Comparison Efficiency of Posteroanterior Cephalometry and Cone-beam Computed Tomography in Detecting Craniofacial Asymmetry: A Systematic Review

Abstract

Objectives: The aim of this systematic review is to compare cone-beam computed tomography (CBCT) and two-dimensional radiography in the assessment of facial asymmetry.

Methods: Three valid electronic databases (PubMed, Scopus, and Web of Science) were searched for articles published from 1973 to February 2017. Hand searching was done through references of selected articles, internal thesis, and national and international conferences. The titles and abstracts obtained from the search were evaluated by reviewers according to the inclusion and exclusion criteria. Results: The established search strategy identified 2137 articles. A total of 2079 articles were from electronic search in three international databases and 58 articles from hand searching. After eliminating duplicate articles and on the basis of inclusion and exclusion criteria, 13 articles and 1 thesis entered the final analysis. Bayesian meta-analysis was done due to the heterogeneity of articles and the differences related to the methodology of the studies. According to this method, analyzing J-J landmark in two studies showed that there were no statistical differences between posteroanterior (PA) radiography and three-dimensional method with reference standard. Conclusion: The results of the study showed that there was no preference between the two techniques in measuring and diagnosing the landmarks and evaluating asymmetry. It can be concluded that in patients having problems other than asymmetry and need more information for the treatment plan, CBCT is more helpful than PA cephalometry.

Keywords: Cephalometry, cone-beam computed tomography, facial asymmetry, reproducibility of results

Introduction

Facial skeleton is made up of several bones, which can show variations in size and shape between the right and left sides.[1] Asymmetry seems to be an intrinsic characteristic of the human face and in many cases is so slight that it cannot be detected by gross observation. In some instances,[1-3] asymmetry of the craniofacial complex can cause functional and esthetic difficulties and require diagnosis and treatment decisions.[2]

The posteroanterior (PA) cephalogram is a two-dimensional (2D) projection of a three-dimensional (3D) object[4,5] that is associated with limitations and errors in landmark identification[6,7] due to superimposition[8] and distortion.[5,9] Other limitations associated with the use of cephalometric radiographs are standardization,[10,11] reproducing head position,[5,10,11] and maintaining film-object distance.[5]

Cone-beam computed tomography (CBCT) is specifically developed for imaging dentofacial structures.[5,12,13] The advantages of CBCT in comparison with conventional CT include significantly less radiation dose,[5,14] lower cost,[5,15] and a smaller size machine.[5,12,15] However, compared to conventional radiography, CBCT delivers substantially higher radiation doses and is generally more costly to the patients.[16,17]

Although the diagnostic accuracy and clinical efficacy of CBCT in the maxillofacial region is well documented, there is lack of evidence to support the application of this imaging modality as standard of care to replace conventional radiography in routine dental practice.[5,18,19] Numerous studies compare CBCT and PA cephalometry from various aspects.
such as accuracy of measurements[20] and reliability[21] and reproducibility of identifying craniofacial landmarks and the probable preference of 3D cephalometry over 2D analyses.[16,20-22]

Currently, there is no systematic review of literature to determine which of the two modalities is preferable in terms of landmark identification accuracy and the diagnosis of facial asymmetry.

Thus, the aim of this study is to investigate in a systematic review whether CBCT in comparison to the 2D radiography is more reliable or not in landmark identification.

Methods

The study protocol was approved by the Research Council of Hamadan University of Medical Sciences (Res. Number 16/35/1/4392), Hamadan, Iran.

In this systematic review, the following inclusion criteria were applied according to the Population, Intervention, Comparison, and Outcome framework to improve search strategy.

Population

1. Studies on dry skulls
2. Studies on patients.

Intervention

Using CBCT, 3D volumetric reconstruction or CBCT PA reconstruction.

Comparison

CBCT 3D volumetric reconstruction or CBCT PA reconstruction in comparison with PA cephalometric technique.

Outcome

Landmark identification; linear and angular measurement accuracy and also assessing head rotation effects.

A comprehensive search through these three electronic databases was conducted until February 2017:
- Web of Science of Knowledge (ISI): 1993–2017
- PubMed: 1950–2017
- Scopus: 1973–2017.

