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Comparative study of the reliability and accuracy of anterior tooth root angulation measurements in lateral skull tele-radiography and CBCT from an image bank of the faculty of dentistry of the University of Cuenca

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Abstract

Purpose: The aim of the present study was to compare the reliability and accuracy of central incisor root angulation measurements performed by two different methods: CBCT and lateral skull teleradiography.

Materials and methods: The inclination angle in the vestibule-lingual direction of the upper and lower central incisor of 40 patients was measured by lateral skull teleradiography and CBCT and used excel 2016.

Results: The angulation of anterior tooth roots presented a statistically significant difference in the measurements performed in the lateral skull teleradiography and CBCT ($p < 0.05$).

Conclusion: Measurements of the vestibulelingual inclination of the upper and lower central incisors performed on CBCT showed greater efficacy and reliability compared to measurements taken on TeleRx.

Keywords: Lateral skull teleradiography; CBCT; Root angulation; Reliability

1. Introduction

In orthodontic treatment it is essential to evaluate the dental positioning in the three planes of space to assess: dental and facial esthetics, for this reason, to achieve the correct dental position, the position of crowns and dental roots is evaluated. Before starting orthodontic treatment, it is necessary to obtain the precise mesiodistal angulation and vestibule-lingual inclination for all the teeth to be treated, because, for an ideal occlusion, it is necessary a correct axial inclination of the teeth, so the clinician should not focus only on aligning the crown, for this purpose the radiographic image is an important diagnostic tool in the evaluation of the patient [1].

Radiographic examinations are a tool that provides information to the dentist and, together with the clinical examination, help in the correct diagnosis and treatment of the patient. In dentistry, both in conventional two-dimensional (2D) and three-dimensional (3D) radiographic examinations, the patient is exposed to X-rays, and this exposure can produce harmful effects. These effects, known as stochastic, are cancer and hereditary effects. Due to the inherent risk posed by exposure to ionizing radiation, the principles of radiation protection must be taken into account and the prescription of each radiographic examination must be justified. In other words, the most appropriate examination for the patient's need should be chosen to obtain a benefit greater than the risk to which he/she is exposed [2,3,4].

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1.1. Lateral skull teleradiography (TeleRx)

Lateral skull teleradiography is a two-dimensional image that allows appreciation of bone structures and their discrepancies in the sagittal direction, which is used for linear and angular measurements using different anatomical reference points. Teleradiography allows a study of the patient's facial growth and an assessment of the structures of the jaws and their relationship with the skull bases.

This technique allows craniometrics or cephalometric measurements to study the growth and development of the patient, and to observe bone structures. It is also widely used in orthodontics to measure and evaluate craniofacial, skeletal, dental, and soft tissue relationships [5], to characterize facial morphology, to predict the growth of the facial skeleton, to plan orthodontic treatment, as well as to evaluate the results of the treatment [6]. This technique presents a dose of exposure < 6 (μSv) [7].

Limitations

A significant limitation of teleradiography is the overlapping of structures that make it difficult to visualize the images, placement of reference points, and distortion of the images so that the measurements to be taken will not be accurate.

Another limitation is the position of the head, which also causes errors in the measurement. And among other limitations are image magnification, errors in measurement point designation, and head rotation [8].

1.2. Cone beam computed tomography (CBCT)

CBCT provides two unique features in orthodontic practice: a) Planar projections (teleradiographic reconstructions) or curved projections (panoramic reconstructions) that are used for orthodontic diagnosis, cephalometric analysis, and treatment planning can be obtained from a single CBCT acquisition, b) CBCT base images can be reconstructed to provide a single image previously unavailable in orthodontic practice [3, 9].

CBCT has advantages in overcoming the challenges of overlap and magnification, providing greater accuracy for diagnosis and analysis than traditional (2D) [5,9]. In addition, the CBCT scan obtained from a patient can also be used to generate a 2D cephalogram as an alternative to traditional CSF, minimizing additional radiation exposure and financial cost [5].

Limitations

The main limitation lies in the ability to differentiate hard and soft tissues simultaneously in the same exam, reason why CBCT has been discarded in many procedures that require visualization and contrast of densities between these two types of tissues; this is given by the technical characteristics of the equipment components (voxel size, Rx tube power, FOV, etc.) which improve or diminish image quality. In the case of CBCT, they maintain a basic scheme to acquire the images but they are different in terms of the type of detectors (hardware), the reconstruction algorithms (software), and also in the exposure parameters. This implies the difficulty to standardize parameters that serve to measure the bone quantity and/or quality. Therefore, the major limitation of CBCT is the low contrast capability with the surrounding soft tissues [3].

