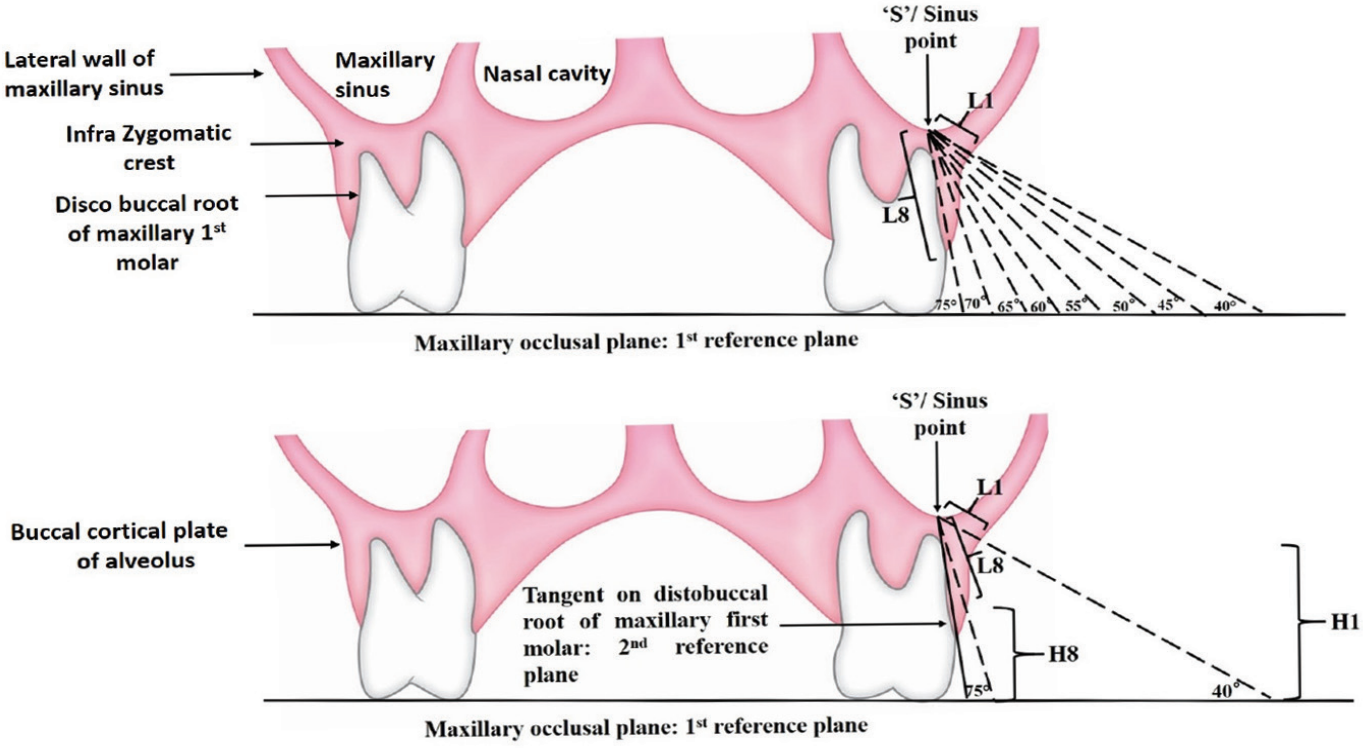

Figure 1. Illustration of the infra zygomatic crest region and reference planes used for the linear measurements
(H: Vertical height of the OMSI insertion from the maxillary occlusal plane at insertion angle, i.e., H1 at 40 40°; H2 at 45°, H3 at 50°, H4 at 55°, H5 at 60°, H6 at 65°, H7 at 70°, and H8 at 75°. L: IZC bone thickness for OMSI insertion angle at various angulation, i.e., L1 at 40 40°; L2 at 45°, L3 at 50°, L4 at 55°, L5 at 60°, L6 at 65°, L7 at 70°, and L8 at 75°)
OMSI, orthodontic miniscrew implant

between the first and second molars.[19] In another investigation, Song et al.[20] concluded that the optimal insertion heights and angles were 12-18 mm from the occlusal plane and 40-70°, respectively, for mini-implant placement in the IZC. The dimension of the OMSI routinely used in the IZC region was in the range of 10-14 mm in length 10-14 mm long, and had a minimum diameter of 2 mm.[20] Most studies have used the mesiobuccal root of the maxillary permanent first molar as a reference plane to assess an accurate site for the placement of OMSI.[16,21] However, the morphological variations of the mesiobuccal root of the permanent maxillary first molar are greater than those of the distobuccal root.[22]

Therefore, the aim of the present study was to evaluate bone thickness in the IZC area using cone beam computed tomography images and develop a guideline for the optimum placement of OMSIs along the distobuccal root of the permanent maxillary first molar. The hypotheses were as follows: 1) the IZC bone thickness increases with an increase in the probable angle of insertion and the height of insertion in relation to the maxillary occlusal plane, and 2) the IZC bone thickness is greater in males than in females.

