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Comparison of Steiner Cephalometric analysis of lateral skull X-ray images with CBCT in a group of students of the dental school of the University of Cuenca

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Abstract

The Steiner analysis from images obtained from cone beam computed tomography is one of the essential tools today for diagnosis in the area of orthodontics, within this aspect its high value for the study of points, angles and cephalometric planes allows the prediction of the possible treatment plan for each patient according to the specific characteristics resulting in each patient.

Objective: To compare the results in Steiner cephalometric measurements obtained in 2D lateral skull radiographs and in 3D cephalograms generated from Cone Beam Computed Tomography (CBCT).

Methodology: Type of comparative analytical study. A non-probabilistic sample was established by convenience consisting of 29 diagnostic studies divided into: 29 lateral skull X-rays and 29 standardized CBCT. Subsequent localization, tracing and measurement of skeletal and dental angles were performed according to Steiner's cephalometric analysis using Nemostudio 2022 software. The study and analysis was performed using the Intraclass Correlation Coefficient.

Results: The mean difference between the skeletal angles SNA, SNB, ANB, SND and Occlusal Plane Angle showed that there is no significant discrepancy when performing a cephalometric analysis in three-dimensional images compared to two-dimensional images.

Conclusion: There is a high degree of reliability and accuracy of cephalometric measurements for obtaining skeletal and dental angles in two-dimensional images obtained from a CBCT with respect to a lateral radiograph.

Keywords: Cephalometry; Digital analysis; CBCT; Orthodontics; Steiner analysis

1. Introduction

Since Angle, in 1899, introduced the classification of malocclusions and the concept of "normal occlusion", the need arose to look for diagnostic tools to facilitate the craniofacial analysis of patients, with the aim of achieving standards considered normal through orthodontic treatment. (1) With the advent of X-rays in 1895, radiography has obtained a significant and indispensable value in diagnosis and clinical practice, allowing the identification and observation of structures impossible to visualize with the naked eye. (2) In this field, in 1931 cephalometry began to be used as a diagnostic method that allows a complete analysis of the facial and bony structures of patients, enabling the evaluation of craniofacial growth and development. (1)(3) At the same time, the professionals of the time sought to meet to

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standardize cephalometric points in order to minimize errors during treatment and the cephalometric analyses proposed by several authors arose (1).

1.1. Steiner cephalometric analysis

Dr. Cecil Steiner's (1953) analysis is useful to determine bone and dental discrepancies through linear and angular measurements obtained from cephalometric points and planes (Table 1). Through the Steiner analysis, it is possible to visualize the patient's profile, and the position of the upper and lower incisors, facilitating the prediction of the type of tooth movement required for each patient. Unlike Downs' analysis, Steiner uses the S (Silla)-N (Nasion) plane as a reference of the cranial base. (1)(4)

Table 1 Points and planes used as a reference for the Steiner analysis

Plan/point	Definition
N- Nasion	The most anterior aspect of the frontonasal suture.
S- Chair	Center of the pituitary fossa.
Point A	The deepest point on the premaxillary contour.
Point B	The deepest point on the contour of the jaw.
Pg- Pogonion	The most anterior point on the symphysis of the mandible.
Me- Chin	The lowest point on the symphysis of the jaw.
Go- Gonion	Point constructed by two tangents, one on the posteroinferior border of the mandible and the other on the posterior border of the ramus. The bisection of these two lines perpendicularly projected on the mandibular angle is the Go point.
Apex of upper incisor - UIA	The apex of the upper incisor root
Apex of lower incisor - LIA	The apex of the lower incisor root
Upper incisal - Is	Incisal tip of the most prominent maxillary incisor
Lower incisal - Ii	The incisal tip of the most prominent mandibular incisor
Molar point - MP	Mesial contact between the upper and lower first molars
Mandibular Plane- MP	Mandibular plane: a line connected from the Me point to the Go point.
Functional Occlusal Plane - BOP	Functional occlusal plane: a line connecting the vertical midpoint between Is and Ii of the incisors and the mesial contact point between the maxillary and mandibular first molars.