There was no limitation in year and language of article publication.

Search strategy was according to the following Mesh type keywords:

(craniofacial landmarks OR cephalometric OR cephalometr*) AND (cone beam computed tomography OR cone beam CT OR cone-beam CT OR CBCT OR 3D volumetric computed tomography OR volume computed tomography OR 3D OR 3-D OR three dimensions OR three-dimensional OR three-dimension) AND (reproducibility OR evaluation OR repeatability OR reliability* OR validity* OR accuracy*).

The retrieved studies were imported into EndNote X5 (Thomson Reuters, Philadelphia, USA) and duplicate articles were eliminated. Two reviewers screened the titles independently and reviewed the abstracts for the studies that were deemed relevant. In case of discrepancy, a third reviewer was consulted.

Full texts of studies that were deemed potentially eligible for inclusion by both reviewers were retrieved.

The reference lists of studies that were seemed potentially eligible were checked to identify additional relevant trials. All available conference proceedings through ISI Web of Science, Scopus, and electronic abstracting services such as IADR.com were searched for relevant studies. In addition, electronic search of published dissertations in Iran (www.thesis.research.ac.ir) and national conference proceedings (www.civilica.com) was performed and researchers in the field were contacted to identify unpublished studies. No language restriction was applied for the research.

By setting alert option in the three databases (ISI Web of Science of Knowledge, PubMed, Scopus), the review authors were made aware of any new indexed articles to consider for inclusion throughout the study.

Final articles were imported to the RevMan 5.3 software (Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark), as this software is for systematic review analysis.

The following items from the STARD guidelines for reporting diagnostic accuracy of studies were used to evaluate the quality of the included studies reporting:[23,24]

1. Description of the study population
2. Description of the eligibility criteria
3. Description of the statistical methods
4. Description of the reference standard and its rationale
5. Description of technical specifications of material and methods
6. Description of landmarks reporting systematic reviews
7. Evaluation of correlation for each landmark
8. Number of times landmarks were identified by each observer
9. Sample size calculation.

Two review authors evaluated each study for adequate, inadequate, and unclear reporting of the items independently and in duplicate. Studies with adequate reporting of all the items were categorized as “high quality.” Studies with one inadequate or unclear reporting item were categorized as “medium quality” and studies with more than one inadequate or unclear reporting item were categorized as “low quality.”

Due to high level of heterogeneity among the studies (high variation in the use of landmarks), the Bayesian meta-analysis method was used. For this purpose,
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R software version 3.3.2 and bmeta software package under R software (www.r-project.org) were used.[25,26]

Funnel plots were drawn for assessing publication bias.

In studies conducted on human dry skulls, the reported measurements were in comparison with standard reference measurements.

However, as the studies conducted on humans had no reference standard and the two modalities were compared together, they were only reported but did not go under analysis.

**Results**

The established search strategy identified 2137 articles. A total of 2079 articles were from electronic search in three international databases (ISI Web of science = 386, PubMed = 469, and Scopus = 1224).

There was one article in Korean language which was translated for evaluation.[27]

Screening of the search results was performed by two reviewers independently with an interexaminer agreement of 92% (kappa statistics).

Following removal of duplicate articles, 1598 records remained.

The second part of the search strategy was hand searching. Three articles were found from the references of included articles.[22,27,28] In the Scopus database, from document part of international conferences, 28 articles were obtained and also 25 articles were found from conference title of ISI database. Two dissertations were retrieved from www.thesis.research.ac.ir, one of which was deemed relevant.[29]

Our search of www.civilica.ir for internal conferences did not reveal any additional studies.

After reading the title and abstract and verification of the inclusion criteria, 1572 articles were deemed irrelevant and were excluded. Full-text copies for the remaining 29 articles and one thesis were obtained and reviewed. Of the 29 articles, 16 were excluded and the 13 conclusive selected articles[16,20‑22,27,28,30‑36] and one thesis[29] were included in qualitative synthesis [Figure 1].