METHODS

The current cross-sectional study was based on pre-orthodontic cone-beam computed tomography (CBCT) scans of patients who presented to the department for orthodontics. This study was approved by the Institutional Ethics Committee of the All India Institute of Medical Sciences, Bhubaneswar (T/IM-NF/Dentistry/120/137). A sample size of 33 was calculated on the basis of a significance level of α of 0.01, a power of 80%, and an effective size of 0.85, as considered in previous studies.[23-25]

The initial sample selection included CBCT scans with limited field of view from 114 patients aged 18-30 years. These scans were obtained from the archives of the Unit of Orthodontics and Dentofacial Orthopedics, Department of Dentistry, All India Institute of Medical Sciences, Bhubaneswar. All CBCT images were acquired using a NewTom scanner (NewTom, Imola, Italy) with an operating voltage potential of 80 kV, a constant voltage wave shape of 4-8 mA, an irradiation time of 13 s, and a field of view of 11 cm, 13 cm.

The inclusion criteria included CBCT scans of subjects aged 18 years with a full complement of teeth and no previous orthodontic and/or orthognathic surgical treatment. The exclusion criteria included CBCT scans with a substandard visible IZC region and those from subjects with pathological conditions including facial trauma, congenital anomalies and syndromes, and bone pathologic conditions. A total of 64 CBCT scans were excluded, and the final sample consisted of CBCT scans from 50 orthodontic patients (25 males and 25 females) with a mean age of 21.58±2.59 years. All measurements on the CBCT images were performed according to the recommendations of Liou et al.[16]. The thickness of the bone at the IZC was measured along the distobuccal root tip of the permanent maxillary first molar. CBCT images with visible IZC bone thickness, distobuccal root tip, and permanent maxillary first molar surface were selected and oriented in all CBCT sections. Multiplanar reformatting of the obtained data and the region of interest were measured using NewTom NNT analysis software. After orienting the CBCT images as suggested by Azevedo et al.,[26] two reference planes were constructed. The first reference plane was constructed horizontally, connecting the mesiobuccal cusps of the permanent maxillary first molars on the left and right sides. This is referred to as the maxillary occlusal plane (Figure 1). At the same time, a second reference plane was constructed by drawing a tangent to the buccal surface of the first molar's distobuccal root. This second plane touched the floor of the maxillary sinus at the sinus point, or "S" point (Figure 1).

From the "S" point, incremental planes were drawn with incremental angulations of 5° between 40° and 75° on the maxillary occlusal plane (Figures 1 and 2). The thickness of the IZC bone, i.e. ,"L" for each incremental plane, was defined as the distance between the plane contacting the IZC bone and the S point. Therefore, 8 IZC bone thicknesses (i.e., L1 to L8) were derived for all subjects for probable insertion angles ranging from 40° to 75°. In addition, the height from the first reference plane (i.e., maxillary occlusal plane) to the probable insertion site at different insertion angles (i.e., 40° to 75°) was plotted on the CBCT images. These heights were derived by drawing a perpendicular line from the probable insertion points on the IZC bone (i.e., 40° to 75°) to the maxillary occlusal plane. Thus, a total of eight vertical heights (H1 to H8) were derived for each insertion angle.

Statistical Analysis

STATA software (StateCorp LLC, Texas, USA) version 20.0 for the window was used for all data analysis. Sidewise (right vs left) OMSI insertion site bone thickness (in mm) and OMSI insertion site bone height from the maxillary occlusal plane at various angulations were statistically computed using descriptive statistics. The normality of a continuous variable was examined using the Shapiro-Wilk test. Student's t-test was used to compare the IZC thickness (L1 to L8) and height (H1 to H8) at OMSI insertion sites for males and females on the right and left sides. A p-value of <0.05 was considered as the level of significance.