Traditionally, the analysis was performed with the manual method, which consists of placing an acetate sheet on the printed lateral radiograph and drawing the main structures of the skull and face, and determining reference points in order to obtain cephalometric lines and planes that will serve to obtain angular and linear data useful for the diagnosis. (3)

Nowadays, with the incorporation of digital radiography, it is possible to manipulate cephalometry with the help of tools included in specialized software, obtaining better visibility of the anatomical structures and greater precision in the tracing of points, planes, and angles required, resulting in greater speed and efficiency in treatment planning. (3)

On the other hand, Cone Beam Computed Tomography (CBCT) has represented a fundamental tool for diagnosis in Dentistry and its specialties, since it is configured to establish and generate high-quality three-dimensional images of the maxillofacial area of the patient with a radiation dose 15 times lower than that of medical tomography. The images generated can be subsequently manipulated, allowing the study of real- scale images, with linear and angular precision measurements, without overlapping or distortion. (2)

CBCT makes an important contribution to treatment planning through the generation of two-dimensional images from coronal, sagittal, and axial slices. (5)(2) Currently, it is feasible to obtain a two-dimensional lateral image of the skull from a lateral skull X-ray or CBCT, with the possibility of performing cephalometric analysis on these images, such as Steiner analysis. Likewise, the creation of programs such as Nemoceph has allowed the management and development of orthodontic treatments with greater ease. (3) In this context, new technologies in dentistry seek to reduce errors and simplify time consumption by means of an effective and highly reproducible evaluation of cephalometry obtained from a CBCT. (3)

Orthodontic treatment requires previous studies such as panoramic radiography and lateral skull radiography for clinical diagnosis. However, in some cases, the demand for additional studies is indispensable, causing exposure to higher doses of radiation for the patient. Thus, CBCT offers the benefit of obtaining 3D images, with the possibility of performing panoramic and lateral cephalic sections as well as 2D radiography, equaling or decreasing the radiation dose received by the patient, offering at the same time a more precise analysis. (3)

On the other hand, it has been shown that obtaining cephalometric data in CBCT can reproduce cephalometry with greater fidelity and precision compared to a conventional lateral skull radiograph. However, it should be noted that the evaluation of anatomical landmarks in CBCT is not standardized, which is a limitation. (3) Thus, based on the above-mentioned, the question arises: Can cephalometric images from CBCT replace conventional lateral skull radiography for the study and cephalometric analysis of Steiner in orthodontic diagnosis and treatment? The objective is to compare and establish the difference in the results of Steiner cephalometric measurements obtained in lateral skull radiographs and in 3D lateral cephalometric images generated from Cone Beam Computed Tomography (CBCT).

2. Material and methods

2.1. Type of study

Observational, investigative, and analytical.

2.2. Study population

The present research was carried out in students over 18 years of age who attended the radiology-imaging department of the dental school of the University of Cuenca in the period 2022-2023.

2.3. Selection and sample size

A non-probabilistic convenience sample was established consisting of 29 diagnostic studies divided into 29 lateral skull X-rays and 29 standardized CBCT in patients over 18 years of age, without active growth, male and female, who attended the Faculty of Dentistry of the University of Cuenca during the period 2022-2023. The 2D and 3D imaging studies were obtained in the radiology-imaging department of the faculty with the same cephalostat and tomograph.

2.4. Inclusion and exclusion criteria

2.4.1. Inclusion Criteria

- Lateral skull radiographs obtained with the cephalostat in the Department of Radiology-Imaging in a group of students over 18 years of age of the Faculty of Dentistry of the University of Cuenca studying in the period 2022-2023.
- Cone beam computed tomography scans in a group of students over 18 years of age from the Faculty of Dentistry of the University of Cuenca studying the period 2022-2023.
- Registration of patients who have both CBCT and lateral skull radiography available.

2.4.2. Exclusion Criteria

- CBCT images that did not allow visualization of the cranial base landmarks (S-Na).
- CBCT files that could not be imported or opened in the NEMOTEC software.
- DICOM files whose import process to the Nemotec software was not possible due to reading errors by the program at the time of opening the CBCT.