The articles were classified as follows:

1. High-quality studies: Studies reporting all nine parameters were considered high-quality studies. Two studies were included in this category.[20,35]
2. Moderate-quality studies: Studies reporting eight out of nine parameters were considered moderate-quality studies. Four studies were included in this category.[16,20,30,34]
3. Low-quality studies: Studies reporting seven or less parameters were considered low-quality studies. Eight studies were included in this category.[21,22,27,28,31‑33,36]

Studies’ quality assessment is shown in Figure 2. Summary of the information in the included articles is shown in Table 1. Five articles were on patient,[21,27,32‑34] eight on symmetric dry skull,[20,22,28,31,35,36] and one article on asymmetric dry skull.[16]

Two articles focused specifically on head rotation.[29,31]

Both studies demonstrated that pulmonary artery catheter (PAC) measurements were more affected by head rotation and the measurements obtained from CBCT after head rotation were reliable, whereas PAC measurements in the mandibular region were more sensitive. Measurements based on 3D CBCT surface images were accurate and small variations in the patient’s head position did not influence measurement accuracy. However, PAC was sensitive to these rotations.[29,31]

Shokri used CBCT-reconstructed PAC,[29] while Hassan et al. obtained the measurements on CBCT 3D volume rendering.[31]

The interventions applied on the image modalities and the system characteristics are illustrated in Table 1. According to this, from 14 present articles, six studies used CBCT-reconstructed PAC[27,29,32,34‑36] and eight studies used 3D CBCT.[16,20‑22,28,31,33] Three studies used metal markers for determining the landmarks.[16,20,28] Three studies on human dry skulls had soft-tissue reconstruction.[20,22,31]

Searching for the same landmarks and their manner of measurement between selected articles is shown in Table 2.

As the studies by Tai et al. and Nur et al. were on patients and did not have reference standard and could not be
compared with human skull studies, they were not included in the analysis.[](^21,^23,^28)

Shokri and Hassan et al. evaluated head orientation; however, due to variations in rotation degrees and differences in reporting the results (one reported mean and the other mean difference) in the two studies, we were unable to perform a quantitative analysis on the results.[](^29,^31)

In Demoraes and Shokri studies, the landmarks were measured from the midline which differed from all the other included studies. Furthermore, no common landmark was identified between the two studies; therefore, they were eliminated from the quantitative analysis.[^20,^29]

Co-Co and Go-Go landmarks were common in three studies,[^16,^22,^28] but as these studies did not use the same statistical index for reporting their results and they could not be changed to each other, they were omitted from quantitative analysis. Thus, only the J-J landmark that was reported in Sfogliano and Cheung studies underwent meta-analysis.[^30,^35]

As the studies were few and there was only one common landmark (J-J), for controlling this variation and its effect on final analysis and for achieving more precise information from assessing the landmark distance on two imaging modalities compared to reference standard, the Bayesian meta-analysis was used.

Meta-analysis was performed for comparing 2D and reference standard, 3D and reference standard, and 2D and 3D separately.

The Bayesian algorithm was converged with \( \hat{R} = 1 \). In this meta-analysis, the mean of posterior distribution of Bayesian procedure was 1.467 (−7.515, 11.075) for comparing 2D and reference standard and 0.341 (−8.58, 10.09) for CBCT and reference standard.

The results of meta-analysis failed to show a significant difference between the measurements obtained from the two modalities for the J-J landmark. This is further demonstrated in the forest plots [Figure 3a and b].

The funnel plots failed to show any publication bias in the two studies and the studies were selected randomly [Figure 3c and d].

For comparing CBCT and PAC, the Bayesian algorithm was converged with \( \hat{R} = 1 \). In this meta-analysis, the mean of posterior distribution of Bayesian procedure was 0.651 (−8.04, 8.92) for comparing 2D and 3D.

As it is shown, the difference was not meaningful for two modalities [Figure 3e] and no publication bias was existing [Figure 3f].

### Discussion

The aim of this systematic review was to compare PA cephalometry and CBCT images in evaluating craniofacial asymmetry.