RESULTS

The thickness of the bone at the IZC varied at different insertion sites for OMSI. It was observed that the greater the angle of insertion of the OMSI, the thicker the IZC bone was (Figures 1 and 2). The No statistically significant differences were observed between the right and left sides in terms of IZC bone thickness at different OMSI insertion angles (Table 1). However, the IZC bone thickness on the right side at OMSI insertion angles of 40°, 45°, 50°, 55°, 60°, and 75° (i.e., L1, L2, L3, L4, L5, and L8) was statistically significant in both male and female subjects

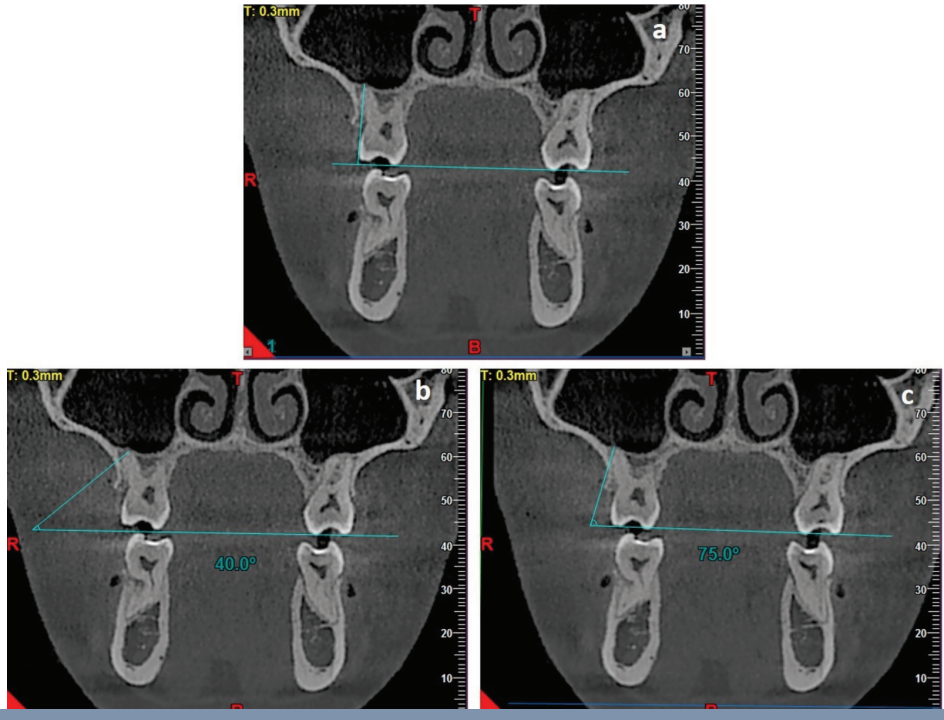

Figure 2. Multi-planar reconstructed CBCT images depicting the coronal sections of 0.3 mm thickness with reference plane contacting the mesio-buccal cusps of maxillary first molars. **a)** The orientation of the CBCT images according to the predefined reference planes for analyzing different linear measurements. **b)** the linear measurement of the infra zygomatic crest at 40 degrees from the reference plane. **c)** the linear measurement of the infra zygomatic crest at 75 degrees from the reference plane

CBCT, cone-beam computed tomography

Table 1. Comparison of OMSI insertion site bone thickness (in mm) at various angulations among males and females at the IZC region

IZC bone thickness at OMSI insertion angulations	Male		Female		Comparison (p-value)			
	Right side (MRTT) Mean±SD (n=25)	Left side (MLTT) Mean±SD (n=25)	Right side (FRTT) Mean±SD (n=25)	Left side (FLTT) Mean±SD (n=25)	MRTT vs. MLTT	FRTT vs. FLTT	MRTT vs. FRTT	MLTT vs. FLTT
40° (L1)	4.46±0.26	4.41±0.28	4.29±0.28	4.40±0.25	0.563	0.106	0.017*	0.531
45° (L2)	5.11±0.39	5.04±0.45	4.70±0.32	4.76±0.49	0.571	0.588	0.002**	0.982
50° (L3)	5.48±0.35	5.58±0.46	5.18±0.26	5.12±2.08	0.373	0.472	0.001**	0.763
55° (L4)	5.83±0.37	5.85±0.33	5.38±0.28	5.36±0.28	0.811	0.763	0.001**	0.861
60° (L5)	6.26±0.43	6.28±0.39	5.84±0.23	5.86±0.32	0.801	0.879	0.001**	0.806
65° (L6)	6.63±0.34	6.52±0.32	6.68±0.42	6.57±0.38	0.279	0.364	0.663	0.159
70° (L7)	7.83±0.39	7.88±0.33	7.79±0.26	7.76±0.32	0.617	0.700	0.644	0.880
75° (L8)	9.16±0.37	9.29±0.41	8.84±0.41	8.82±0.41	0.249	0.811	0.005**	0.577

*p<0.05, **p<0.01
MRTT, male right side thickness (in mm); MLTT, male left side thickness (in mm); FRTT, female right side thickness (in mm); FLTT, female left side thickness (in mm), OMSI, orthodontic miniscrew implant; IZC, infrazygomatic crest; SD, standard deviation

(Table 1).