2.5. Data collection

In order to obtain a more precise location of the reference points for the Steiner analysis, 3 researchers were calibrated to perform this procedure.

The initial sample included 35 two-dimensional cephalic images and 35 CBCT images, from which 4 CBCT images in which the cranial base was not completely visualized and 2 DICOM files that could not be processed in the Nemoceph software were excluded, resulting in a final sample of 29 two-dimensional cephalic images and 29 CBCT images.

For the comparative analysis, CBCT and lateral skull radiographs were taken at the imaging-radiology department of the Faculty of Dentistry of the University of Cuenca were used. The equipment complied with the specifications and standardized calibrations prior to the acquisition. The measurements were performed under the same environmental conditions throughout the study. The database of the group of students who represented the study sample was accessed to collect the digital lateral cephalometric radiographs and the cone beam computed tomography virtual lateral cephalograms. For the lateral cephalometric radiographs, the patient's position in terms of the Frankfort plane was parallel to the floor, obtaining images that included a millimeter ruler for image calibration in the Nemoceph software. Cone beam CT scans were obtained by placing the patient in a natural head position and in maximum intercuspation.

The Nemoceph software was used to elaborate the Steiner cephalometric analysis, following the established protocol: for each study, a file was created for each patient; the conventional cephalometry was imported in JPG format recorded in the computer, with the disk capture>lateral radiography option. In addition, the DICOM file folder was imported and through the NemoFab software, the 3D sagittal slice CBCT image was obtained (Figure 1) and added to each patient.



Figure 1 Sagittal section obtained from CBCT in NemoFab software

Next, the 2D and 3D cephalometric images were calibrated using the millimeter ruler. Next, the Steiner analysis was selected and the cephalometric points requested by the program were located (Figure 2). Subsequently, the fine adjustment of points and curves was performed. Finally, the software automatically generated the skeletal and dental measurements according to the selected analysis, and the report was saved to disk in PDF format.



Figure 2 Finalized cephalometric tracing in two-dimensional lateral skull radiography, according to Steiner

There was a need to record the use of informed consent for this analysis, to which all the participants agreed. The data obtained from the software were recorded in Microsoft Excel 2010 for tabulation and analysis.

3. Results

Based on the study population selected according to the inclusion and exclusion criteria, the sample consisted of 29 lateral skull radiographs in digital format and 29 digital cephalometrics obtained from the CBCT, which were obtained from students over 18 years of age in their fourth year who attended the department of radiology-imaging of the dental faculty of the University of Cuenca in the period 2022-2023, of which 14 students were male and 14 students were female.

Two cephalometric measurements were obtained from each of the students, for this purpose, the images were acquired from both the lateral skull radiograph and the CBCT and each cephalometry was performed giving us a total of 60 cephalometric tracings from which a concordance test was performed between these measurements.

The angular elements chosen for the study consisted of the following:

- **SNA angle:** Formed by the Silla-Nasion and Nasion-Point A planes. It indicates the anteroposterior position of the maxilla with respect to the skull base in three different ways: 1) A normal position. 2) An anterior to normal position (prognathia). 3) A position posterior to normal (retrognathia). (4)
- **SNB angle:** Formed by the Silla-Nasion and Nasion-Point B planes. It indicates the anteroposterior location of the mandible with respect to the base of the skull. Angles greater than the norm indicate a forward mandible, while angles less than the norm indicate a retruded mandible. (4)
- **ANB Angle:** Formed by the Nasion-Point A and Nasion-Point B planes. It indicates the anteroposterior relationship between the maxilla and mandible. Increased angles indicate a class II relationship, while negative angles indicate a class III relationship. This angle indicates the maxillomandibular relationship but does not indicate whether the problem is due to the mandible or the maxilla. (4)
- **SND angle:** Formed by the Silla-Nasion and Nasion-Point D planes. It indicates the basal anteroposterior location of the mandible with respect to the base of the skull, complementing the interpretation of the SNB angle. (4)
- **Occlusal Plane Angle:** Indicates the inclination of the occlusal plane with respect to the skull base. It increases in patients with vertical growth patterns and decreases in patients with horizontal growth patterns. (4)
- **IS angle:** Indicates the angulation of the upper incisor. (4)
- **Angle II:** Indicates the angulation of the upper incisor. (4)

3.1. Concordance test

The intraclass correlation coefficient (ICC), used in the RLC and CBCT radiographic technique, was used to check the affinity between the first and second measurements.

