Comparison of infrazygomatic crest bone screw position using a postero-anterior cephalogram versus cone-beam computed tomography: a cross sectional study

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Background: The position of infrazygomatic crest bone screws is an important consideration in determining the success of orthodontic treatment. The aim of this study was to compare the position of infrazygomatic crest (IZC) bone screws in relation to skeletal and dental parameters using postero-anterior (PA) cephalograms and cone beam computed tomography (CBCT).
Methods: A CBCT scan and a PA cephalogram were taken of 19 patients (8 males; 11 females) after IZC bone screw placement. Each CBCT image was reconstructed and oriented using the CS 3D CBCT software (Carestream Dental LLC, Atlanta, USA) and was subsequently analysed. The landmarks were traced on the PA cephalogram. The angulation of the IZC bone screw was measured with respect to three skeletal and two dental landmarks and compared between the two imaging modalities. A paired *t* test was applied to compare the means of different variables between the PA cephalogram and CBCT scan.
Results: The results showed no statistically significant difference between the two imaging modalities with respect to four landmarks, i.e., the inter-jugale plane, the mid sagittal plane, the zygomatic arch and the perpendicular long axis to the 1st molar but a small statistically significant difference was seen with respect to measurements from the facial surface of the 1st molar ($P \leq 0.05$).
Conclusion: The angulation and position of an IZC bone screw are consistent between the two imaging modalities. A PA cephalogram may be used as a substitute for a CBCT scan to reduce the radiation exposure to patients.
(Aust Orthod J 2023; 39: 64 - 70. DOI: 10.2478/aoj-2023-0023)

Received for publication: February, 2023
accepted: June, 2023.

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Introduction

Orthodontic anchorage is defined as the resistance that a tooth or a group of teeth offers, when subjected to a force. The main aim of treatment is to maintain sufficient anchorage control, in order to prevent the movement of teeth in an unwanted direction.[1] Traditionally, intermaxillary elastics, headgear, a Nance palatal arch, a transpalatal arch and lingual arches have been used for anchorage reinforcement. However, due to factors related to aesthetics and poor patient compliance, Temporary Anchorage Devices (TADs) have been introduced. Their popularity is associated with their small size and source of intraoral skeletal anchorage which is less cumbersome for the patient than extraoral skeletal anchorage devices such as headgear. Other benefits include a minimally invasive surgical procedure, lesser armamentarium, good patient compliance and the availability of

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multiple insertion sites for different types of tooth movement.[2]

Common miniscrew insertion sites in the maxilla include the buccal alveolar aspect, the palate and the infrazygomatic crest region. Recently, the infrazygomatic crest has been considered as an alternative site for miniscrew anchorage because the miniscrews inserted in these locations are far from the tooth roots and will not hinder orthodontic tooth movement.[2]

The two important considerations during TAD placement are safety and stability. Safety is associated with the avoidance of injuries to any adjacent anatomical structure whereas stability depends on the amount of cortical bone thickness present at the insertion site to prevent premature loosening and loss of the TADs. In order to achieve safety and stability by proper positioning of the TADs, a knowledge of insertion site anatomy is important.[3]

The assessment of cortical bone thickness and the position of the bone screw after placement using Cone-beam Computed Tomography (CBCT) has proven to be an accurate tool. However, the disadvantages of CBCT are the limited availability, the high cost and its high radiation exposure. A comparison between the effective doses of 2D and 3D radiological examinations has shown an effective dose of 3.85 to 38.0 μSv for panoramic radiography (OPG), 1.1 to 5.6μSv for a lateral cephalometric examination[4] and 61 to 134 μSv for a CBCT examination.[5] A CBCT scan is not considered as a standard method to assist orthodontic diagnosis, and its routine clinical use is not acceptable as a substitute for conventional radiographs in both children and adults. Because of the higher radiation doses compared with 2D radiographs, CBCT examinations should be performed only for valid diagnostic or treatment reasons and with the minimum exposure necessary for adequate image quality. These include retained and impacted permanent teeth, severe craniofacial anomalies, severe facial disharmony indicating orthodontic-surgical treatment, and bone irregularities or malformation of the TMJ accompanied by signs and symptoms.[6]

