The reliability of cephalometric measurements in oral and maxillofacial imaging: Cone beam computed tomography versus two-dimensional digital cephalograms

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ABSTRACT

Context: This study compared digital two-dimensional (2D) lateral cephalograms and cone-beam computed tomography (CBCT) total and half-skull images for the reliability of cephalometric measurements.

Aims: (1) To compare the accuracy of cephalometric measurements and reproducibility between the digital and CBCT cephalograms in the Indian population. (2) To compare interobserver variability in landmark identification through their cephalometric measurements by comparing different imaging modalities (CBCT total skull, CBCT half-skull, and conventional lateral cephalogram). (3) To further compare half-skull with the total skull synthesized CBCT and digital cephalograms in the same regard.

Materials and Methods: Thirty patients, who had consented with orthodontic treatment, participated in the study. Informed consent was obtained from the patient before the radiographic procedures. 2D digital lateral cephalograms and their corresponding CBCT scans were taken and imported in DICOM format to OnDemand 3D software. Twenty-three landmarks were identified by 3 observers and 9 linear and 14 angular measurements were digitally traced. The values were sent for statistical analysis using ANOVA to check the interobserver reliability between the imaging modalities.

Statistical Analysis Used: ANOVA, Student’s t-test, and post hoc test were used for the statistical analysis.

Results: The interobserver reliability was high between the modalities. CBCT total skull received an overall intraclass correlation coefficient (ICC) value of 0.76. The ICC value for the CBCT half-skull was 0.79 and for the digital cephalograms it was 0.80. The reliability for CBCT total skull was marginally less when compared to the CBCT half-skull and digital cephalograms, but more for the mid-sagittal measurements. Digital cephalograms showed the most variation with measurements of the mandibular plane when compared to CBCT.

Conclusions: CBCT has the potential to be used for cephalometrics, especially the half-skull images, but further studies are required to prove whether CBCT total skull images can be used. 2D cephalometry, however, still does remain as the mainstay of orthodontic diagnosis and treatment planning and cannot be easily replaced by three-dimensional cephalometry.

Key words: Cone beam computed tomography half-skull, computed tomography, cone beam computed tomography, digital cephalometry

Diagnostic is not the end, but the beginning of practice.” A good diagnosis is always instrumental for proper treatment planning. Cephalometric radiography is a standardized
method of production of skull radiographs, which are useful in making measurements of the cranium and the orofacial complex.\(^2\) It is an essential tool for orthodontic practice and research, which provides elaborate information for diagnosis and treatment planning.\(^2\)

Digital cephalometry was introduced in the late 1960s using the same principles which aided in reducing the time consumption for image acquisition.\(^3\) Recently, cone-beam computed tomography (CBCT) became the preferred method instead of CT due to the reduction in the radiation dosage for the patient.\(^4\) It has proved its value in dental practice when conducting craniofacial measurements.\(^5\)

The aim of this study is to compare the interobserver reliability and precision of cephalometric landmark identification and measurements using CBCT and digital two-dimensional (2D) lateral cephalograms and to evaluate if CBCT is a more accurate choice in orthodontic diagnosis and treatment planning. A recently introduced half-skull CBCT cephalogram will also be evaluated and compared with total-skull CBCT and digital lateral cephalograms. Measurements and landmark identification for both the cephalograms will be done digitally using a computer-aided software for analysis.

**MATERIALS AND METHODS**

The study was carried out on thirty patients visiting the Department of Orthodontics at Bangalore Institute of Dental Sciences for Orthodontic treatment. Informed consent for the study to be carried out was taken from the patients, and ethical clearance was obtained from the University Board. The procedure was explained to the patients in their own language. Patients with no gross asymmetry were included in the study. Patients who suffered any trauma to the maxillofacial region, or were medically compromised were excluded from this study.