3.1.1. Intraclass correlation coefficient (ICC) values

Table 2 Intraclass correlation coefficient values (ICC)

ITC value	Matching strength
>0.90	Very good
0.71-0.90	Good
0.51-0.70	Moderate
0.31-0.50	Mediocre
<0.30	Poor or none

3.1.2. CCI values between RLC and CBCT radiographic technique

Table 3 CCI values between RLC and CBCT radiographic technique. A high RLC value is observed for the SNA, SNB, ANB, SND, and A. OCLUSAL PLANE angles, while there was a low RLC value for the IS and II angles.

An average calculation was made between the two measurements to check the normality and comparison tests between the two measurements. The result obtained was: CCI= 0.891.

In the first measurement on digital lateral radiographs for SNA mean: 82.33 with a SD: 3.62, SNB mean: 79.00 with a SD:4.42, ANB mean: 3.79 with a SD:3.34, SND mean: 76.17 with a SD:3.97, SN occlusal plane angle mean: 18.86 with a SD:5.23, IS angle mean: 21.66 with a SD:7.79, II angle mean: 28.34 with a SD:8.74.

Table 3 CCI values between RLC and CBCT radiographic technique

First and second measurement	CCI	
SNA	0.923	Very good
SNB	0.876	Good
ANB	0.930	Very good
SND	0.789	Good
A. OCCLUSAL PLANE	0.912	Very good
ANGLE IS	0.478	Mediocre
ANGLE II	0.655	Moderate

Table 4 Average cephalometric measurements in lateral skull radiographs in students of the Faculty of Dentistry of the University of Cuenca

Variables	No. Values	Media	Medium	Standard deviation	Minimum	Maximum
ANGLES						
SNA		82.33	82.00	3.62	72.00	89.00
SNB		79	78.00	4.42	69.00	89.00
ANB		3.79	5.00	3.34	-5.00	9.00
SND		76.17	76.00	3.97	70.00	85.00
OCCLUSAL PLANE ANGLE		18.86	18.00	5.23	7.00	30.00
ANGLE IS		21.66	19.00	7.79	7.00	37.00
ANGLE II		28.34	29.00	8.74	10.00	49.00

Table 5 Average cephalometric measurements in lateral skull sections obtained from CBCT in students of the School of Dentistry of the University of Cuenca

Variables	No. Values	Media	Medium	Standard deviation	Minimum	Maximum
ANGLES						
SNA		82,52		5,75	63	97
SNB		78,93		6,28	62	89
ANB		3,48		4,08	-7	10
SND		76,21		5,56	60	86
OCCLUSAL PLANE ANGLE		18,72		7,28	3	31
ANGLE IS		17,10		14,03	-8	40
ANGLE II		25,59		6,81	10	36

In the second measurement on CBCT slices for SNA mean: 82.52 with a SD: 5.75, SNB mean: 78.93 with a SD:6.28, ANB mean: 3.48 with a SD:4.08, SND mean: 76.21 with a SD:5.56, SN occlusal plane angle mean: 18.72 with a SD:7.28, IS angle mean: 17.10 with a SD:14.03, angle II mean: 25.59 with a SD:6.81.

