Dental Research Journal

Review Article

Assessment of infra-zygomatic area for ideal placement of miniscrews: A systematic review and meta-analysis

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ABSTRACT

Background: The infrazygomatic crest (IZC) is a commonly used extra-alveolar site for orthodontic miniscrew placement because of its favorable anatomical position and relatively dense cortical bone. However, variations in bone thickness, insertion height, and angulation can influence the stability and success of miniscrew placement. To systematically evaluate and synthesize the available evidence on the infrazygomatic crest region to determine the most suitable site, insertion height, and angulation for orthodontic miniscrew placement.

Materials and Methods: A systematic search was conducted across PubMed, Embase, Web of Science, Scopus, the Cochrane Library, and grey literature sources including Google Scholar and OpenGrey for studies published up to March 2023. Studies assessing cortical bone thickness and anatomical characteristics of the IZC relevant to miniscrew placement were included. Thirteen studies met the inclusion criteria for qualitative synthesis, and nine studies providing quantitative data were included in the meta-analysis. Mean values and standard deviations of bone thickness and insertion height along the distobuccal root of the maxillary first molar at 70° angulation were extracted. Forest plots were generated to compare findings across studies. Risk of bias was assessed using the Quality Assessment of Measurement Accuracy Studies (QUAMAS) tool.

Results: Among the included studies, most reported adequate bone thickness in the region buccal to the maxillary first molar. Meta-analysis indicated that sufficient bone thickness is generally observed when miniscrews are inserted at an angulation of approximately 60°–70°. The optimal insertion height was commonly reported between 10 and 15 mm above the occlusal plane, where greater cortical bone thickness was observed. Increasing insertion angulation and decreasing insertion height were associated with improved bone engagement and primary stability.

Conclusion: The current evidence suggests that the region buccal to the maxillary first molar in the infrazygomatic crest is the most favorable site for orthodontic miniscrew placement. An insertion angle of approximately 60°–70° and a height of 10–15 mm above the occlusal plane appear to provide optimal bone thickness and stability.

Key Words: Bone thickness, cone beam computerized tomography, infrazygomatic crest, mini-implants, mini-screw, temporary anchorage devices

Received: 02-Jan-2025
Revised: 19-Feb-2026
Accepted: 25-Feb-2026
Published: 03-Aug-2026

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Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480
DOI: 10.4103/drj.drj_4_25

How to cite this article: Felix N, Sreenivasagan S. Assessment of infra-zygomatic area for ideal placement of miniscrews: A systematic review and meta-analysis. Dent Res J 2026;23:24.

INTRODUCTION

Temporary anchorage devices (TADs), commonly called as mini-implant screws, or mini-screws, are absolute means of anchorage system without relying on patient cooperation. Over recent years, TADs have been emerged as promising mechanics due to their ease of placement and removal, cost-effectiveness and noncompliance from patients.[1] They can be placed in areas where natural anchorage or conventional orthodontic appliances are difficult to place, such as edentulous spaces in the alveolus of the upper and lower arch, the palate, the zygomatic process, the retromolar region and the ramus.[2-4] Since TADs can retract the whole dentition, it can eliminate adverse reciprocal movement, anchorage loss and increase the treatment efficacy.[5,6]

The infrazygomatic crest (IZC) is one of the major sites for placement of implant in maxilla due to its location and solid bone structure. The IZC is a well palpable, slightly elevated bone column that runs down the lateral wall at the most inferior point of the zygomatic-maxillary suture, towards the alveolar process of the maxilla. It is located lateral to the first and second maxillary molars.[7,8] There are several variations in the thickness of the IZC due to differing root morphologies, pneumatization of the maxillary sinus, inclination of the maxillary first molar and height of the alveolar processes of individuals.[8,9] Therefore, it is important to understand the anatomical variations present in this area when placing mini-screws at this site for orthodontic purposes.

Mini-implants placed in the IZC region are referred to as extra-alveolar (EA) mini-implants. They are most commonly used for distalizing the whole maxillary dentition as they provide better anchorage and primary stability. It is also used in cases of asymmetry correction of the occlusal plane and midline deviation, segmental or en masse dentoalveolar retraction of maxillary arch, canine and premolar distalization with sliding mechanics and posterior teeth intrusion, along with retraction of the entire dental arch.[10]

It is necessary to know the cortical and overall bone thickness of the IZC to achieve initial stability and success. The site of placement and angle of miniscrew insertion play a major role in primary stability.[10-13] The aim of this systematic review was to assess the most suitable site of mini-implant placement in maxillary IZC area based on cortical bone thickness and angle of insertion.