The 2D digital lateral cephalograms for thirty patients were obtained at the institution using the Rotograph Evo D Machine (Villa Sistemi Medica, Milan, Italy) (72 kV, 10 mA, 4.5 s). Following that, their corresponding CBCT scans were taken using KODAK 9500 CBCT Machine (Carestream Health Inc, Rochester, New York, USA) (90 kV, 10 mA, 10.8 s). All the images were then saved in DICOM format and imported into the OnDemand 3D software (Cybermed Inc., Korea) for analysis.

For the image acquisition of the 2D digital images and the CBCT images,\(^5\) standard guidelines for the patient positioning were employed [Figure 1]. In the software, two techniques were used for controlling the anteroposterior head rotation for the CBCT. The Frankfort horizontal plane was adjusted so that it was completely horizontal in the sagittal view. In the axial view, the mid-saggital plane was oriented vertically and in the coronal view, the transporionic line was oriented horizontally\(^5\) [Figure 2]. The right-side half-skull images were generated by segmenting a section of the total three-dimensional (3D) reconstructed volumetric image and eliminating the unwanted left side. The thickness of the generated image was reduced by half\(^4\) [Figure 3].

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**Figure 1:** Acquired image in the digital lateral cephalogram

**Figure 2:** Orientation for the cone beam computed tomography total skull images was done by using intra-cranial reference planes

**Figure 3:** Cone beam computed tomography half-skull images were synthesized by using the segmentation tool in the software to remove the unwanted side of the skull. The image thickness was also reduced by half.
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Cephalometric analysis was performed on both the digital and CBCT-synthesized cephalograms (total and half-skull images) using the same software. Three observers (a postgraduate student, a senior lecturer, and an assistant professor) from the Department of Orthodontics, Bangalore Institute of Dental Sciences, Bengaluru, were selected to plot the landmarks at different times. The observers were trained on the usage of the software, and a list of standard definitions of the chosen landmarks was given to each of them for their reference. Facilities of changing the sharpness, contrast, and the brightness for better viewing of the images were available in the software for each observer as per their requirements. While doing the analyses for the digital cephalograms, a magnification factor of 1.1 mm was subtracted from each measurement as per the manufacturer settings of the Rotograph Evo D machine. The axial slice thickness used was standard at 0.4 mm with isotropic voxels for the CBCT images. The software had the option of doing 2D and 3D measurements, so for the CBCT total skull, 3D measurements were calculated directly on the 3D volumetric image. For the half-skull CBCT and digital cephalograms, they were synthesized into 2D DICOM images, and 2D measurements were obtained on them. A total of 23 landmarks were plotted for thirty patients. Fourteen angular and 9 linear measurements were done for each imaging modality per patient [Table 2]. The obtained values were then transferred to an Excel Master Chart (Microsoft Excel 2007) for statistical analysis using SPSS software 18.0 for the analysis of the interobserver variability and the comparison with the measurements obtained of the skull. The ANOVA test was done to evaluate the interobserver variability and accuracy of landmark identification and their measurements for each imaging modality. The intraclass coefficient was used to analyze the agreement of the measurements between the three observers.

RESULTS

Twenty-three landmarks were identified by 3 observers and 9 linear and 14 angular measurements were plotted.