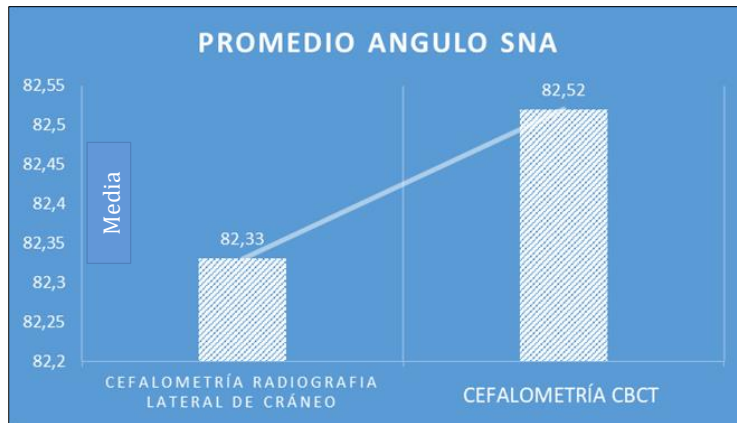


Figure 3 Average and difference of SNA angle

SNA angle: No relevant differences were obtained between CLR and CBCT, since it obtained a minimum difference of: 0.19°.

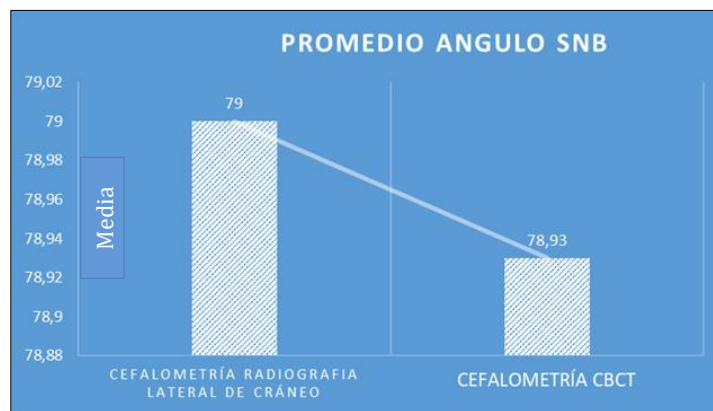


Figure 4 Average and difference of SNB angle

SNB angle: No relevant differences were obtained between the RLC and the CBCT since it obtained a minimum difference of: 0.07°.

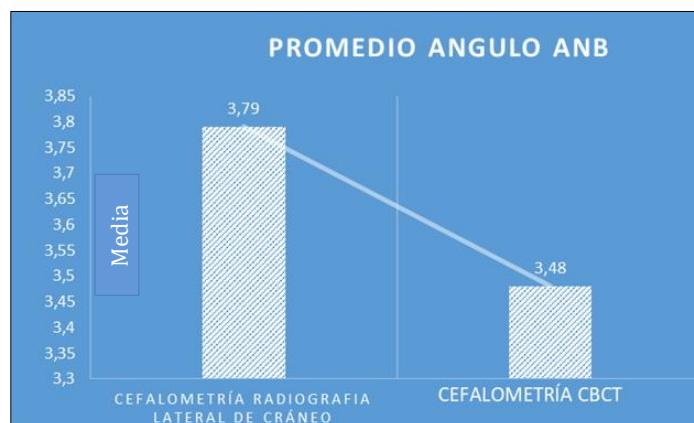


Figure 5 ANB angle average and difference

ANB angle: No relevant differences were obtained between the RLC and the CBCT since it obtained a minimum difference of: 0.31°.

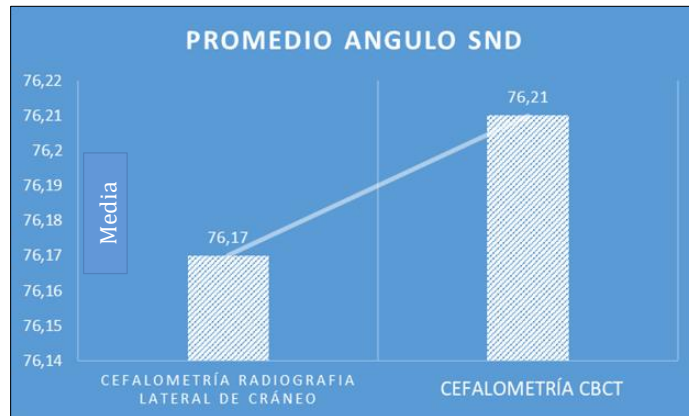


Figure 6 Average and difference of the SND angle

SND angle: No relevant differences were obtained between CLR and CBCT, since the difference obtained was a minimum of 0.04°.