Excessive radiation is a special concern for clinicians as most orthodontic patients are children who are considered to be particularly vulnerable since they possess tissues with higher radiosensitivity due to a greater number of cell divisions, and a longer overall lifespan for cancer development.[6]

The literature states that past authors have evaluated and assessed the position of miniscrews via a CBCT scan, IOPARs[7] and orthopantomograms.[8] The potential benefits of the 3D images in evaluating the position of an IZC bone screw should be carefully considered against the higher radiation dose before CBCT imaging can be justified. Postero-anterior (PA) cephalograms have not yet been used as an assessment tool. As there are no studies comparing the accuracy of CBCT images and PA cephalograms for the assessment of the position of IZC bone screws, the aim of this study was to evaluate and compare the position of IZC bone screw on PA cephalogram against CBCT images.

Material and methods

The study protocol was approved by the ethics review committee of Ramaiah University of Applied Sciences, Bangalore, India (Reference No: EC-2022/PG/203). The cross-sectional study was conducted on Postero-Anterior cephalograms and full skull Cone Beam Computed Tomography scans obtained from 19 patients (8 males and 11 females) undergoing fixed orthodontic treatment in the Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, Ramaiah University, Bangalore. All of the scans were obtained by placing the patient in the natural head position during image capture. Using the Carestream software (CS 9300, Carestream Health, Rochester, NY, USA) with the exposure parameters of 6.3 mA, 90 kvp, 300 μm resolution with a full field of view (FOV) of 17 × 13.5 cm and an exposure time of 11.30 sec, the CBCT images were captured and the postero-anterior cephalogram was obtained using the parameters of 10 mA, 90 kvp, 300 μm resolution and a full field of view (FOV) of 24 × 30 cm and an exposure time of 2 sec. A sample size was calculated based on the study of Murugesan et al., using the G* Power 3.1.9.7 software (Heinrich Heine Universitat, Dusseldorf, Germany). The minimum sample size of each group was calculated, following the input conditions of a power of 80% and an alpha error of 0.05. Therefore, the total sample size was estimated to be 19.

- The Inclusion Criteria were:
  - (i) Healthy individuals of both the genders aged between 15 and 40 years
  - (ii) Patients undergoing orthodontic treatment in whom an IZC bone screw was indicated

(iii) The presence of permanent first and second molars
(iv) No congenitally missing teeth except the 3rd molars

- The Exclusion Criteria were:
  (i) Patients with craniofacial anomalies
  (ii) Patients with periodontal disease
  (iii) Patients with impacted teeth in the region of IZC
  (iv) Patients with any underlying systemic diseases

IZC bone screws (SK Surgicals, Hyderabad, Telangana, India) (diameter: 2 mm; length: 12 mm) were used for the study. The bone screws had a 2-component design consisting of an upper head and a lower screw portion. The attached gingiva at the placement site in the infrazygomatic crest region was perforated using a tissue punch under local gingival anaesthesia (less than a quarter of a 1.8 mL volume). The surgical site was monitored for bleeding, following which the screw portion of the bone screw was inserted. Following the placement of the IZC screw, each patient agreed and underwent two sets of radiographs, the first a postero-anterior cephalogram and the other a full skull CBCT scan as a protocol. The protocol was reviewed by the appropriate institutional review body (Reference No: EC-2022/PG/203), and each subject participating in the project signed detailed informed consent.

The cephalometric points [Table I] were plotted and planes [Table II] were drawn. The position of the IZC bone screw was determined by measuring the angles formed by the long axis of the screw and the five planes as shown in Table II on both the PA cephalogram and CBCT scan. Measurements were conducted on both the left and right sides of the maxilla [Figures 1, 2].

The angular measurements of the IZC bone screw position in relation to the skeletal and dental landmarks were made and compared by a single observer (SA). The values were rechecked to ensure consistency between the readings by the same observer after intervals of 10 days.

Statistical analysis

Sample size estimation

The G* power software (3.1.9.7) was used to estimate the sample size. Input parameters related to the effect size, power and alpha error (probability) were applied and the sample size generated was 19.

t tests - Means: Difference between two dependent means (matched pairs).

Analysis: A priori: Compute required sample size.