Table 1: Definitions of the Chosen Cephalometric Landmarks

| Landmarks | 2D Definition | 3D Definition |
|-----------|--------------|--------------|
| Porion    | The highest bony point on the upper margin of the External Auditory Meatus. | The most superior point of the External Auditory Meatus. |
| Sella     | The point representing the mid – point of the Sella Turcica | Midpoint of the fronto – nasal suture. |
| Orbitale  | The lowest point on the inferior bony margin of the orbit. | The most anterior point of the Foramen Magnum. |
| Nasion    | The most anterior point midway between the frontal and nasal bones on the fronto – nasal suture | Most anterior mid – point of the chin on the outline of the Mandibular Symphysis. |
| Basion    | Median point of the anterior margin of the Foramen Magnum. | Most anterior – inferior point on the contour of the mandibular symphysis. |
| Pogonion  | Most anterior point of the bony chin in the median plane. | Most inferior midpoint of the chin on the outline of the mandibular symphysis. |
| Gnathion  | Most antero – inferior point on the symphysis of the chin. | The point of maximum concavity in the midline of the alveolar process of the maxilla. |
| Menton    | Most inferior midline point on the mandibular symphysis. | The intersection of the posterior border of the vertical mandibular ramus and the outer margin of the cranial base. |
| Gonion    | Constructed point at the junction of ramal plane and the mandibular plane. | The most supero – point of the Mandibular Condyle. |
| Point A   | Deepest point in the midline between the anterior nasal spine and the alveolar crest between the two central incisors. | Most posterior – superior point of the Mandibular Condyle. |
| Articulare| Point at the junction of the posterior border of the ramus and the inferior border of the basilar part of the Occipital Bone. | The point of maximum concavity in the midline of the alveolar process of the mandible. |
| Condylion | The most superior point on the head of the Condyle. | Most anterior mid – point of the anterior nasal spine of maxilla. |
| Point B   | The deepest point in the midline between the alveolar crest of mandible and the mental process. | Most posterior mid – point of the posterior nasal spine of the palatine bone. |
| Anterior Nasal spine | The anterior tip of the sharp bony process of the maxilla in the midline of the lower margin of anterior nasal opening. | The intersection of a continuation of the anterior wall of the pterygo – palatine fossa and the floor of the nose, marking the distal limit of the maxilla. |
| Posterior Nasal spine | The intersection of a continuation of the anterior wall of the pterygo – palatine fossa and the floor of the nose, marking the distal limit of the maxilla. | Most inferior point of the alveolar process of the maxilla in the, in the median plane, between the upper central incisors. |
| Upper 6 Occlusal  | Most superior point of the mesio – buccal cusp of the upper first molar. | Most inferior anterior point on the alveolar portion of the premaxilla, in the median plane, between the upper central incisors. |
| Lower 6 Occlusal | Most superior point of the mesio – buccal cusp of the lower first molar | Most anterior superior point on the mandible at its labial contact, in the median plane, between the mandibular central incisors. |

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The standard deviation of error was generally high for the CBCT total skull when compared to the CBCT half-skull and digital cephalogram for six of the linear measurements and four of the angular measurements. The linear measurements of ANS-Me, N-ANS, and S-N showed the least standard deviation in CBCT total skull. For these measurements, the digital modality had the highest standard deviation. The angular measurements involving the Ar landmark (SNAr, SArGo, and ArGoMe) showed the highest standard deviation, more so in the CBCT total skull. BaSN also showed a high standard deviation. The angles involving the mid-sagittal plane, showed less standard deviation in the CBCT when compared to the digital cephalograms. CBCT half-skull standard deviations were consistently low for all the measurements. From this, we can infer that for the mid-sagittal measurements involving the N landmark, CBCT proved to be a more precise modality, whereas, for the lateral measurements, the digital cephalograms were more precise.

The overall significance level was assessed based on variation in the measurements between the three tested modalities and also the interobserver variation in the measurements within each modality. There was a high level of significance between groups as well as within each group for both linear and angular measurements. The only nonsignificant linear measurements were N-Me and ANS-Me, which showed once again that there was a good agreement between the observers as well as the modalities for the mid-sagittal landmarks and measurements. Five angular measurements did not show any level of significance between the observers (FMA, IMPA, NAPog, ABN, and SNA).

Post hoc tests were further done to assess which modality displayed the highest variations in the measurements [Tables 5 and 6]. The measurements with no significant variation were omitted from this test. There was a high level of significance for the measurements involving the CBCT total skull modality. The comparison between CBCT total skull with the half-skull as well as with the digital cephalogram revealed a high level of significance. The only less significant linear measurement involving the total skull and half-skull was N-ANS, another measurement involving...
the mid-sagittal plane. The P value for this measurement was 0.040, which is almost nonsignificant. However, the same measurement showed a high level of significance when compared with the digital. The angular measurement ArGoN showed a high level of agreement between CBCT total skull and digital cephalograms, with a P value of 0.100, but high variation when compared to the CBCT half-skull image. Comparison of the linear and angular measurements between the CBCT half-skull and the digital cephalogram was nonsignificant, showing a high level of reliability. Only three angular measurements showed a high level of significance between CBCT half-skull and digital cephalograms (U1SN, U1NA, and MeGoN).