The included studies were divided into studies that involved human dry skulls and clinical studies. The dry skull studies also included symmetric and asymmetric skulls. Furthermore, CBCT images were CBCT-derived PA cephalometry reconstruction or 3D volume-rendered CBCT.

In dry skull studies, the effect of soft-tissue attenuation on images was omitted. This allowed for greater contrast and easier landmark identification.

In addition, the skull was fixed in the machine which eliminates patient motion artifacts during image acquisition and provides the radiologist with control over the adjustment of head orientation.

In the clinical studies, there were no standard references and no direct physical measurements, so the two imaging modalities were compared to each other. However, in dry skull studies, the physical measurements on the skulls were considered as standard references.

One study was performed on asymmetric skulls.[^16] In this study, Damstra et al. concluded that CBCT imaging provides more accurate information on the antegonial distance compared to conventional PA cephalograms. By nature, when mandibular asymmetry is present, point menton (Me) is most likely to deviate from the facial midline. Therefore, in such cases, the structures will not be located at relatively the equal distances, making left and right side comparisons unreliable, while one of the main indications of ordering PA cephalogram is in asymmetric patients.[^16]

In Sfogliano’s study which was classified as a high-quality study, no significant difference was observed between the linear measurements obtained from CBCT-constructed PA radiographs, conventional 2D PA radiographs, and direct measurements, and CBCT only provided a more comprehensive and detailed understanding of craniofacial anatomy.[^35]

In this study, the only superiority of CBCT in relation to PAC was additional anatomical information of craniofacial
| 1st author, year | Country | Population | Sample size | Landmarks | Statistics | Using metal marker | Soft-tissue construction | CBCT image type | Device and setting | Results |
|-----------------|---------|------------|-------------|-----------|------------|-------------------|------------------------|-----------------|-------------------|---------|
| Sfogliano et al., 2016[35] | USA | Symmetric skull | 23 dry skulls | 17 landmarks | Pearson/mean difference | - | - | Constructed Orthopantomograph ®OP300, instrumentarium, finland. (tube voltage 73 kVp, tube current 3.2 mA, scan time 8.0 s; i-CAT (Imaging Sciences International, Hatfield, PA), A resolution of 0.3 voxel, 8.9 s, mAs of 18.54, kVp of 120. FOV=12. Intrareliability test: ICC ≥0.90 (good intraobserver reliability). Interreliability test: ICC ≥0.80 (good interobserver reliability) the use of 2D conventional PA radiography is comparable to 3D CBCT measurements and to the direct measurements and clinically reliable to be used for developing frontal cephalometric assessment such as in ricketts frontal analysis. |
| Shokri et al., 2015[29] | Iran | Symmetric skull | 10 dry skulls | 6 landmarks | Paired t-test/ICC | - | - | Constructed Scana II Planmeca (Helsinki, Finland). KVP68, mA10, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). KVP110, mA8/2, s3/15; NewTom 3G volume scanner (QR srl, Verona, Italy). |