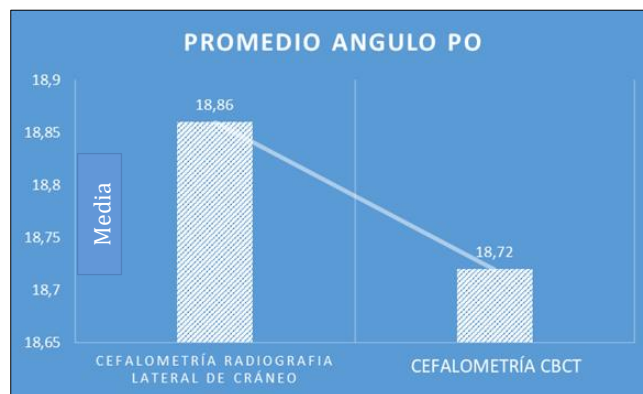


Figure 7 PO angle average and difference

PO angle: No relevant differences were obtained between CLR and CBCT since it obtained a minimum difference of: 0.14°.

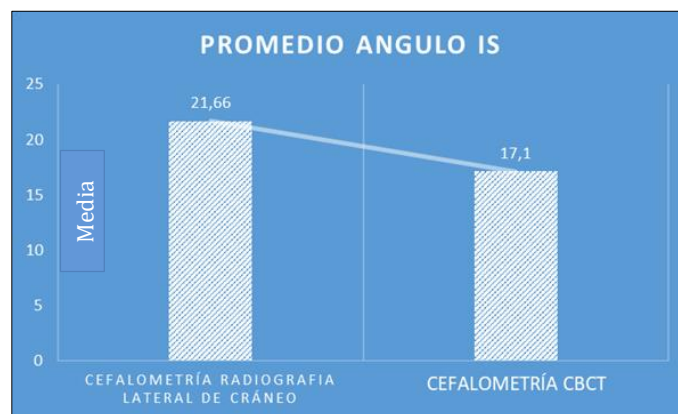


Figure 8 Average and difference of IS angle

IS angle: There was a relevant discrepancy between the RLC and the CBCT since it obtained a difference corresponding to: 4.56°

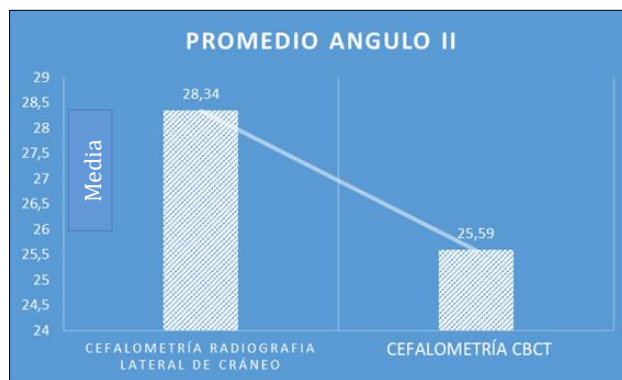


Figure 9 Average and difference of angle II

Angle II: There was a relevant discrepancy between the CLR and CBCT since it obtained a difference corresponding to: 2.75°

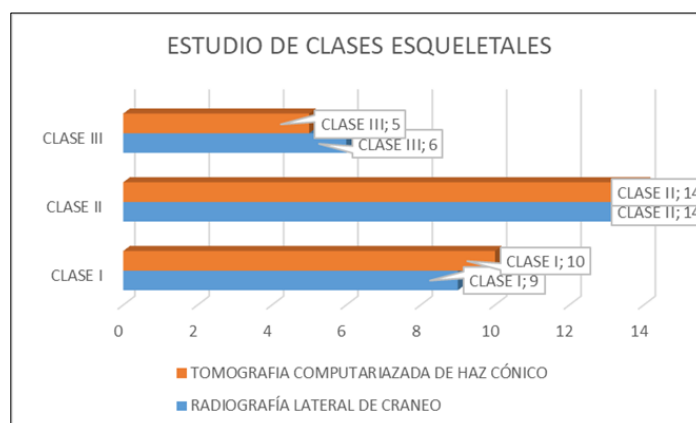


Figure 10 Comparison of skeletal classes obtained from cephalometrics on lateral skull radiographs as cone beam computed tomography