The sidewise comparison (i.e. right vs. left) for all subjects regardless of gender revealed no statistically significant difference in the IZC bone thickness at different insertion angles (Table 2). The IZC bone thicknesses on the right and left sides were combined for all subjects, and the mean thickness was derived (Table 2). The mean bone thickness of the combined sample (i.e., right + left) ranged from 4.39±0.25 mm (L1) to 9.03±0.45 mm (L8) for OMSI insertion angles from 40° to 75°. The combined mean IZC bone thickness of the subjects was close to or above 6 mm at insertion angles of 55°-75°, i.e., L4-L8 (Table 2).

The height of OMSI placement from the maxillary occlusal plane (first reference plane) at different insertion angles showed remarkable variations (Figure 1). However, a general trend was observed for the placement height and OMSI insertion angle, i.e., the placement height decreased with increasing OMSI insertion angle (Table 3). A statistically significant difference ($p<0.05$) in insertion height was observed for the right and left sides of the male subjects at insertion angles of 60° (H5) and 70° (H7). Further comparison between the female right-side insertion height and the female left-side insertion height revealed that the difference in the mean insertion height was statistically significant at insertion angles of 50°, 65°, and 70°, i.e., H3, H6, and H8, respectively (Table 3). Similarly, a trend was observed for right-side height in males and right-side height in females at insertion angles of 40°, 60°, and 75° (Table 3).

Overall, sidewise comparisons (right vs. left) for OMSI insertion height for male and female subjects revealed a statistically significant difference when the male subjects' right side was compared with the female subjects' right side at insertion angles of 40°, 60°, 70°, and 75°, i.e., H1, H5, H7, and H8 (Table 3). A similar trend was observed when the height of the left side of male subjects was compared with the height of the left side of female subjects (Table 3). A sidewise comparison (right vs. left) was performed for all subjects for the insertion heights at different OMSI insertion angles. The insertion height was statistically significant at OMSI insertion angles of 50° and 70°, i.e., H3 and H7, respectively (Table 4).

DISCUSSION

Our study followed the observations of Ahmed et al.[22] in selecting the second reference plane. They observed that 78% of the mesiobuccal roots of the permanent maxillary first molar had a distal curvature and 1% had an S-shaped root. In contrast, for the distobuccal root, the mesial and distal curvatures were 19% and 17%, respectively, which is much less than the mesial

Table 2. Sidewise (right vs. left) comparison of probable OMSI insertion site thickness (in mm) at various angulations among all subjects

IZC bone thickness at OMSI insertion angulations	Right side Mean±SD (n=50)	Left side Mean±SD (n=50)	p-value	Combined (Rt+Lt) thickness at IZC region Mean±SD (n=100)
40° (L1)	4.37±0.25	4.41±0.26	0.531	4.39±0.25
45° (L2)	4.91±0.41	4.90±0.49	0.982	4.91±0.45
50° (L3)	5.33±0.34	5.36±0.44	0.763	5.34±0.40
55° (L4)	5.60±0.39	5.60±0.40	0.960	5.60±0.40
60° (L5)	6.05±0.40	6.07±0.41	0.806	6.06±0.41
65° (L6)	6.65±0.38	6.55±0.35	0.159	6.60±0.41
70° (L7)	7.81±0.33	7.82±0.33	0.880	7.82±0.33
75° (L8)	9.01±0.42	9.06±0.47	0.577	9.03±0.45

OMSI, orthodontic miniscrew implant; IZC, infrazygomatic crest; SD, standard deviation

Table 3. Comparison of probable OMSI insertion site bone height (in mm) from the maxillary occlusal plane at various angulations among males and females at the IZC region