Thesis: CBCT reconstructed PA cephalogram is more reliable than conventional PA cephalogram. There are more differences in landmarks that have more distance from the midline compared to landmarks that have less distance. Measurements of CBCT reconstructed PA cephalometric images are more influenced by head rotation than conventional PA cephalometry. In comparison of interobserver reliability in two techniques, CBCT reconstructed PA cephalometry and conventional PA cephalometry there were not statistically significant difference between them. The highest agreement in conventional PA cephalogram was 99% (Ag) and the lowest agreement 71% (Zyg arch). In CBCT reconstructed PA cephalogram the highest and the lowest agreement was: 99% (J) and 72% (zygomaticofrontal suture) respectively.
| 1st author, year | Country | Study type | Sample size | Landmarks | Statistics | Metal marker | Soft-tissue construction | CBCT Setting | Results |
|------------------|---------|------------|-------------|-----------|------------|--------------|--------------------------|---------------|---------|
| Cheung et al., 2013 | Australia | Symmetric skull | 28 dry skulls | 2 landmarks | Bland–Altman/ICC | - | - | Sirona Galileos Cone Beam Imaging System at 85 kVp, 42 mAs (7 mA, 6000 ms) and a 15° FOV; 80 kV, 10 mA, and 0.2 s (Quick Ceph Systems Inc, San Diego, CA, USA) | ICC for CBCT: 0.861–0.964 (high agreement) ICC for PAC: 0.794–0.796 (low agreement) CBCT landmark identification demonstrated better correlation with BS than PAC results and was accompanied by smaller mean differences and overestimation. CBCT imaging was more reliable than PAC in assessing an intermaxillary transverse discrepancy using J/J/Ag-Ag ratios, as fewer skulls were incorrectly diagnosed |
| de Moraes et al., 2011 | Brazil | Symmetric skull | 10 dry skulls | 17 landmarks | κ | + | | Eureka X-ray tube (Duocon Machlett, GEC Medical, Machlett Laboratories, Chicago, Ill. 80 kV, 10 mA, 0.04 s CB Mercu-Ray (Hitachi Medical, Tokyo, Japan), 0.4 mm, 3 voxels, 8 bits per voxel. 100 kV, 15 mA, and 14 s | Kappa for 2D = 0.0609 (poor agreement) Kappa for CBCT = 5.02 (perfect agreement) There was poor agreement between the digital 2D and the physical measurements, but the CBCT showed almost perfect agreement with the physical measurements. CBCT has the potential to better evaluate craniofacial morphology when compared with digital 2D images |
| Adams et al., 2004 | USA | Symmetric skull | 9 dry skulls | 13 landmarks, 76 measurements | ICC/ANOVA/ Bland–Altman | + | - | 2D great variability from the gold standard Mean ICC for 2D: 0.983 and high accuracy Mean ICC for 3D: 0.998 and high precision |

Table 1: Contd...
| 1st author, year | Country | Study type | Sample size | Landmarks | Statistics | Metal marker | Soft-tissue construction | CBCT Setting | Results |
|------------------|---------|------------|-------------|-----------|------------|--------------|-------------------------|--------------|---------|
| Hilgers et al., 2005[^22] | USA | Symmetric skull | 25 dry skulls | 11 landmark-10 linear measurement | ANOVA/mean Difference | - | + | Quint Sectograph (Model QS 10-1627 W; Denar, Anaheim, Calif) 78 kVp, 200 mA, 2/15 s. resolution 1280×1024,32 bit 1–3 mA and 120 kVcp, 0.5-mm spot size | Cephalometric evaluation of radiographic images taken in the conventional 2D system often renders both inaccurate and imprecise measurements. In contrast, the relatively new 3D cephalometric system (Sculptor) provides a much more precise evaluation of linear measures and only slightly inaccurate measures that are underestimated by about 1.0 mm |
| Van Vlijmen et al., 2009[^36] | Netherlands | Symmetric skull | 40 dry skulls | 10 landmarks | Pearson/mean difference | - | - | Constructed Adult: 70 kV, 10 mA, 0.6 s. Children: 70 kV, 10 mA, 0.5 s ICAT CBCT (Imaging Sciences International, Inc. Hatfield, PA, USA) 129 kVp, 47.74 mA, 40 s, 0.4 voxel ICC between the first and second measurements ranged between 0.23 and 0.99 with an average of 0.76 for the conventional frontal radiographs and between 0.57 and 1.00 with an average of 0.85 for the constructed frontal radiographs There is a clinically relevant difference between angular measurements performed on conventional frontal cephalometric radiographs, compared with measurements on frontal cephalometric radiographs constructed from CBCT scans, owing to different positioning of patients |

[^22]: Yousefi et al. CBCT and PA cephalometry for detecting facial asymmetry.
[^36]: Yousefi et al. CBCT and PA cephalometry for detecting facial asymmetry.
Table 1: Contd...