Table 6 Difference of cephalometric measurements in lateral skull radiographs with respect to cephalometric CBCT images in students of the Faculty of Dentistry of the University of Cuenca

	Two-dimensional cephalometry	3D Cephalometry	
Variables	Media	Media	Difference between measurements
SNA	82.33	82.52	0.19
SNB	79.00	78.93	0.07
ANB	3.79	3.48	0.31
SND	76.17	76.21	0.04
OCCLUSAL PLANE ANGLE	18.86	18.72	0.14
ANGLE IS	21.66	17.10	4.56
ANGLE II	28.34	25.59	2.75

According to the analysis of the skeletal classes, we can indicate that there is a higher prevalence of students with skeletal class II (in this case corresponding to a number of 14 participants) with respect to a minority with skeletal class I and III (in this case corresponding to a number of between 9-10 and 5-6 participants).

The difference in means between the skeletal angles SNA, SNB, ANB, SND, and Occlusal Plane Angle showed that there is no significant discrepancy when performing cephalometric analysis in three-dimensional images compared to two-dimensional images. In the IS and II angles, a greater difference was observed between the measurements of one cephalometric analysis modality with respect to the other.

4. Discussion

Steiner's cephalometric analysis comprises a series of points and planes, from which measurements necessary for orthodontic diagnosis and treatment are obtained. Lateral skull radiography is a widely used diagnostic tool in orthodontics; however, it has certain limitations, such as the inaccuracy of the measurements obtained and the overlapping of structures. Nevertheless, conventional cephalometric analysis has not lost its validity in orthodontic treatment planning. Nowadays, the accuracy of CBCT images is recognized due to their 1:1 ratio, being a totally reliable tool. With the possibility of generating multiplanar reconstructions in a sagittal section from a CBCT, it has been proposed that the cephalometric tracing in a 3D image through specific software is more accurate in relation to conventional cephalometry. The present research aims to compare the efficiency and accuracy of Steiner's cephalometric analysis in lateral skull radiography in contrast to the lateral cephalic image obtained from a CBCT. (5)

Gholinia and Pourgholi (2020) compared the reliability of cephalometric measurements between CBCT images and two-dimensional cephalometry, and obtained as a result a higher accuracy in the measurements made in CBCT images, which supports the idea that cutting two-dimensional images in any of the three planes, sagittal, coronal or axial from a 3D image allows obtaining a better visualization of them as well as a wide range of options for treatment planning. (6) Likewise, Moshiri et al (2007), studied the accuracy of linear measurements in digital images of lateral radiographs and CBCT with reference to dry human skulls. (7) This study showed that images created from a CBCT are more accurate than lateral skull radiographs in terms of linear measurement analysis, so the deferred results argue for a high level of reliability when generalizing cephalometric measurements in digital images from a CBCT. (7)

On the other hand, Heinz, Stewart, and Ghoneima in their study in which they compared the reproducibility of linear measurements in superimpositions produced from 2D and 3D lateral cephalograms and concluded that no differences were recorded between linear measurements made from 2D and 3D superimpositions, establishing that both results of 2D and 3D cephalometric measurements are considered reliable and reproducible, a fact that agrees with the results of the present investigation. (8) Likewise, other studies have been performed for the comparison of lateral cephalometric measurements with CBCT images and lateral skull radiographs. Kumar et al. performed the comparison of cephalometric measurements in which 5 were linear plane analysis and 2 were angular measurements; this study concluded that the results acquired did not distinguish significant statistical differences between the 2 imaging modalities, as in the present study where it was resolved that the range of difference in the tracing and measurement of cephalometric points was minimal, therefore there was a non-significant variation. (9)

With respect to the degree of reliability and accuracy sought in the identification of cephalometric points in 3D programs or software, Sam et al. argue that it is necessary arduous research work in order to assess the degree of confidence in the location of 3D cephalometric landmarks, therefore, further development of software is necessary when using the transition from 3D to 2D images, which will require greater demands for its computational operation, higher cost and longer adaptation time for the operator (10).