MATERIALS AND METHODS

This systematic review was prepared based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[14] Before the start of the review, following the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions, a review methodology was established.[15]

Inclusion and exclusion criteria

The inclusion criteria for our systematic review were randomized controlled trials and observational retrospective studies reporting the evaluation of maxillary IZC for mini-implant placement with some predictive outcome, and datasets used should be clearly mentioned. Articles in which the evaluation of cortical bone thickness and total bone thickness at different insertion heights in IZC crest have been included in the study. Studies in which the comparison of interradicular distance between all the maxillary teeth and the maxillary anterior region for mini-implant placement were not included. Unpublished papers, articles with only abstracts and with no full text and paper not published in English were excluded from this study. Exclusion and inclusion criteria were structured in accordance with the study design, participant, intervention, comparison and outcome.

Outcome measures

The primary outcome measure is to determine the ideal site for mini-implant placement in an IZC, and the secondary outcome measure was to evaluate how effective the mini-implants can be in assisting in orthodontic application when placed in an IZC of the maxilla among different populations.

Information sources and study selection

Our search strategy for the review was cross-disciplinary and included descriptive, retrospective and randomized clinical trials on the assessment of IZC area for mini-implant placement amongst different populations. All the original research articles, review articles, published bibliographies and relevant citations related to maxillary IZC were checked for relevant information and used in this review.

A comprehensive search was performed on PubMed, Embase, Web of science, Cochrane engine and grey to obtain our topic-related articles which were published till March 2023 with no restriction based on

the language and the published year. A combination of index words such as orthodontic anchorage, IZC, maxillary anchorage, cortical bone thickness and mini-implant insertion was used for the search strategy. The PRISMA statement guidelines were followed [Figure 1]. The electronic search resulted in multiple articles, in which a total of 541 articles related to mini-implant placement in the IZC area. The supplemental manual search was done on hand by reviewing the reference lists of the related papers and review articles.

Data extraction and synthesis

Two reviewers carried out the entire search and screening procedure ($\kappa = 0.78$, inference-near perfect agreement between the two examiners). From the heading and abstracts obtained from the electronic search, the articles were removed from our study based on the inclusion and exclusion criteria as discussed above in four stages. In Stage 1, non-relevant citations were simply excluded. In Stage 2, all heading and abstracts were analyzed by one person to determine whether the article met the criteria of our study. When the reviewer was sure about the information unavailability of any article which did not meet the inclusion criteria, it was immediately removed from the study. In case of any query, the article was downloaded for full study, and the second thought was taken from another reviewer.

In Stage 3, all the articles selected in Stage 1 were examined by two independent reviewers to determine whether they met the eligibility factors. During this time, care was taken to exclude the articles with a lack of proper design and necessary data. The articles not referenced correctly were also excluded.

In Stage 4, all refined articles were thoroughly gone through, and relevant data were obtained from all of them. The clinical methodology of the studies scrutinized finally assessed thoroughly by examining the types of outcome measures and intervention of each study.

The data were extracted from the selected articles by the first examiner and then rechecked by the second