| First author, year | Country        | Study type | Sample size | Landmarks | Statistics | Metal marker | Soft-tissue construction | CBCT Setting | Results |
|--------------------|----------------|------------|-------------|-----------|------------|--------------|--------------------------|--------------|---------|
| Hassan et al., 2009 | Netherlands    | Symmetric skull | 8 dry skulls | 10 linear distances | Mean difference | - | + | NewTom 3G CBCT system (Quantitative Radiology, Verona, Italy). 3.24 mAs, 110 kvp, 20 s, 9° detector, 0.25 voxel | in both devices. Positioning of the patient in the CBCT device seems to be an important factor in cases where a 2D projection of the 3D scan is made. The largest observed difference between the mean 3D models and gold standard measurements was<0.5 mm (MD=0.39 mm, SD=0.29), for 2D tomographic slices, the largest observed difference with the gold standard measurements was<1.0 mm. Small variations in patient head position in a CBCT examination do not affect the accuracy of linear measurements based on 3D models. Linear measurements based on 2D PA projections were sensitive to small variations in head position. ICC for CBCT>0.957 (reliable and very accurate) PAC for=0.686 (least reliable and not accurate). CBCT imaging provides more accurate information regarding the characteristics of mandibular asymmetry than conventional PA cephalograms. Therefore, a CBCT scan should be considered when a visible chin deviation is present which requires surgical correction. |
| Damstra et al., 2013 | The Netherlands | Asymmetric skull | 6 asymmetric dry skulls | 10 landmarks, 14 linear distances | ICC ANOVA/mean difference | + | - | PA: ProMax, DiMax 2 Digital Cephalometric Unit, Planmeca, Helsinki, Finland) resolution quality of 2272 × 2045 pixels at a 24 bit depth CBCT: KaVo 3-D eXam scanner (KaVo Dental GmbH, Biberach/ Riß, Germany) 0.30 voxel size resolution (120 KV, 37.07 mAs and 26.9 s) | CBCT imaging provides more accurate information regarding the characteristics of mandibular asymmetry than conventional PA cephalograms. Therefore, a CBCT scan should be considered when a visible chin deviation is present which requires surgical correction. |
| First author, Country, Year | Sample size | Study type | Landmarks | Statistics | Metal marker | Soft-tissue construction | CBCT Setting | Results |
|----------------------------|-------------|------------|-----------|------------|--------------|-------------------------|--------------|---------|
| Nur et al., Turkey, 2012[34] | 30 adult patients | Human study | 4 angular-14 linear-3 ratio | Pearson/mean Difference | Constructed PA: 80 kV, 10 mA, 0.2 s. cephalostat (Venviewpocs, Morita)-CBCT: (FOV) 5 18.4 x 20.6 cm, voxel size = 0.3 mm, scan time = 10.8 s, 90 kV, 10 mA | Reproducibility of measurements ranged from 0.85 to 0.99 for CBCT-constructed FRs, and from 0.78 to 0.96 for conventional FRs A difference has been noted between measurements performed on conventional FRs and those performed on CBCT-constructed FRs, particularly in terms of linear measurements. No statistically significant difference has been observed between angular and ratio measurements |
| Kim et al., Korea, 2012[32] | 30 adult patients | Human study | 9 linear measurement - 9 angular measurement | Mean difference | Constructed PA: Planmeca PM 2002 CC Proline; Planmeca, Helsinki, Finland). 60e80 kVp-11 mA. 2.3 s. fixed focus of 152.4 cm | CBCT frontal cephalograms, generated by means of the Raycast method (Group CTRaycast), were more comparable to the conventional PA cephalograms in their measurements than were the others Groups (CTMIP, CT generator). Frontal cephalograms derived by 3D CBCT reorientation can be effectively employed in clinical applications |
| Lee et al., Korea, 2014[33] | 20 men and 20 women | Human study | ICC/mean difference | | PA: Cephalometric x-ray equipment (OrthoCeph OC100, Instrumentarium Imaging Co, Tuusula, Finland) CBCT: CB MercuRay (Hitachi Medical Co, Tokyo, Japan). 120 kV, 15 mA, voxel size 0.3 mm, FOV 150 mm | Mean ICC of 0.874 (excellent reliability) Statistically significant differences in maxillary and mandibular bone widths were detected at different levels and sites on CBCT images. There was a statistically significant correlation of the maxillomandibular width at the first molar area between CBCT images and PA cephalograms |
| 1st author, year | Country | Study type | Sample size | Landmarks | Statistics | Metal marker | Soft-tissue construction | CBCT Setting | Results |
|------------------|---------|------------|-------------|-----------|------------|--------------|--------------------------|--------------|---------|
| Tai et al., 2014  | Australia | Human study | 31 patients | 15 distances | Bland–Altman/ICC | - | - | CBCT: 15" FOV, 85 kVp, 7 mA | ICC for each of the measurements was above 90% (good reliability) |
| Sun et al., 2009  | Korea   | Human study | 30 patients | 6 angular, 5 width, 7 height | Correlation/mean Difference | - | - | Constructed (OrthoCeph OC100, Instrumentarium Shooting conditions of the Imaging Co., Tuusula, Finland) 12 mA, 80 kVp, distance 150 (Alphard Vega, Asahi A shooting condition of Roentgen Co., Kyoto, Japan) 80 kV, 5 mA, voxel 0.39 m × 0.39 m × 0.39 m | Higher correlations in all measurements than the virtual cephalograms without the use of HPA |