Recently Wen et al (2017) indicated certain guidelines about the disadvantages and advantages of generating a 2D cephalometry from a CBCT, in this study it is clarified that in a certain way, one of the advantages would be the fact that the generation of these cephalometries are an alternative as far as lateral skull radiography is concerned for those patients who have a previously taken CBCT, In the same way, a higher radiation dose exposure for the patient would be avoided, consequently reducing expenses by taking a new two-dimensional image. (11) As for the disadvantages of this measure, we have that the value that a cephalometry can take for each orthodontic case is not certain, and even more so if the image generated does not meet the appropriate parameters to produce an adequate study image on which to work. (11) Furthermore, with regard to the degree of reliability and precision that is sought in the identification of cephalometric points in 3D programs or software, Sam et al. argue that arduous research work is necessary in order to evaluate the degree of confidence in the location of 3D cephalometric reference points; therefore, further development of software is necessary when resorting to the transition of images from 3D to 2D, which will require greater demands for its computational operation, higher cost and longer adaptation time for the operator.(10) This is in agreement with

the present investigation since when performing the tracing of certain points and angles of the Steiner analysis, difficulties were reflected at the moment of obtaining angles conformed by points whose position was not clearly visible in images obtained from CBCT due to the FOV of the 3D image; this also happened with the location of points such as Na, Gb, Si or Me; which reflects the importance of developing standardized parameters for the 3D cephalometric tracing. (6)

However, previous studies have been performed for the comparison of lateral cephalometric measurements with CBCT images and lateral skull radiographs. Kumar et al. performed a comparison of cephalometric measurements in which 5 were linear plane analyses and 2 were angular measurements. This study concluded that the results acquired did not distinguish significant statistical differences between the 2 imaging modalities. According to Moshiri et al, who studied the accuracy of linear measurements on digital images of lateral radiographs and CBCT with reference to dry human skulls. This study showed that images created from a CBCT are more accurate than lateral skull radiographs in terms of linear measurement analysis, so the deferred results argue for a high level of reliability when generalizing cephalometric measurements in digital images from a CBCT. (5) .

Although the use of CBCT complies with and satisfies its use in different circumstances, being likewise optimal for different patients who require it, the decision to opt or not for a cone beam computed tomography over a CBCT will be purely up to the clinician, who will be responsible for seeking the best benefit for the patient above all circumstances, always considering the possible risks involved in such a decision, especially in children and young adult patients where the imaging study will always be selected as a complement based on the history, clinical examination and signs or symptoms recorded in the clinical history of each patient. (5)

5. Conclusion

Based on this study and the results obtained, it is possible to reach the following conclusions:

- The comparison of data from cephalometric measurements through Steiner analysis obtained from both lateral skull radiographs and CBCT allows us to corroborate that, by establishing certain parameters, it is ideal to perform cephalometric analysis on images obtained through CBCT, without presenting incongruent or different data from those cephalometric measurements obtained from lateral skull radiographs.
- Aspects that may limit the use of a CBCT depend on the patient's treatment plan, the level of experience and practice on the part of the operator, the risk-benefit cost to the patient of being exposed to a certain amount of radiation, as well as the economic cost that differs in obtaining a lateral skull x-ray with respect to a CBCT.
- There is a high degree of reliability and accuracy of cephalometric measurements for obtaining skeletal and dental angles in two-dimensional images obtained from a CBCT with respect to a lateral radiograph.
- The particularity of providing a greater number of tools, construction of appropriate orthodontic treatment plans, and the ease of visualizing different planes and views of a patient, allow CBCT to be ahead of two-dimensional radiographs in many aspects; in turn, the possibility of obtaining a greater amount of information from a 3D image has managed to interconnect this tool in various fields of dentistry, being its use increasingly greater and suitable in day-to-day life.

Compliance with ethical standards

Acknowledgments

We thank all the participants included in the study who gave us their consent to carry out the research.

Disclosure of conflict of interest

The authors agree no conflict of interest

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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