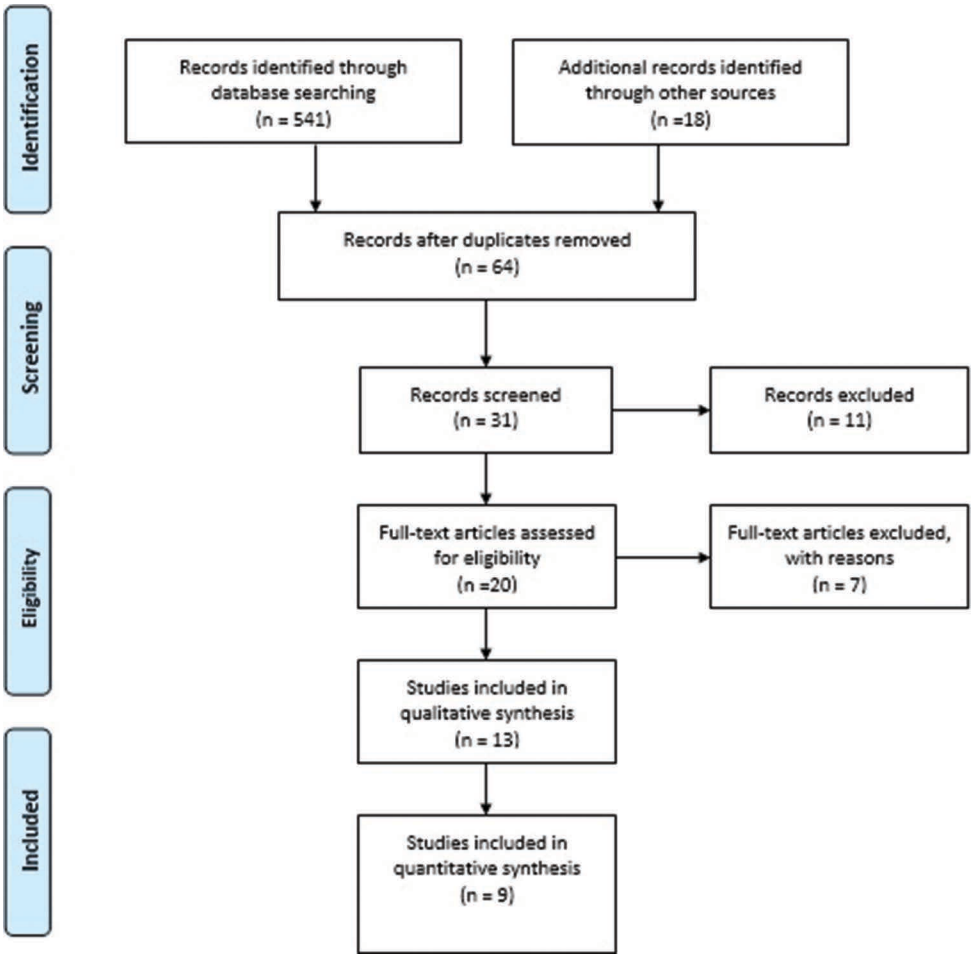

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart.

examiner. Data extraction was made equivalently from each approved articles that were selected based on the inclusion criteria. It is prepared in a standard form in the electronic format through the computer feeding (Office Excel 2013 software, Microsoft Corporation). Information was tabulated and filled under the following heading-author, year, sample size, population, age group, area of interest, imaging method, measurement reference, reference plane, reference area, reference points, outcome, inference and added data [Table 1].

Risk of bias assessment

The risk of bias was assessed by 2 independent examiners. All the included studies were assessed using the Quality Assessment of Measurement Accuracy Studies (QUAMAS) tool, as per the literature [Table 2]. The QUAMAS tool comprises 3 domains which include study design, study measurement and statistical analysis. The maximum score of a study was 15. Studies that scored not <10 were considered high quality. Studies with scores between 7.5 and 9.5 were considered medium quality. Studies with scoring <7.5 were considered low quality. The Quality Assessment of Diagnostic Accuracy Studies tools (i.e. QUADAS-1 and -2), designed for the quality assessment of diagnostic accuracy (instead of measurement accuracy) of studies, were not used for this study because of their unsuitability.

Statistical analysis

The data were tabulated in Microsoft Excel 2010, and statistical analysis was performed in R statistical package version 4.1.1 (10-08-2021 release) from R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/. Means (M) and standard deviations (SDs) of bone thickness along the distobuccal root of the first molar at 70° angulation were collected from the included studies and tabulated [Table 3]. In studies that gave Confidence intervals, SD was calculated from the confidence intervals. M and SD of insertion height along the distobuccal root of the first molar at 70° angulation were also collected and tabulated [Table 4]. Forest plot was drawn with M and SD and compared among the participant studies.

RESULTS

Study selection

The selection of articles for our study was based on the PRISMA flowchart. The literature search resulted in 541 studies relevant to the topic and 7 studies obtained from additional records. 495 articles were excluded as they were irrelevant, duplicates, and data were not available. The screening procedure was done, and nearly 31 articles were obtained. From this, 20 full-text articles were assessed for the eligibility criteria in which 7 articles were excluded with reasons and 13 articles were elaborated in the present systematic review. 9 articles provided valid quantitative data and were included in meta-analysis [Figure 1].

Characteristics of included studies

This review included 13 articles, which provided ideal placement of mini-implant in the maxillary IZC area. The first study was given by Liou *et al*. in 2007, in which he found the ideal site in adults to be 14–16 mm above the maxillary occlusal plane in the maxillary first molar region at an angle of 55° to 70° to the maxillary occlusal plane (Liou *et al*. 2007).[7] This was followed by another study that the greatest bone depth was available at 11–13 mm apical from the cemento-enamel junction (CEJ) of the maxillary first molar and decreased rapidly further apically.[8] This was followed by Santos *et al*.,[11] in 2017, in which he found the overall M thickness of the IZC was 2.49 mm with respect to measurement 1 and 2.29 mm for measurement 2, with no statistically significant differences between sexes.[11] A study in 2019 in which she found the best possible site for miniscrew insertion is 12–17 mm above the occlusal plane at an angle of 65° to 70° with no injury to the adjacent anatomical structures.[13] Ms and SDs of bone thickness along the distobuccal root of the first molar at 70° angulation were collected from the included studies and summarized in Table 3. This was followed by Paul *et al*. in 2020, in which he found the ideal site for insertion of TADs in the IZC region, which lies between the maxillary first and second molars at a height of 12 mm in all facial types.[16] This was followed by Vargas *et al*. in which he also found that the best site to install miniscrews in the IZC is buccal to the first molar mesiobuccal root.[17] This was followed by Krishnakumaran *et al*. in 2021, in which they found the superolateral area in IZC as the most appropriate site for miniscrew insertion in all age groups.[18] This was followed by Matias *et al*., in 2021, in which they found that the best site to install miniscrews is at the 11 mm apical to the mesiobuccal cusp tip of the maxillary first molar.[19] This was followed by Du *et al*., in which he preferred