FOV: Field of view; CBCT: Cone-beam computed tomography; PA: Posteroanterior; 3D: Three dimensional; 2D: Two dimensional; MD: Mean deviation; SD: Standard deviation; CT: Computed tomography; CT MIP: CT Maximum Intensity Projection; HPA: Head position appliance; ICC: Intra class correlation; i-cat: CBCT machine; BS: Base standard; TMJ: Temporo mandibular joint; FRs: Frontal radiographs
region. However, the necessity of having these informations and their application in treatment planning is unclear.[35]

In Cheung’s study, significant difference was noted in the measurements of J-J and Ag-Ag in PAC and J-J in CBCT.[30] Points located at an intersection are easier to identify compared to points located on broad curves. Jugale was defined by an intersection, whereas antegonion was located on a curve. This definition is inappropriate in 3D imaging, as the intersection between the tuberosity only exists in two dimensions. The exception is the antegonion location on dry skulls as the landmark was identifiable by palpation and hence demonstrated a much lower intraobserver error than other measurements.[30]

It has been further shown that measurements from single landmarks are inaccurate representations of mandibular or maxillary dental or skeletal width, and the superiority of CBCT to assessment of surfaces, areas, and volumes of maxilla and mandible needs more studies.

However, CBCT is superior to PAC because CBCT achieved greater intercorrelation coefficient and smaller mean differences when compared with standard values. In addition, the presence of metallic hardware in the dry skulls examined in this study caused artifacts which affected the measurement accuracy in the scans.

de moraes et al. used bilateral landmarks for diagnosis of facial asymmetry.[20]
One of the limitations of this study was the use of radiopaque markers to identify landmarks which were associated with higher interobserver reliability and reproducibility of landmark compared to no use of metal marker.\textsuperscript{20}\text\footnote{de moraes et al. believed that even by using a large number of reference points, if asymmetries do not affect the selected reference points, they could not be detected, so they did not use asymmetric skulls in their study. There was a poor agreement between the digital 2D and the physical measurements, but the CBCT showed almost perfect agreement with the physical measurements. It is necessary to consider that cephalometric radiographs have many limitations, such as distortion and magnification, and there are chances of errors in recording measurements. According to this study, 3D images provide more precise information and more details for diagnosis and treatment planning of facial asymmetries.\textsuperscript{20}}

Hilgers et al. found a high level of accuracy in measurements obtained from CBCT scans compared to direct anatomic measurements, whereas measurements obtained from conventional cephalograms were significantly greater than the actual anatomical measurements.\textsuperscript{22} Although the higher measurements in conventional radiographs could have resulted from operator error, the author believed that this is unlikely because each measurement was repeated three times. CBCT images in 2D plane have inherently higher contrast. This gives the observer a specific 2D plane and a structure without anatomical noise due to superimposition on which it is easier to identify landmarks.\textsuperscript{22}