1.3. Radiation

CBCT exposes the patient to a dose of approximately 48 - 652 (μSv), so imaging requires a lower radiation dose to the patient compared to medical computed tomography but requires a higher radiation dose than lateral skull teleradiography

2. Material and methods

The aim of this study was to determine the reliability and accuracy of central incisor root angulation measurements performed by two different methods: CBCT and lateral skull teleradiography of a group of students of the University of Cuenca, Faculty of Dentistry attending during the school period September 2022 to February 2023.

2.1. Materials

For the study, 40 people with skull teleradiography and CBCT from an image bank of the Faculty of Dentistry of the University of Cuenca who attended during the years 2022 and 2023 were randomly selected.

2.1.1. Inclusion criteria were

- X-rays of patients with, lateral skull teleradiography, and CBCT performed at the same time.
- Presence of upper and lower central incisors.
- Patients with no apparent pathological data and without distinction of sex.
- Availability of records in perfect condition to be studied.

2.1.2. Exclusion criteria were

- Unavailability of records, poor visualization, and errors in the recording that did not allow the subsequent study.
- Patients with lateral skull teleradiography, and CBCT were not performed at the same time.
- Patients with dental morphology alterations.
- Presence of the upper and lower central incisors
- Records in poor condition that cannot be studied

There was an initial sample of 40 patients who had both records performed at the same time; however, after applying the inclusion and exclusion criteria, the final sample consisted of 39 patients with lateral skull teleradiography and CBCT. Some 64.1% were women and the remaining 35.9% were men.

2.2. Methods

2.2.1. Record taking

The radiographs and CBCT were taken at the Department of Radiology of the Faculty of Dentistry of the University of Cuenca. The lateral radiographs were taken with the Morita Accuitomo 170 device under the following conditions: 25 kV, 15 mA, and an exposure time of

2.2.2. 0.04 seconds

The CBCT were taken with the Morita Accuitomo 170 device, with a kilovoltage of 70 kV, amperage of 1-20 mA, exposure of 3.6 to 5.4 seconds, a sensor of 15 x 15 cm and a voxel measurement of 0.03 x 0.03 x 0.03 x 0.03.

The angular measurements analyzed were: vestibule-lingual inclinations of the roots of the upper and lower central incisors.

The angular measurements on the radiographs were obtained through the Nemotec Dental Studio NX program.

2.2.3. Variables studied

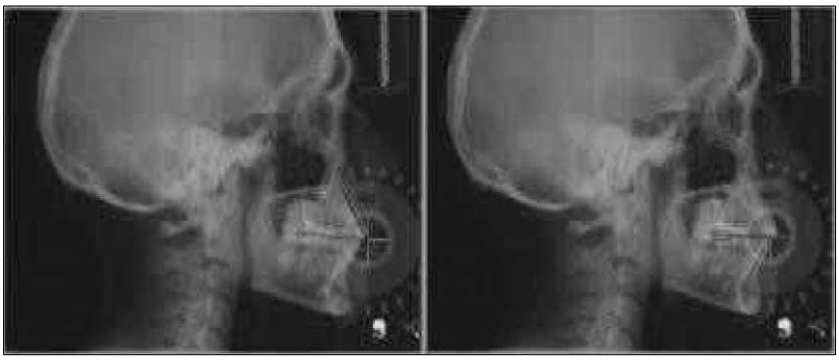

Figure 1 Image of the angle formed by the occlusal plane, the incisal edge, and the apex of the upper and lower central *inc*isor respectively on the TeleRx

Lateral skull teleradiographs were saved in .jpeg format and CBCTs were saved in .jpeg format. .dcm for subsequent measurement. Measurements on lateral skull teleradiographs were performed using the NEMOESTUDIO®2022 program. The radiographs were entered in .jpg format as images in the program.

In the lateral cranial teleradiographs, to define the occlusal plane, a line was drawn through the incisal edge of the upper incisors and through the mesial cusp of the first upper molar. At the level of the upper and lower incisors, a line was

drawn passing through the tip of the apex and the incisal edge of each incisor. The lines crossed the occlusal plane so that the angulation results for the teeth measured were obtained using the angle tracing option of the program (Figure 1).