Bone height at IZC region for OMSI insertion angles	Male		Female		Comparison (p-value)			
	Right side (MRTH) Mean±SD n=25	Left side (MLTH) Mean±SD n=25	Right side (FRTH) Mean±SD n=25	Left side (FLTH) Mean±SD n=25	MRTH Vs. MLTH	FRTH Vs. FLTH	MRTH Vs. FRTH	MLTH Vs. FLTH
40° (H1)	18.02±0.64	17.94±0.62	17.50±0.64	17.37±0.50	0.623	0.323	0.001**	0.000***
45° (H2)	17.24±0.28	17.03±0.58	16.95±0.79	16.96±0.40	0.298	0.935	0.082	0.613
50° (H3)	16.59±0.60	16.30±0.70	16.65±0.27	16.40±0.57	0.129	0.042*	0.652	0.636
55° (H4)	16.28±0.59	15.96±0.72	16.09±0.23	16.06±0.35	0.096	0.739	0.136	0.551
60° (H5)	15.88±0.55	15.28±0.51	15.51±0.31	15.49±0.37	0.024*	0.836	0.004**	0.401
65° (H6)	15.12±0.34	15.06±0.54	15.09±0.27	14.83±0.26	0.853	0.001**	0.933	0.065
70° (H7)	14.92±0.51	14.60±0.51	14.11±0.46	13.86±0.34	0.028*	0.034*	0.000***	0.000***
75° (H8)	14.38±0.51	14.16±0.53	13.17±0.39	13.04±0.44	0.148	0.267	0.000***	0.000***

*p<0.05, **p<0.01, ***p<0.001
MRTH, male right side height; MLTH, male left side height; FRTH, female right side height; FLTH, female left side height; OMSI, orthodontic miniscrew implant; IZC, infrazygomatic crest; SD, standard deviation

Table 4. Sidewise (right vs. left) comparison of probable OMSI insertion site height (in mm) from the maxillary occlusal plane at various angulations among all subjects

Bone height at IZC region for OMSI insertion angles	Right side Mean±SD (n=50)	Left side Mean±SD (n=50)	p-value	Combined (Rt+Lt) height of OMSI insertion at IZC region (n=100)
40° (H1)	17.76±0.60	17.65±0.63	0.372	17.71±0.61
45° (H2)	17.09±0.56	16.99±0.50	0.378	17.04±0.53
50° (H3)	16.22±0.46	16.34±0.65	0.016*	16.28±0.56
55° (H4)	16.18±0.45	16.01±0.56	0.096	16.10±0.52
60° (H5)	15.70±0.48	15.39±0.87	0.300	15.54±0.71
65° (H6)	15.10±0.54	14.95±0.44	0.307	15.03±0.71
70° (H7)	14.51±0.63	14.23±0.57	0.020*	14.37±0.62
75° (H8)	13.77±0.76	13.60±0.74	0.248	13.69±0.75

*p<0.05
OMSI, orthodontic miniscrew implant; IZC, infrazygomatic crest; SD, standard deviation

root curvature. The curvature of the root tip causes problems when drawing the tangent along the root surfaces because the root tip is oriented in one plane and the tangent at the root surface is oriented in another plane. Previous studies have used the mesiobuccal root of the permanent maxillary first molar to construct the second reference plane.[16,21] More recent studies are optimistic about using the distobuccal root of the permanent maxillary first molar to avoid errors in drawing the tangent along its surface compared with the mesiobuccal root.[25,27]

The present study revealed a variation in IZC bone thickness from 4.39 mm to 9.03 mm with a proposed OMSI insertion angle of 40° to 75° in relation to the maxillary occlusal plane. The corresponding OMSI insertion heights ranged from 17.71 to 13.69 mm above the maxillary occlusal plane (i.e., the first reference plane). Our findings were consistent with the results of the studies of Liou et al.[16] and Baumgaertel et al.[21], who pointed out that anatomically, the IZC has two cortical plates (i.e., a vestibular and a lateral wall of the maxillary sinus). This works in favor of the IZC because it allows bicortical engagement of the OMSI, thus enhancing primary stability.[16,28] The greater thickness of the IZC allows better contact between the OMSI and bone, which enhances the primary stability of the OMSI.