As previously mentioned, the limitation of using dry skull is lack of soft-tissue attenuation. In three studies, soft tissue was reconstructed on skulls.\textsuperscript{20,22,31} According to Hassan et al’s study, the difference between measurements obtained from CBCT volumetric reconstructions and the gold standard was relatively small.\textsuperscript{31} This may be due to the fact that hard tissues are rigid in nature, thus scan position does not influence the location of anatomical landmarks relative to each other.\textsuperscript{31} It is thought that soft tissues are not necessarily rigid and when the patient is positioned incorrectly in the scanner, the outcome of the measurements may be influenced.\textsuperscript{31} Furthermore, Nur et al. in their clinical study believed that dry skulls do not suffer from distortion caused by soft tissues, thus the chance of error in landmark identification is reduced.\textsuperscript{14} Two studies evaluated the effect of head rotation on measurement accuracy of reference landmarks.\textsuperscript{29,31} Shokri et al. concluded that CBCT-reconstructed PA cephalogram is more reliable compared to conventional PA cephalogram and greater difference was observed in landmarks farther from the midline.\textsuperscript{29} CBCT-reconstructed PA cephalograms are more sensitive to rotation than conventional PA cephalograms.\textsuperscript{29} No significant difference was statistically shown in tilt and tip positions, whereas 10° and 20° rotations had statistically significant difference in relation to central position.\textsuperscript{29} Hassan et al. concluded that the difference between CBCT measurements and the gold standard was small and in rotation position, conventional PA cephalograms are less accurate than CBCT-reconstructed PA cephalograms.\textsuperscript{31} Small variations in patient head position when a CBCT examination is performed do not affect the accuracy of linear measurements.

Due to the small sample size (Shokri et al. [10 skulls] and Hassan et al. [8 skulls]) and variations in head orientation, the results of these studies are deemed inconclusive. While the goal of a technologist or technician is to achieve optimal stability of head position during scan acquisition, minor variations and minimal involuntary movements are believed to have minimal effect on the accuracy of the scan.

To reduce landmark identification errors, three studies involved the use of metal markers on dry skulls; however, in human studies and dry skull studies without metal markers, both landmark identification and linear measurement accuracy can be discussed.

The efficacy of 3D volumetric rendering in comparison with CBCT-reconstructed PA cephalogram in landmark identification is unclear and needs further investigation. Of the nine studies performed on human dry skulls, three studies used CBCT-reconstructed PA cephalogram and six used 3D volumetric rendering.

Cheung et al. believed that measurements obtained on reconstructed cephalograms have comparable accuracy to conventional films. However, reconstructed radiographs are associated with the same limitations as conventional PACs, i.e., variations in head position and superimposition. Thus, it is suggested that the effect of CBCT image reconstruction on landmark identification and linear, angular, and volumetric measurements be assessed in future studies.

Figure 4 shows risk of bias in included studies according to STARD checklist. Study population, materials and methods, correlation for each landmark, and number of
times landmarks were identified by each observer were the items mentioned in all studies.

The item that was not reported in the majority of studies was sample size calculation.

Most of the studies focused on landmark identification, linear and angular measurements. Although asymmetry is the principle indication of PAC, it was less discussed in the studies.

No study was conducted on maxillary and chin deviation. As only one study was conducted on asymmetric dry skull,[10] it was difficult to draw a definitive conclusion due to small sample size.

According to Bayesian meta-analysis, the mean difference in measurement accuracy between PAC and standard reference and CBCT and standard reference was almost one unit; however, no significant difference was noted between the two techniques and the standard reference. This finding suggested that within the limitations of this study, due to small number of included studies because of the variation in landmarks identified in the studies and lack of a definite analysis for measurements, for J-J landmark, CBCT does not have superior performance compared to PAC.

As this study aimed to determine the preference of two modalities in terms of landmark identification accuracy and the diagnosis of facial asymmetry, the results could be useful to academics designing future studies to help develop some sort of standard approach to landmark inclusion.

**Conclusion**

The results of this systematic review revealed that there is no preference between the two techniques in measuring and diagnosing landmarks and evaluating asymmetry. However, it can be concluded that cases with multiple complications such as presence of supernumerary tooth, the relation of impacted tooth to the inferior alveolar nerve canal, or airway analysis for which further information may be required for treatment planning, CBCT may be indicated.

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**Conflicts of interest**

There are no conflicts of interest.

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