The intra-class correlation coefficient (ICC) showed the level of reliability between each modality [Tables 7-9]. All three modalities had a substantially high interobserver reliability for each measurement. The CBCT total skull had a higher reliability with the mid-sagittal linear measurements. The conventional cephalograms had a more consistent and marginally higher ICC values overall when compared to the CBCT total skull. The CBCT half-skull also had a high interobserver reliability, and the overall ICC values were in agreement with the digital cephalograms. The lowest ICC value obtained was 0.69 for the IMPA angle, by the digital cephalograms. The lowest interobserver reliability, and the overall ICC values were marginally higher ICC values overall when compared to conventional cephalograms had a more consistent and reproducibility of cephalometric measurements. CBCT is increasingly becoming the investigative modality of choice when it comes to diagnosis and treatment planning, but as obtained in this study, there are variations in which type of CBCT image will provide accurate measurements.

The CBCT total skull image showed a high standard deviation of error for some of the linear and the angular measurements but was generally comparable to that of 2D lateral cephalograms. For example, linear measurements

DISCUSSION

This study focused on the comparison between digital lateral cephalometry and CBCT in the variability and reproducibility of cephalometric measurements. CBCT is increasingly becoming the investigative modality of choice when it comes to diagnosis and treatment planning, but as obtained in this study, there are variations in which type of CBCT image will provide accurate measurements.

The CBCT total skull image showed a high standard deviation of error for some of the linear and the angular measurements but was generally comparable to that of 2D lateral cephalograms. For example, linear measurements

### Table 3: Example of the Recorded Linear Measurements of a Patient

| PT. No. | Observer | Modality       | Co-Gn | Go-Me | S-N | ANS-Me | Ar-Go | S-Ar | N-Me | N-ANS | S-Go |
|---------|----------|----------------|-------|-------|-----|--------|-------|------|------|-------|------|
| 1       | 1        | CBCT Total Skull | 112.38| 76.02 | 85.49| 59.94  | 49.66 | 25.18| 101.51| 42.79 | 67.61|
| 2       | 2        | CBCT Total Skull | 109.19| 76.61 | 87.37| 59.67  | 96.90 | 28.81| 101.77| 43.27 | 119.58|
| 3       | 3        | CBCT Total Skull | 109.82| 76.19 | 86.38| 59.63  | 99.04 | 29.92| 101.77| 43.56 | 118.15|
| 1       | 1        | CBCT Half Skull  | 101.87| 63.03 | 63.58| 61.12  | 50.75 | 22.08| 101.82| 44.83 | 69.81|
| 2       | 2        | CBCT Half Skull  | 104.71| 66.28 | 64.48| 62.25  | 44.60 | 20.71| 100.86| 41.31 | 63.36|
| 3       | 3        | CBCT Half Skull  | 102.64| 63.33 | 63.90| 60.70  | 49.16 | 23.11| 101.20| 44.22 | 69.54|