Input:

- Tail(s) = One
- Effect size dz = 0.6
- α err prob = 0.05
- Power (1-β err prob) = 0.80

Output:

- Noncentrality parameter δ = 2.6153394
- Critical t = 1.7340636
- Df = 18
- Total sample size = 19
- Actual power = 0.8079091

The Statistical software SPSS 19.0 (Windows version, 2013. Armonk, NY: IBM Corp) was used

Table I. Points.

Points	Location
Crista galli (Cg)	Most superior point at intersection with sphenoid.[8]
Jugale left (Jl)	At jugal process, intersection of outline of maxillary tuberosity and zygomatic buttress on left side.[9]
Jugale right (Jr)	At jugal process, intersection of outline of maxillary tuberosity and zygomatic buttress on right side
Upper 6 left (U6l)	Most buccal point at upper first molar crown on left side.[10]
Upper 6 right (U6r)	Most buccal point at upper first molar crown on right side
Menton (Me)	Most inferior point of symphysis of mandible.[11]
Zygomatic point (Zl)	The point on the postero-inferior border of zygomatic arch on left side
Zygomatic point (Zr)	The point on the postero-inferior border of zygomatic arch on right side

Table II. Planes.

S.NO.		
Skeletal landmarks		
1	Inter-jugale plane	Two jugale points are marked on either side of the maxilla. A horizontal line is drawn joining the two jugale points. This is the inter-jugale plane
2	Mid-sagittal plane	A vertical line is drawn from the crista galli to the menton. This is the mid-sagittal plane
3	Zygomatic arch	A tangent is drawn along the zygomatic point
Dental landmarks		
5	Long axis of the maxillary 1st molar	Two reference lines are drawn. First line is a horizontal line that represents the maxillary occlusal plane and the second line is a vertical line along the long axis of the maxillary 1st molar perpendicular to the occlusal plane
6	Facial plane of maxillary 1st molar	A vertical line tangent to the buccal surface of the distobuccal root of the molar is drawn. This is the facial plane

for the analysis of the data and Microsoft Word and Excel were used to generate the graphs and tables. Descriptive and inferential statistical analysis was carried out and the results of continuous measurements are presented as Mean and Standard Deviations. Statistical significance was assessed at the 5% level ($P \leq 0.05$). A paired *t* test was applied to compare the means of different variables between the PA cephalogram and the CBCT scan.

Results

Table III depicts the comparison of the position of the IZC bone screw with respect to the skeletal landmarks on the PA cephalogram and the CBCT scan. There was no statistically significant difference ($P \leq 0.05$) noted in the measurements in the position of IZC bone screw between the two imaging techniques bilaterally.

Table IV depicts the comparison of the position of the IZC bone screw with respect to the dental landmarks on the PA cephalogram and the CBCT scan. There was no statistically significant difference ($P \leq 0.05$) seen in the measurements in the position of the IZC bone screw between the PA cephalogram and the CBCT scan with respect to the perpendicular long axis of the maxillary 1st molar whereas the facial plane of the maxillary 1st molar showed a statistically significant difference ($P = 0.02$) in the position of the IZC bone screw between the two imaging modalities bilaterally.

Discussion

The aim of this study was to evaluate and compare the angulation of infrazygomatic crest (IZC) bone screws using postero-anterior (PA) cephalograms and CBCT images on both the left and right sides. Previous literature has confirmed the absolute accuracy of CBCT images[9–13] and validated the use of CBCT scans to evaluate the position of IZC bone screw position. The accuracy of CBCT imaging in determining the position of a bone screw is important for the safety and stability of the screw as they are critical in determining the success of TADs and therefore overall treatment. An optimum combination of mini-implant dimensions and insertion angle are required to achieve proper primary stability, reduce the risk of sinus perforation and to achieve good clinical performance.[14,15] Data observed from this study suggests that, from a clinical perspective, the IZC screw's position remains stable and could be effectively used as anchorage to support orthodontic tooth movement.[16]

The collective effective dose of lateral cephalometry, PA cephalometry and panoramic radiography is 25 to 35 mSv, whereas the effective dose of a CBCT scan with a large field of view used for orthodontic diagnosis ranges from 68 mSv to 1073 mSv, which is several times greater.[17] Therefore, the use of a CBCT scan for the determination of miniscrew position could be substituted by 2D methods utilizing a lesser radiation dose.