Table 1: Characteristic table

Study	Year of publication	Sample size	Population	Age group	Area of interest	Imaging method	Measurement reference	Reference plane	Reference area	Reference points	Outcome	Inference	Added data
Liou *et al.*	2007	16	Taiwan	27.0±5.2 years	IZC area	CBCT	Maxillary occlusal plane	Maxillary occlusal plane, line tangent to the buccal surface of the mesiobuccal root of the maxillary first molar	Through S point, another 8 reference lines were established at increments of 5°, from 40° to 75°, to the maxillary occlusal plane	S point, B1 to B8	IZC thickness and the miniscrew insertion position	The ideal site is to insert it 14–16 mm above the maxillary occlusal plane and the maxillary first molar at an angle of 55°–70° to the maxillary occlusal plane	Bone thickness of the IZ crest above the maxillary first molar is 5–9 mm, when it is measured at 40°–75° to the maxillary occlusal plane and 13–17 mm above the maxillary occlusal plane
Baumgaertel and Hans	2009	29	Human skull	30.1±10.8 years	IZC area	CBCT	Accurex™ software	Line perpendicular to the buccal bone surface tangent to the tip of the mesiobuccal or the disto-buccal root tip	Mesiobuccal root of 6, middle of furcation, distobuccal root of 6	Three sites associated with IZC and five different measurement levels	Bone depth at IZC for mini implant placement	The greatest bone depth was 11.48±1.92mm apical from CEJ of the maxillary first molar and decreased apically	The largest distance was recorded at the mesio-buccal root, followed by the disto-buccal root, while the buccal furcation presented with the least distance from the buccal CEJ to the first measurement
Santos AR *et al.*	2017	40	Brazilian	22–56 years	IZC area	CBCT	Dolphin imaging software	Line along the buccal wall of the IZC	distobuccal root of each permanent first maxillary molar	A-2 mm above the distobuccal root apex of 6 B-2 mm above A	Thickness of IZC and its comparison between males and females	The overall mean thickness of the IZC was 2.49 mm at A and 2.29 mm at B	No statistically significant differences between sexes
Arathy Murugesan *et al.*	2020	10	Dravidians	20–30 years	IZC area	CBCT	As per Liou *et al.*	Maxillary occlusal plane, tangent to the buccal surface of the distobuccal root of the molar	Distobuccal root tip of the maxillary first molar	S point, B1 to B7 point based on 40°–75° angles	Bone thickness of IZC at different insertion angles, height and angulation of miniscrew	The best possible site for miniscrew insertion is 12–17 mm above the occlusal plane at an angle of 65°–70°	The ideal IZC screw length for Dravidian population is 9–11 mm

Contd..

Table 1: Contd...

Study	Year of publication	Sample size	Population	Age group	Area of interest	Imaging method	Measurement reference	Reference plane	Reference area	Reference points	Outcome	Inference	Added data
Paulin Paul *et al.*	2020	33	Indian	23–30 years	IZC area	CBCT	-	Line passing through the CEJ of both the right and left molars, the line parallel to the long axis of the molars	Mesial to 6, furcation area of 6, inter radicular bone region between 6 and 7, furcation area of 7 and distal to 7	8 mm, 10 mm, 12 mm and 14 mm from CEJ towards maxillary sinus floor	Cortical bone thickness in the IZC region between low, normal and high angle cases	The ideal site for insertion lies between the maxillary first and second molars at a height of 12 mm in all facial types	Low angle patients had significantly higher values of bone thickness compared to normal and high-angle patients between the first and second molars at a height of 12 mm and distal to second molars at a height of 14 mm
Amaral Vargas *et al.*	2020	100	Brazilian	19.1±5.5 years	IZC	CBCT	0.3 mm	Line at the apex of the mesiobuccal root, line tangent to the buccal cortical bone	Buccal roots of the maxillary left first molar and the region between the first and second molars	Root tip, 70° and 65° angulation	Bone thickness of IZC area. Correlation of bone thickness with gonial angle and various facial heights	The best site to install miniscrews is buccal to the first molar mesiobuccal root	There was no correlation between the gonial angle and bone width in the IC
Mahalakshmi *et al*	2021	60	Tamilan	8 to 25 years	Infra zygomatic crest	CBCT		The horizontal plane-most inferior border of the zygomatic process of maxilla. Vertical plane-most anterior point of the infratemporal fossa	HB+2, HB+4, HB+6, HB+8, and HB+10) (V-2, V-4, V-6, V-8, and V-10	Point of intersection of the planes	Bone thickness of IZC and to correlation of the bone thickness with CVMI	The superior and the lateral regions of the zygomatic process of maxilla have the maximum bone thickness and are the most appropriate site for placement of miniscrews	Bone thickness increased with cervical vertebrae maturation age.