### Table 4: Example of Recorded Angular Measurements of a Patient

| PT. No. | Observer | Modality       | SNA  | SNB | ABN | U1NA | U1SN | NAPog | SNAr | S-Ar | Go-Me | Ar-Go | ArGoMe | MeGoN | BaSN | FMA | IMPA |
|---------|----------|----------------|------|-----|-----|------|------|-------|------|------|-------|-------|--------|-------|------|-----|-----|
| 1       | 1        | CBCT Total Skull | 83.8  | 81.2 | 3.9 | 6.4 | 45.0  | 177.0 | 63.6 | 63.5 | 9.7  | 5.7  | 54.9   | 64.3  | 103.4 | 25.2 | 92.7|
| 2       | 2        | CBCT Total Skull | 85.2  | 81.7 | 8.9 | 8.5 | 46.4  | 169.8 | 26.4 | 109.3 | 113.3 | 50.7 | 66.8   | 106.1 | 26.7 | 94.4|
| 3       | 3        | CBCT Total Skull | 78.8  | 77.5 | 5.5 | 5.8 | 42.9  | 173.7 | 69.1 | 136.0 | 126.7 | 62.2 | 68.2   | 73.2  | 28.5 | 97.8|
| 1       | 1        | CBCT Half Skull  | 78.9  | 76.0 | 5.4 | 5.2 | 51.6  | 176.9 | 15.2 | 126.2 | 126.5 | 54.1 | 75.3   | 154.7 | 22.4 | 86.1|
| 2       | 2        | CBCT Half Skull  | 80.2  | 76.5 | 6.1 | 4.9 | 51.2  | 173.9 | 17.9 | 135.7 | 124.9 | 54.9 | 72.9   | 151.8 | 26.6 | 81.3|
| 3       | 3        | CBCT Half Skull  | 80.9  | 75.9 | 7.1 | 2.6 | 53.9  | 173.4 | 7.3  | 118.0 | 125.8 | 52.5 | 74.7   | 137.4 | 24.9 | 85.3|
| 1       | 1        | Digital Ceph     | 79.5  | 74.2 | 5.4 | 3.3 | 49.3  | 171.4 | 15.8 | 132.6 | 132.2 | 56.4 | 75.4   | 151.7 | 28.8 | 80.9|
| 2       | 2        | Digital Ceph     | 78.4  | 73.8 | 8.2 | 3.5 | 49.9  | 169.5 | 16.3 | 138.4 | 129.0 | 53.5 | 75.2   | 152.1 | 33.8 | 78.6|
| 3       | 3        | Digital Ceph     | 79.1  | 74.1 | 6.2 | 3.1 | 52.7  | 171.5 | 9.7  | 122.7 | 128.9 | 52.8 | 73.9   | 146.8 | 23.1 | 84.3|

### Table 5: Post Hoc Tests for the Linear Measurements Showing the Agreement Between Each Modality

| Dependent Variable | Modalities                  | Mean Difference | Significance (P value) |
|--------------------|----------------------------|-----------------|------------------------|
| Co-Gn              | Total skull vs. Half Skull  | 7.1557143       | 0.001                  |
|                    | Total skull vs. Digital Ceph| 8.5693857       | 0.001                  |
| Go-Me              | Half skull vs. Digital Ceph | 1.4136714       | 0.747                  |
|                    | Total skull vs. Digital Ceph| 13.5102524      | 0.001                  |
| S-N                | Total skull vs. Half skull  | 20.5952381      | 0.001                  |
|                    | Total skull vs. Digital Ceph| 21.4185524      | 0.001                  |
|                    | Half skull vs. Digital Ceph | 0.6233143       | 0.615                  |
| Ar-Go              | Total skull vs. Half skull  | 26.2404762      | 0.001                  |
|                    | Total skull vs. Digital Ceph| 29.3993571      | 0.001                  |
| S-Ar               | Total skull vs. Half skull  | 3.1588810       | 0.573                  |
|                    | Total skull vs. Digital Ceph| 22.8789286      | 0.001                  |
|                    | Half skull vs. Digital Ceph | -0.3544810      | 10.001                 |
| N-ANS              | Total skull vs. Half skull  | 1.5291667       | 0.040                  |
|                    | Total skull vs. Digital Ceph| 2.8209667       | 0.001                  |
|                    | Half skull vs. Digital Ceph | 1.2918000       | 0.125                  |
| S-Go               | Total skull vs. Half skull  | 30.6002381      | 0.001                  |
|                    | Total skull vs. Digital Ceph| 32.6325333      | 0.001                  |
|                    | Half skull vs. Digital Ceph | 2.0322952       | 10.001                 |