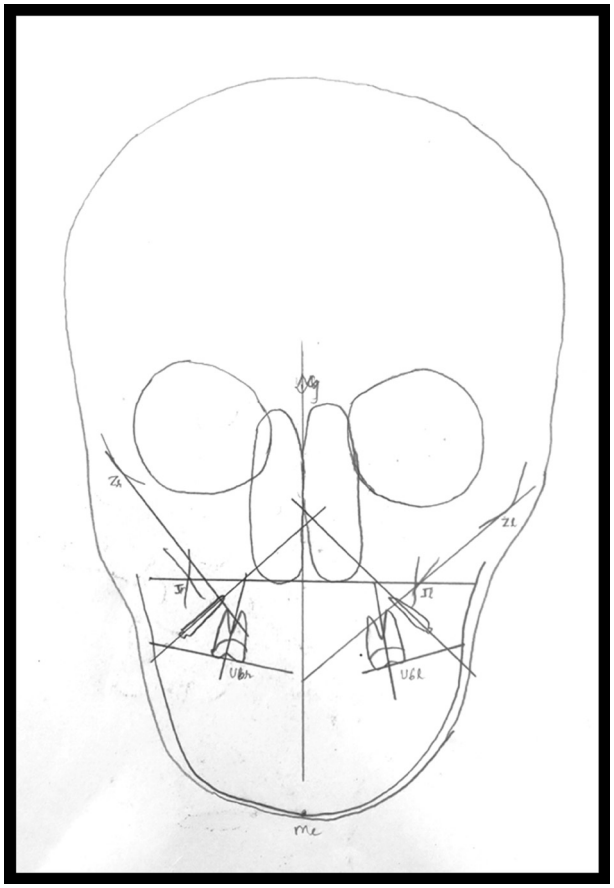


Figure 1. Postero-anterior cephalogram measurements.

Most conducted studies have assessed the position of a miniscrew using a CBCT scan.[18–20] The literature also compares bone-screw position between an OPG and a CBCT scan.[21] However, there are few studies which have compared bone-screw position on a postero-anterior cephalogram against a CBCT scan obtained from the same patient. Past authors[22] have indicated that the systematic errors in landmark identification were the same for both types of radiographs; therefore, to prevent any systematic error, a single observer conducted this study. The difference in the measurements with respect to the facial plane of the maxillary 1st permanent molar between the PA cephalogram and the CBCT image was statistically significant at a *P*-value of 0.02 ($P < 0.05$). The difference in measurements with respect to the facial plane of the permanent 1st molar is explained by the noise and superimposition of different structures.

The positioning of the patient is critical when taking a PA cephalogram because rotation of the head results in measurement differences.[23–25] Head disorientation, such as rotation or tipping while taking the cephalogram, affects the relationships of the landmarks, making it difficult to evaluate and measure horizontal distances.[26,27] In this study, the patient's head was upright without rotation nor tilting while the PA cephalogram and the CBCT scan were taken.

Damstra et al.[12] showed that CBCT scans were more accurate in determining the difference between mandibular dimensions (ramus length, body length, and total length) than conventional PA cephalometry as the points of gonion (Go) are not accurately identifiable on PA cephalograms. Therefore, in this study, only the maxillary and midline structures were used to determine the position of the IZC bone screw.

In the current study, the difference in the measurements of the IZC bone screw with respect to the mid-sagittal plane, zygomatic arch, inter-jugale plane and the perpendicular long axis of the maxillary 1st molar was statistically insignificant which is in agreement with previous studies.[23,24]

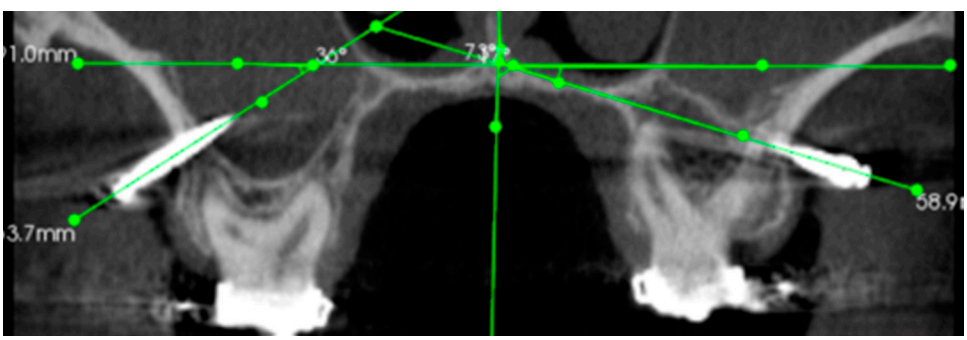


Figure 2. CBCT measurements.