Contd..

Table 1: Contd...

Study	Year of publication	Sample size	Population	Age group	Area of interest	Imaging method	Measurement reference	Reference plane	Reference area	Reference points	Outcome	Inference	Added data
Murilo Matias *et al*	2021	78	Italians, Portuguese and Spanish	14-38 years	Infrazygomatic crest	CBCT	Dolphin imaging software	Line 70 degrees to the occlusal plane. Horizontal axis along buccal surface of IZC	Apex of distobuccal root of max first molar	11, 13, 15 mm apical to mesiobuccal cusp tip of 6.	Bone thickness at IZC and comparison between various facial heights	Maximum thickness at 11mm apical to the mesiobuccal cusp tip of max first molar	The Infrazygomatic Crest cortical bone thickness was similar among the 3 facial groups
B Du *et al*	2021	36	Chinese	20-28 years	Infra zygomatic crest	CBCT	Mimics 14.01 software	buccal root plane, distal plane of U6, mesial plane of U7, alveolar bone plane, and bisection plane of U6 and U7	Maxillary first and second molar region	13, 15, and 17 mm above the horizontal reference plane on the buccal alveolar bone	the bone depth and thickness of different insertion paths at IZC	Ideal site is at a disposition of 15 mm height above the POP, a gingival tipping angle of 60-70˚, and a distal tipping angle of 30˚	A miniscrew should not be inserted at 17 mm insertion height above the POP or a gingival tipping angle of 50˚
Tavares A *et al*	2021	58	Not mentioned		Infrazygomatic crest	CBCT	Osirix software	Line passing through the point of proximal contact between the maxillary first and second molars	Maxillary first and second molar region	4, 5, 6 mm from CEJ at 60, 70, 80 insertion angles	Bone thickness at IZC and comparison between various facial heights and different sagittal pattern	Ideal site is at the distance of 4 mm from the CEJ at an insertion angle of 60° for all individuals	. Class II and mesofacial subjects show g lower bone depth at greater angles and at a more apical level.
Q Song *et al*	2022	32	Chinese	25.1±5.5 years	Infrazygomatic crest	CBCT	MCT 1 scanner	Line along mesiobuccal cusp, buccal groove, distobuccal cusp of 1 and 2nd molar	between the maxillary first and second molars	0 mm to 12 mm from the alveolar crest at 1 mm each	Cortical bone and overall bone thickness at IZC	optimal insertion heights and angles were 12 mm to 18 mm from the occlusal plane, and 40 to 70 degrees	Sex and age had an impact on CBT and OBT.
Dangal R *et al*	2022	44	Nepali	>18 years	Infrazygomatic crest	CBCT	voxel size of 300 µm	Maxillary occlusal plane, e tangent line to the buccal surface of the distobuccal root of 1st molar	distobuccal root of maxillary first molar.	S point, B1 to B8 points	bone thickness, height and angle of insertion	Optimal site for insertion is at the angle of 70˚ and 13 mm from the occlusal plane	Thickness increases with the increase in insertion angle and the decrease in height

Contd..

Table 1: Contd...

Study	Year of publication	Sample size	Population	Age group	Area of interest	Imaging method	Measurement reference	Reference plane	Reference area	Reference points	Outcome	Inference	Added data
Ujala Saif *et al*	2022	116	Pakistani	23.03±3.92 years	Infrazygomatic crest	CBCT		maxillary occlusal plane and a line tangent to distobuccal root of 1st molar	along the distobuccal root of 1 st molar	S point to the points B1, B2, B3, B4 and B5	infrazygomatic bone thickness	miniscrew should be inserted at an angle of 55° to 70° at distances of 16mm to 18mm from maxillary occlusal plane	The IZC bone thickness found in Pakistani population is thin when compared to other populations

IZC: Infra zygomatic crest; MSCT: Multi-slice computed tomography; CBCT: Cone beam computed tomography; CVMI: Cervical vertebral maturation index; CEJ: Cementoenamel junction

mini-implant placement at a disposition of 15 mm height above and a gingival tipping angle of 60°–70° and a distal tipping angle of 30°.[20] Tavares *et al*. found an ideal site at the distance of 4 mm from the CEJ at an insertion angle of 60° for all individuals.[21] This was followed by Song *et al*. in 2022, who found that the optimal insertion heights and angles were 12 mm to 18 mm from the occlusal plane, and 40°–70° for mini-implants at IZC.[22] This was followed by Dangal *et al*. in 2022 on the Nepali population, in which he found the optimal site for placement in IZC at the angle of 70°and 13 mm from the occlusal plane.[23] This was followed by Ujala *et al*., in 2022, in which they found that the miniscrew should be inserted at an angle of 55° to 70° at distances of 16 mm to 18 mm from the maxillary occlusal plane.[24] The author, year, sample size, population, age group, area of interest, imaging method, measurement reference, reference plane, reference area, reference points, outcome, inference, and added data are described in Table 1.