The CBCTs were obtained in DICOM (digital imaging and communications in medicine) format from the Morita Accuitomo 170 3D machine. NEMOESTUDIO 2019 software was used. After preparing the image for visualization using the program, a true occlusal plane was defined, passing through the mesio-vestibular cusps of the upper first molars and the incisal edge of the upper central incisors (Figure 1). The longitudinal axis of the tooth was then defined. At the incisor level, this was the line passing through the apex of the incisors and the midpoint of the incisal edge for each tooth.

Figure 2 Image of the angle formed by the occlusal plane, the incisal edge, and the apex of the upper central incisor on CBCT

2.3. Statistical Analysis

2.3.1. Intraoperator analysis

In order to assess the reliability of the measurements, 6 patients were randomly selected from the sample. Measurements were performed on both CBCT and TeleRx and 2 repetitions were performed, the first one after one week and the second one after two weeks.

Only one researcher performed all the measurements of the patient sample with each technique (CBCT, TeleRx). In order to control the measurements performed with the different techniques, a database in Excel® 2016 format (Microsoft) was elaborated. The work was statistically validated so that the measurements used are correct and comparable with each other.

2.3.2. Measurements

A database in Excel® 2016 format (Microsoft) was used to find the angulation differences between the values obtained in the teleradiographies and the CBCTs.

Statistically significant differences were established with a p-value <0.05. Clinically significant differences were established when the difference in measurements between one method and the other was > 5 degrees

3. Results

3.1. Values of the variables studied

3.1.1. Measurements on vestibule-lingual angulation

Table 1 shows the values obtained by comparing the radicular vestibule-lingual inclinations performed on lateral skull teleradiographs and CBCT.

Table 1 Comparison of radicular vestibule-lingual inclinations performed on lateral skull teleradiographs and CBCT

Variables	n	Group	Arithmetic Mean (AM)	SD	P-value
Upper central incisor	39	TeleRx	49.38	5.19	0.0299*
		CBCT	52.70	6.31	
Lower central incisor	39	TeleRx	60.51	8.37	0.000008***
		CBCT	62.50	8.35	

(NS p>0, 05; * p<0, 05; **p<0, 01; ***p<0,001).

Table 2 and Table 3. Show the differences in vestibule-lingual angulations between TeleRx- CBCT. Negative values indicate greater vestibular tilt in TeleRx than in CBCT, and positive values indicate greater vestibular tilt in CBCT than in TeleRx.

Table 2 Differences in vestibule-lingual angulation between TeleRx and CBCT of the centralincisors

CBCT	TeleRx	DISCREPANCY
50.61	52.7	-2.09
60.44	60	0.44
47.05	46.9	0.15
57.05	56.4	0.65
44.82	43.9	0.92
57.93	50.4	7.53
63.16	53.4	9.76
57.75	51.9	5.85
51.13	44.8	6.33
59.47	54.2	5.27
50.77	48.1	267
44.27	45.6	-1.33
58.8	56.7	2..1
55.4	53.1	2.3
53.92	50.4	3.52
55.9	49.8	6.1
45.17	44.5	0.67
55.52	51.2	4.32
49.96	42.9	7.06
58.59	54.7	3.89
60.13	50.01	10.12
57.8	56.9	0.9
49.08	42.3	6.78
39.44	37.3	2.14
51.26	52.5	-1.24

50.38	49.7	0.68
51.41	51.4	0.01
52.65	42.1	10.55
58.1	56.2	1.9
54.3	51.4	2.9
53.8	46.5	7.3
54.5	53.4	1.1
59.96	46.7	13.26
47.33	43.3	4.03
46.1	50	-3.9
46.1	47.7	-1.6
637	52.8	10.9
41.9	41.2	0.7
39.8	42.9	-3.1

Table 3 Differences in vestibule-lingual angulation between TeleRx and CBCT of the lower central incisors

CBCT	**TeleRx**	**DISCREPANCY**
62.23	70.6	-8.37
65.13	61.1	4.03
61.15	58.3	2.85
54.02	55.6	-1.58
51.18	52.6	-1.42
57.99	53.2	4.79
76.01	77.2	-1.19
45.77	51.6	-5.83
69.38	69.2	0.18
59.41	60.5	-1.09
62.86	64.4	-1.54
58.82	54.3	4.52
56.71	517	5.01
68.83	64	4.83
52.39	49.3	3.09
48.3	47.2	1.1
63.19	60	3.19
69.35	65.2	4.15
71.37	42.9	28.47
54.91	52.14	2.77