*. The mean difference is significant at the 0.05 level
such as ANS-Me, N-ANS, and S-N displayed the least standard deviation, whereas the highest standard deviation came from the measurements involving Ar, i.e., S-Ar, Ar-Go, and S-Go. The standard deviation for the angular measurements involving the mid-sagittal plane and the dental structures, i.e. U1NA, U1SN, and ABN was found to be consistently <3°. This correlates with the study by Farhadian et al.,[8] which also showed that there was a high standard deviation for the Ar-Go measurement. However, in their study, the U1SN measurement revealed a much higher standard deviation than our study. The highest standard deviations were seen in the measurements involving the Ar landmark, such as ArGoMe, SArGo, and SNAr, which were consistently high. Even though the measurements involving the ramus height do appear to have a higher standard deviation, CBCT seems to be a good alternative as a gold standard.[8]

The CBCT half-skull also showed a high standard deviation for selected measurements but was consistently low when compared to the CBCT total skull. For the linear measurements, the highest standard deviation was seen in the measurements Co-Gn, Ar-Go, and S-Go. The highest standard deviations for the angular measurements were present for the SArGo and BaSN angular measurements. This implies that the CBCT half-skull produces consistent angular measurements, which could lead to a good interobserver reliability. This is in accordance to the study by Liedke et al.,[4] because the outcome of his study also revealed that CBCT half-skull produced consistent angular and linear measurements. Their study states that the reproducibility of measurements is a crucial factor in cephalometric analyses.[4] CBCT-synthesized half-skull images appear to be competent in cephalometric analyses. They allow for the representation of the right and left sides of the skull separately and therefore the accurate positioning of the landmarks is further enhanced.[8] The question of superimposition is out of the equation in this case and has been proven in this study.

The digital lateral cephalograms displayed a relatively high standard deviation also. The standard deviation was higher than the CBCT total and half-skull for four out of the nine linear measurements, namely, S-Go, N-ANS, N-Me, and Co-Gn, all involving the mandibular and mid-sagittal planes. This corresponds to the study by Navarro et al.,[9] who stated that the measurements involving the mandibular plane had the greatest standard deviation in the digital lateral cephalograms. The angular measurements were also less consistent when compared to the CBCT half-skull. It was found that the standard deviation was high in the measurements involving the mandibular plane, which was in accordance with the study by Farhadian et al.[8] They also got high standard deviations for mandibular plane angles.

### Table 6: Post Hoc Tests for the Angular Measurements Showing the Agreement between Each Modality

| Dependent Variable | Modality       | Mean Difference | Significance (P value) |
|--------------------|----------------|-----------------|------------------------|
| SNB                | Total skull vs. Half skull | 2.2155          | 0.004                  |
|                    | Total skull vs. Digital Ceph | 2.9468          | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 0.7313          | 0.887                  |
| U1NA               | Total skull vs. Half skull   | 2.5024          | 0.001                  |
|                    | Total skull vs. Digital Ceph | 4.2520          | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 1.7496          | 0.002                  |
| U1SN               | Total skull vs. Half skull   | -7.7679         | 0.001                  |
|                    | Total skull vs. Digital Ceph | -6.2626         | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 1.5052          | 0.029                  |
| SArGo              | Total skull vs. Half skull   | 16.4702         | 0.001                  |
|                    | Total skull vs. Digital Ceph | 16.7489         | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 0.2786          | 10.001                 |
| ArGoMe             | Total skull vs. Half skull   | -33.0274        | 0.001                  |
|                    | Total skull vs. Digital Ceph | -32.5777        | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 0.4497          | 10.001                 |
| ArGoN              | Total skull vs. Half skull   | 2.1719          | 0.003                  |
|                    | Total skull vs. Digital Ceph | 1.4771          | 0.100                  |
|                    | Half skull vs. Digital Ceph  | -0.7408         | 0.852                  |
| MeGoN              | Total skull vs. Half skull   | -8.9238         | 0.001                  |
|                    | Total skull vs. Digital Ceph | -6.7872         | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 2.1366          | 0.029                  |
| BaSN               | Total skull vs. Half skull   | -40.0274        | 0.001                  |
|                    | Total skull vs. Digital Ceph | -35.5446        | 0.001                  |
|                    | Half skull vs. Digital Ceph  | 4.4828          | 0.068                  |