Synthesis of results

Two forest plots were performed in this study. One was based on the cortical bone thickness of the IZC area obtained from the 9 studies with homogeneity. Another forest plot was drawn based on the insertion height of IZC area from the 5 studies with homogeneity. The studies which provided quantitative data on cortical bone thickness for mini-implant placement and insertion height were included. Since the studies provided variable data, the homogeneity was obtained for cortical bone thickness by selecting the values along the buccal aspect of maxillary first molar at 70 angulation, which were commonly measured in all the studies. The homogeneity was obtained for insertion height by selecting the values along the buccal aspect of the maxillary first molar at 70° angulation, which were commonly measured in all the studies. The data from several studies were mentioned as the right and left sides of the arch and also male and female groups. This was generalized by taking the average of both the groups.

Ms and SDs of bone thickness along the distobuccal root of the first molar at 70° angulation were collected from the included studies and tabulated. In studies that gave confidence intervals, SD was calculated from the confidence intervals. M and SD of insertion height along the distobuccal root of the first molar at 70° angulation were also collected and tabulated. Forest plot was drawn with M and SD and compared among the participant studies. Each line in the graphical display represents a study with upper and lower limits.

Table 2: Quality Assessment of Measurement Accuracy Studies tool parameters

Evaluation parameters	Naming	Description	Score
Study design	A	Objective clearly formulated	1
	B	Randomized sample	1
	C	Sample size: Considered adequate	1
	D	Similar baseline characteristics	1
	E	Selection criteria: Clearly described and adequate	1
Study measurement	F	Measurement method is appropriate	1
	G	Gold standard is appropriate	1
	H	Adequate examiners and independent measurement	1
	I	Reliability: Described and adequate level of agreement	1
	J	Appropriate examination time interval	1
Statistical analysis	K	Statistical analysis is appropriate for data	1
	L	Reliability: Intra-examiner and inter-examiner	2
	M	*P* value and confidence intervals	2

Table 3: Sample size, mean and standard deviation of bone thickness of infrazygomatic crest area of included studies at 70° angulation

Study	Mean±SD (for bone thickness)	Sample size	Mean±SD (for bone thickness)	Sample size
Ujala Saif *et al.*	4.2±1.2	116	16.7±3.2	116
R Dangal *et al.*	6.7±1.8	44	12.9±2.8	44
A Tavares *et al.*	8.7±3.1	116	-	-
Du *et al.*	7.4±2.4	36	-	-
Arathi *et al.*	7.8±3.2	10	12.8±2.7	10
A Vargas *et al.*	3.6±2.2	100	-	-
Liou *et al.*	7.7±1.9	16	13.8±3.8	16
Baumgaertel and Hans	6.6±4.2	29	12.1±1.7	29
Murilo Matias *et al.*	7.2±1.9	78	-	-

SD: Standard deviation

The width of the study lines extending through the boxes showed their confidence intervals, and the center dot represents the M [Figures 2 and 3]. Based on forest plot 1, the majority of included studies showed bone sufficient bone thickness of about 6–8 mm along the buccal aspect of maxillary first molar at 70° angulation. Based on forest plot 2, the majority of included studies showed appropriate insertion height of about 10–15 mm for achieving sufficient bone thickness. This showed that there was a statistically significant difference in the bone thickness of the IZC area, with majority of studies supporting that the area buccal to the maxillary first molar is the most ideal site of mini implant placement. The ideal insertion angle should be 60°–70°, and ideal insertion height should be 10–15 mm as the bone thickness increases with an increase in insertion angle and a decrease in the insertion height.

Quality of studies

Among the 13 included studies, 10 studies were rated as high quality, and 3 studies were rated as medium quality [Table 4]. The study by Song *et al.* provided the highest quality rate of 13.5, and study by Santos *et al.*and Mahalakshmi *et al.* provided the lowest quality rate of 8. The major methodological limitations were unclear baseline characteristics, reliability, and examination time intervals.