Many previous studies have shown ethnic differences in bone thickness, which could be of great importance in selecting the appropriate dimensions (length and thickness) of OMSI for a particular patient.[16,18,27] The proposed OMSI insertion angle and position of 40° is technically simpler and reduces the incidence of OMSI slippage and root injury.[16,21] However, this angulation and position could result in a lower OMSI-bone contact depth and may carry a higher risk of alveolar/buccal mucosa irritation. On the other hand, the proposed OMSI insertion angle and position at 75° is technically challenging because of the actual insertion angle between the OMSI and the IZC.[16,21] This position poses a higher risk of slippage of the OMSI and bone stripping. In addition, at this insertion angle, a slight deviation in the insertion of the OMSI could increase the risk of root injury. Another complication of high OMSI insertion angles is the emergence of its thread after placement in the IZC region in the alveolar mucosa. This could result in soft tissue inflammation, overgrowth, and, in rare cases, infection around the OMSI. Studies have shown that these problems can be prevented and minimized if OMSI is placed at the keratinized gingiva or at the mucogingival junction.[2,29-32]

This study demonstrated that the proposed angle of insertion should be greater than 55°. The insertion height should be less than 15.59 mm above the occlusal plane; so that the OMSI-bone contact will be maintained at a thickness of not less than 6 mm. This finding is in agreement with Baumgaertel and Hans[21] who pointed out that insertion of an OMSI of 6 mm or more in the IZC region has a higher probability of penetrating the Schneiderian membrane lining.[19] In addition, several researchers have observed that a 6-mm OMSI bone contact is sufficient for the OMSI to be stable during orthodontic loading in adult patients.[33,34]

Optimal angulation and position of the OMSI in the IZC region are critical for minimizing damage or perforation of the maxillary sinus.[35,36] Anatomical variations, such as the reverse fold and the presence of septa, must be considered and checked along with bone thickness before placing the OMSI.[37] The best site for OMSI insertion was 14.50-16 mm in relation to the probable insertion angle of 55°-75° with reference to the maxillary occlusal plane along the distobuccal root surface of the permanent maxillary first molar. Similar observations were reported by Song et al.[20] They concluded that the optimal insertion heights and angles were 12-18 mm from the occlusal plane and 40-70°, respectively, for mini-implant placement in the IZC in relation to the distal root of 1st permanent maxillary molar.

The dimension of the OMSI routinely used in the IZC region is 10-14 mm long and has a minimum diameter of 2 mm. The present study demonstrated that OMSI with the above dimensions could be used safely, and the likelihood of damage or perforation of the maxillary sinus is very low. In addition, our

study found that the optimal OMSI insertion zone in the IZC region was 16.10-13.69 mm above the maxillary occlusal with an insertion angle of 55°-75°. Our findings are in agreement with Tavares et al. observation, who believed that the best bone availability between 1st and 2nd maxillaries is seen between 1st and 2nd molars in the IZC for inserting the extra-alveolar bone miniscrew at a distance of 4 mm from the CEJ at an insertion angle of 60° for all individuals.[37] Arango et al.[38] reported a similar observation and pointed out that the IZC bone thickness distal to the maxillary permanent first molar was larger at 55°, 65°, and 70° in men. Recently, Wilmes et al.[39] used a novel CAD-CAM fabricated approach for positioning the OMSI on the palatal aspect. This approach facilitates precise and safe positioning and insertion of the OMSI. A similar approach can be considered and used for the predictable placement of OMSI in the IZC region. The hypotheses proposed in this study appear to be relevant and true. Furthermore, the parameters of our study provide good guidelines to clinicians for the safe placement of OMSI in the IZC region. The final positioning of the OMSI depends on the clinical judgment of the orthodontist, who consider certain anatomic variations in some individuals.

Study Limitations

The limitation associated with our study is the morphological variations in the roots of the maxillary first permanent molar. The data should be used with caution, in cases where the distobuccal root exhibits anatomic variation. Clinical judgment for placement of OMSI should be based on the extent of anatomic variation of the distobuccal root and adjacent structures.

CONCLUSION

• The thickness of the IZC bone ranged from 4.39 mm to 9.0 mm at a probable insertion angle of 40° to 75°, which corresponded to a height of 13.60 mm to 17.65 mm in relation to the maxillary occlusal plane along the distobuccal root surface of the permanent maxillary first molar.

• From OMSI insertion angles of 55° to 75°, bone thickness in the IZC region corresponded to 6 and 9 mm. Furthermore, the same corresponds to an insertion height of 16-14.50 mm from the maxillary occlusal plane.

• There was no statistically significant change in IZC bone thickness between males and females.

• CAD-CAM technology could be facilitated to improve the safe placement of IZC implants.

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Ethics

Ethics Committee Approval: This study was approved by the Institutional Ethics Committee of All India Institute of Medical Sciences, Bhubaneswar (T/IM-NF/Dentistry/120/137).

Informed Consent: Written informed consent was obtained from each patient for comprehensive orthodontic treatment and to use their records for various academic and research activities.

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