* The mean difference is significant at the 0.05 level

### Table 7: Inter-observer Reliability for Linear Measurements

| Modality   | Linear measurements | Co-Gn | Go-Me | S-N | ANS-Me | Ar-Go | S-Ar | N-Me | N-ANS | S-Go | Overall |
|------------|---------------------|-------|-------|-----|--------|-------|------|------|-------|------|---------|
| CBCT Half Skull |                     | 0.79  | 0.70  | 0.83 | 0.71   | 0.80  | 0.77 | 0.80 | 0.85  | 0.88 | 0.79    |
| CBCT Total Skull |                   | 0.76  | 0.76  | 0.89 | 0.74   | 0.81  | 0.80 | 0.79 | 0.73  | 0.86 | 0.79    |
| Digital Ceph   |                     | 0.76  | 0.86  | 0.85 | 0.76   | 0.83  | 0.83 | 0.77 | 0.74  | 0.77 | 0.80    |

ICC values of 1.0 are reliable at the baseline

### Table 8: Inter-observer Reliability for Angular Measurements

| Modality   | Angular measurements | SNA  | SNB  | ABN  | U1NA | U1SN  | NAPog | SAr | SArGo | ArGoMe | ArGoN | MeGoN | BaSN | FMA | IMPA | Overall |
|------------|----------------------|------|------|------|------|-------|-------|-----|-------|--------|-------|-------|------|-----|-----|---------|
| CBCT Half Skull |                     | 0.71 | 0.79 | 0.75 | 0.77 | 0.87  | 0.84  | 0.86 | 0.88  | 0.72   | 0.87  | 0.73  | 0.82 | 0.80 | 0.73 | 0.80    |
| CBCT Total Skull |                   | 0.75 | 0.74 | 0.85 | 0.85 | 0.74  | 0.70  | 0.72 | 0.76  | 0.78   | 0.84  | 0.74  | 0.70 | 0.78 | 0.83 | 0.73    |
| Digital Ceph   |                     | 0.75 | 0.84 | 0.75 | 0.81 | 0.88  | 0.82  | 0.72 | 0.88  | 0.87   | 0.84  | 0.70  | 0.84 | 0.86 | 0.69 | 0.80    |

ICC values of 1.0 are reliable at the baseline
Final comparisons indicated that the interobserver reliability was found to be substantially high for all the modalities. There was a high reliability between the CBCT half-skull and the digital cephalogram modalities. It was found that the measurements involving the mid-sagittal plane were more accurate in CBCT when compared to the digital cephalograms. This correlates with the study by Gribel et al.,[13] who found that the mid-sagittal measurements had a greater variation in the digital cephalograms, and they attributed this to the magnification. This is an important finding because it has always been difficult to locate mid-sagittal landmarks.[14] The mid-sagittal plane is significant for orthodontic treatment planning because it gives the extent of the dental asymmetry. A study by Ruellas et al.[14] stated that CBCT is a valid tool for evaluating the dental asymmetry in relation to the skeletal midline. In their study, all the dental-related landmarks were found to be reproducible.

CONCLUSION

Therefore, based on the results obtained, we found that the 2D images generated by CBCT, like the half-skull, were competent in performing cephalometric analysis, but further studies are required to determine the efficacy of CBCT total skull for the same. It was also established that digital cephalometry still remains to be a mainstay in orthodontics and cannot be completely replaced by 3D cephalometry. Further studies are also required to obtain an imaging modality that can act as a gold standard for cephalometric measurements, but for now, 2D digital lateral cephalometry is here to stay as the gold standard for cephalometric measurements. However, CBCT is a more than competent modality for performing cephalometric measurements, especially the CBCT half-skull images.

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There are no conflicts of interest.

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