DISCUSSION

Liou *et al.* in 2007 conducted a study on Taiwan population to measure the thickness of the infrazygomatic (IZ) crest above the maxillary first molar at different angles and positions to the maxillary occlusal plane.[7] As per this study, the bone thickness of the IZ crest above the maxillary first molar is 5–9 mm, when it is measured at 40° to 75° to the maxillary occlusal plane and 13–17 mm above the maxillary occlusal plane. By adopting 6 mm as the minimum IZ crest thickness for sustaining a miniscrew well throughout treatment and avoiding injury to the mesiobuccal root of the maxillary first molar, the clinical implication for miniscrew insertion in the IZ crest of adults is 14–16 mm above the

Table 4: Quality assessment scores of included studies based on Quality Assessment of Measurement Accuracy Studies tool

Study	Study design					Study measurement					Statistical analysis			Total
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Liou *et al.*	1	1	1	0.5	1	1	1	1	1	0.5	1	1	2	13
Baumgaertel and Hans	1	0	1	0.5	0.5	0.5	0	1	0.5	0.5	1	1	2	9.5
Santos AR *et al.*	1	0.5	1	0.5	1	0	0.5	0.5	0.5	0.5	0	1	1	8
Arathy Murugesan *et al.*	1	1	0.5	0.5	1	1	1	1	0.5	1	1	1	2	12.5
Paulin Paul *et al.*	1	1	0.5	0.5	1	1	1	1	0.5	0.5	1	1	2	12
Amaral Vargas *et al.*	1	1	1	0.5	0.5	1	1	1	0.5	0.5	1	1	2	13
Murilo Matias *et al.*	1	1	1	0.5	1	1	1	1	1	0.5	1	1	2	13
B Du *et al.*	1	1	1	0.5	1	1	1	1	0.5	1	1	1	2	13
Tavares A *et al.*	1	0.5	1	0.5	0.5	1	1	1	0.5	1	1	1	2	12
Q Song *et al.*	1	1	1	1	0.5	1	1	1	1	1	1	1	2	13.5
Dangal R *et al.*	1	1	1	0.5	1	1	1	1	1	1	1	1	2	13.5
Ujala Saif *et al.*	1	1	1	0.5	1	1	1	1	0.5	0.5	1	1	2	12.5

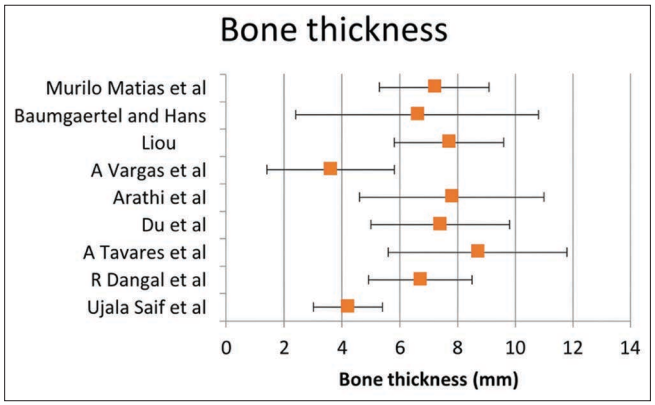

Figure 2: Forest plot of bone thickness of studies included for meta-analysis.

Figure 3: Forest plot of insertion height of studies included for meta-analysis.

maxillary occlusal plane and the maxillary first molar, and at an angle of 55° to 70° to the maxillary occlusal plane.

Study conducted on the human skull to investigate the bone depth at the IZC with regard to orthodontic mini-screw insertion.[10] As per this study, the level of the greatest bone depth was located on average 11.48 mm apical from the buccal CEJ of the maxillary first molar. This would indicate the ideal level for mini-screw insertion.[9] More in detail, at the mesio-buccal root, the ideal insertion site would be located farthest in the vestibule, on average 12.18 mm apical from the CEJ. Furthermore, this study demonstrated that on average, mini-screw insertion (6 mm length or more) could lead to perforation of the maxillary sinus or the nasal cavity.

In the Brazilian population, to verify the thickness of the IZC and compare it between male and female adult subjects, by using coronal slices from cone beam computerized tomography (CBCT) imaging.[8] As per this study, the M thickness of the IZC in males was 3.55 mm for measurement 1 and 2.84 mm for measurement 2, whereas in females, these were 2.37 mm and 2.24 mm with no statistically significant difference between the gender. Furthermore, the M thickness of the IZC to be significantly thinner than the length of miniscrews commonly used in this region, which may cause maxillary sinus perforation if miniscrews of 5 mm or longer are used for miniplate anchorage.[12]

In the Dravidian population, to assess the bone thickness in the IZC area around the distobuccal root of the maxillary first molar using CBCT and determine the best possible site and angulation for the placement of the miniscrew. The measurements were made along the distobuccal root of the maxillary first molar at different angulations ranging from 75° to 40° to the occlusal surface of the molar. As per this study, the best possible site for miniscrew insertion is 12–17 mm above the occlusal plane at an angle of

65°–70°, with no injury to the adjacent anatomical structures, no mucosal irritation, and adequate stability for the miniscrew. The ideal IZC screw length for the Dravidian population is 9–11 mm.[25]