Table III. Comparison of IZC bone screw angulation with respect to skeletal landmarks on PA cephalogram and the CBCT scan.

Landmarks	*N*	Mean	SD	*T*	*P*
INTER-JUGALE PLANE					
RIGHT					
PA-CEPH	19	45.9	8.70	0.1	0.4
CBCT	19	46.3	8.79		
LEFT					
PA-CEPH	19	45.0	8.76	0.3	0.3
CBCT	19	44.6	10.36		
MID-SAGITTAL PLANE					
RIGHT					
PA-CEPH	19	48.3	8.18	0.15	0.4
CBCT	19	48.4	7.88		
LEFT					
PA-CEPH	19	50.6	11.29	1.2	0.1
CBCT	19	50.9	11.27		
ZYGOMATIC ARCH					
RIGHT					
PA-CEPH	19	88.7	9.32	0.2	0.4
CBCT	19	88.5	9.85		
LEFT					
PA-CEPH	19	84.7	12.27	0.8	0.2
CBCT	19	84.1	11.23		

Table IV. Comparison of IZC bone screw angulation with respect to dental landmarks on the PA cephalogram and the CBCT scan.

Landmarks	N	Mean	SD	T	*P*
LONG AXIS OF MAXILLARY 1ST MOLAR					
RIGHT					
PA-CEPH	19	42.1	10.28	0.65	0.2
CBCT	19	44.1	10.21		
LEFT					
PA-CEPH	19	43.3	10.54	0.7	0.2
CBCT	19	41.7	11.99		
FACIAL PLANE OF MAXILLARY 1ST MOLAR					
RIGHT					
PA-CEPH	19	39.0	12.83	2.1	0.02*
CBCT	19	44.5	7.39		
LEFT					
PA-CEPH	19	40.1	11.56	2.1	0.02*
CBCT	19	44.9	9.28		

Of the five landmarks used, the difference in four landmark measurements (three skeletal and one dental) was not statistically significant ($P < 0.05$) and 1 dental landmark, i.e. the facial surface of the 1st maxillary molar showed statistically significant differences at $P = 0.02$ ($P < 0.05$) between the PA cephalogram and the CBCT scan. This could be due to the superimposition of various structures in the alveolar region.[27]

The limitation of this study was the clinically small but statistically sufficient (as per the power of the study) sample size. However, a higher sample size would also lead to high radiation exposure to the patients.

The CBCT measurement results were comparable to the measurements made on conventional PA cephalograms. Skeletal landmarks, i.e. the mid-sagittal plane, the inter-jugale plane, zygomatic arch and dental landmark, i.e. the long axis of the 1st molar can be used to determine the position of an IZC bone screw on a PA cephalogram as they showed no statistically significant difference in the measurements. This suggests that PA cephalograms can replace CBCT scans to determine the position of an IZC bone screw and therefore reduce patient irradiation during orthodontic treatment.

Conclusion

- Overall, the angular measurements between an IZC bone screw position using skeletal landmarks (mid-sagittal plane, inter-jugale plane, zygomatic arch) and one dental landmark (long axis of the 1st molar) showed no statistically significant difference on both the PA cephalogram and CBCT scan. This finding suggests that a PA cephalogram may be substituted for a CBCT scan to evaluate the position of an IZC bone screw.
- There was a statistically significant difference seen in the angular measurements of the IZC bone screw with respect to the facial plane of the 1st molar on both the PA cephalogram and the CBCT scan. This significance in the difference suggests that the facial plane of the 1st maxillary molar is not a reliable parameter to determine the position of an IZC bone screw on a PA cephalogram due to the superimposition of neighbouring teeth.

• A PA cephalogram is a reliable alternative to a CBCT scan to determine IZC bone screw position following its placement.

Conflict of interest

The authors declare that there is no conflict of interest

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