Another study on the Indian population to evaluate cortical bone thickness in the IZC region for subjects with low, normal, and high angle facial patterns by bone mapping using CBCT. As per this study, low-angle patients had significantly higher values of bone thickness compared to normal and high-angle patients between the first and second molars at a height of 12 mm and distal to the second molars at a height of 14 mm. The ideal site for insertion of TADs in the IZC region lies between the maxillary first and second molars at a height of 12 mm in all facial types.[18]

A study 2020 on the Brazilian population to determine bone thickness in the mandibular buccal shelf (MBS) and the IZC in individuals with different vertical facial heights for the ultimate placement of miniscrews. As per this study, bone thickness in the MBS increased posteriorly, whereas bone thickness in the IZC decreased posteriorly. There was no correlation between the IZC and the gonial angle. The best site to install miniscrews in the MBS is buccal to the second molar distal root, whereas in the IZC, it is buccal to the first molar mesiobuccal root.[17]

A study was conducted on the Tamil population to evaluate the bone thickness of the IZC in different cervical vertebrae maturation index (CVMI) and to compare it between male and female subjects, by using CBCT imaging. As per this study, a statistically significant difference in IZC bone thickness was seen in various CVMI stages. Maximum bone thickness was 11 mm, and minimum bone thickness was 1 mm. No significant difference was observed between male and female populations. The superolateral area in the IZC is the most appropriate site for miniscrew insertion in all age groups.[19]

Based on the study on Italian, Spanish, and Portuguese population to evaluate through CBCT, ideal areas for insertion of EA miniscrews in the IZC and MBS based on different craniofacial patterns. As per this study, there were no significant differences in IZC bone thickness between the 3 groups. Maximum thickness was present at 11 mm apical to the mesiobuccal cusp tip of max first molar.[19]

In Chinese population to measure the bone depth and thickness of different insertion paths for safe placement of IZC crest miniscrews between the first and second maxillary molars by 3D reconstruction and to explore their clinical significance. As per this study, A miniscrew insertion path may be preferred at a disposition of 15 mm height above the POP, a gingival tipping angle of 60°–70°, and a distal tipping angle of 30°. A miniscrew with 9–11 mm in length and 1.6–2.3 mm in diameter may be proper in this region.[20]

Tavares *et al*. conducted a study to evaluate bone availability at the IZC for EA bone miniscrew insertion in subjects with different vertical and sagittal skeletal patterns. As per this study, bone availability was lower at the apical level, especially in Class II and mesofacial subjects. Therefore, when the planned insertion site is located in the apical direction, it is recommended to choose shorter miniscrews (2.0 mm × 12 mm) and a smaller insertion angle (60°) and/or to plan a miniscrew bone insertion deep enough to allow bicortical fixation.[21]

In another study on the Chinese population 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. Open beta testing (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. Closed beta testing and OBT were significantly influenced by sex and age. The optimal insertion heights and angles were 12 mm to 18 mm from the occlusal plane, and 40°–70° for mini-implants at IZC.[22]

In Nepali population, to find out the most suitable site for micro-implant placement in the IZC area, the IZC bone thickness, when measured at an angle of 40° to 75° and 11–17 mm above the occlusal plane of the maxillary first molar, was 3–9 mm. There was no significant gender and side variation in bone thickness of IZC and insertion height. IZC thickness increases with the increase in insertion angle and the decrease in height. The optimal site for miniscrew placement in IZC in an adult is at the angle of 70°and 13 mm from the occlusal plane.[23] A dynamic navigation guide could be the future and help in accurate placement with clinical integration.[26,27]

Ujala *et al*. conducted a study on the Pakistani population to evaluate IZ bone thickness for safe placement of IZ implant using CBCT. As per this study, bone thickness at insertion angles of 55° to

75° ranged from 3.07 ± 0.94 mm to 4.91 ± 1.59 mm to maxillary occlusal plane. This value increased with increasing insertion angles. The height from the occlusal plane also varied with higher values at small insertion angle i.e. 18.5 mm at 55°, and smaller values at high insertion angle, i.e. 16.02 mm at 75°. The miniscrew should be inserted at an angle of 55° to 70° at distances of 16 mm to 18 mm from the maxillary occlusal plane.[24]

The limitations of this review are that articles that were included in the review, but some heterogenecity among articles and study design was present. Most of the articles were done in Asian countries and population and lesser articles from other regions.

CONCLUSION

The current evidence suggested that there was a statistically significant difference in the bone thickness of the IZC area with the majority of studies supporting that the area buccal to maxillary first molar is the most ideal site of mini implant placement. As per maximum evidences, the ideal insertion angle should be 60°–70°, and ideal insertion height should be 10–15 mm as the bone thickness increases with an increase in insertion angle and decrease in the insertion height.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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