71.31	69.44	1.87
60.56	68.5	-7.94
65.71	62.4	3.31
66.82	61.8	5.02
67.99	71.4	-3.41
84.64	68.5	16.14
57.45	51	6.45
60.86	66.8	-5.94
82.89	82.1	0.79
62.32	61.6	0.72
53.71	53.7	0.01
52.87	53.6	-0.73
63.07	61.9	1.17
63.64	62.5	1.14
62.26	66.2	-3.94
63.35	60.9	2.45
57.37	52.5	4.87
61.65	63	-1.35
69.84	61.1	8.74

Table 4 Shows the difference in measurements between CBCT and TeleRx showing that values >5° are clinically significant in both upper and lower incisors.

Table 4 Difference between CBCT and TeleRx measurements

CBCT-TeleRx 1		
	Upper central incisor	**Lower central incisor**
>5°	13	6
<5°	26	33

4. Discussion

This study aims to compare and quantify the differences that occur when measuring the root inclinations of upper and lower central incisor roots using TeleRx and those of more recent implantation (CBCT).

Ramirez HJV et al [8] in their study concluded that there were no statistically significant differences between CBCT measurements and skull radiographs, so the present study differs from their results and with the results of this author since a statistically significant difference was found between lateral teleradiography and CBCT ($p < 0.05$). This study and that of Ramirez HJV et al [8] found that CBCT measurements of the vestibule-lingual inclination of the upper and lower central incisors in 3D did not show clear evidence of greater efficacy and reliability compared to measurements taken in 2D. However, it is true that the identification of anatomical landmarks on CBCT is complex because there is currently no standard of features for proper identification, although 3D anatomical landmarks are currently under development. The results of the statistical analysis showed a clear difference in the vestibule-lingual inclination of the upper and lower central incisors since the measurement is taken on lateral teleradiographs and is a flat image that does

not allow clear identification of the points to calculate the angles. In contrast, the cone-beam measurement allows the identification of a more natural and accurate structure.

A study by Bouwens showed clinically significant deviations, i.e., deviations greater than 5 degrees in angulation, in 50.5% of the maxillary teeth and 56.2% of the mandibular teeth [11]. Compared to our study, clinically significant differences (greater than 5 degrees) were found for 33.3% of the upper incisors and for 66.6% of the lower incisors. With this, in comparison with the aforementioned study, it is agreed that the mandibular teeth present greater angulation compared to the maxillary teeth.

Regarding the vestibule-lingual inclination found in the present study, higher values were found in the vestibule-lingual inclination of the upper and lower central incisors in the CBCT than in the lateral skull teleradiographies, and in addition, some of these values had statistically significant differences. In the study by Garriga, vestibule-lingual inclination values were higher on CBCT, however, no statistically significant differences were found in any of the cases. Higher values mean that the incisors are more verticalized since the reference angle measured is the angle formed by the axis of the incisor and the occlusal plane, always palatally or lingually of the incisors [11].

The study by Wen et al. concluded that there were significant differences between lateral skull teleradiography and CBCT, these measurement values with significant differences were generally higher in 3D CBCT scans than in 2D cephalograms, which coincides with the results of the present study because there are significant differences between the measurements [5]. Wen's study, however, concludes that there is greater reliability in CBCT measurements because lateral skull teleradiography often makes it difficult to locate the apex of a tooth accurately because the contrast between the image of the root apex and the surrounding tissues is often poor. It is also difficult to distinguish the central and lateral incisors, especially in patients with anterior crowding or when the lateral incisor is more prominent than the central incisors. In contrast, these anatomical structures and landmarks can be more obviously recognized in 3D CBCT scans. In addition, the 3D technique could also minimize errors in projection and landmark identification. These may contribute to the significant differences between 2D lateral teleradiography and 3D CBCT scans in the measurements of this study [5]. With the advent of CBCT, there was an increase in the quality of the examinations, allowing better diagnosis and more accurate treatment planning for patients. However, it should be noted that despite the improvement in quality, X-radiation is used to obtain these images, and even at low intensity can cause damage to the DNA of the cells of the human body. Also, it is known that CBCT provides more information regarding the anatomical structures; therefore, the indication of these methods should be done thinking about the benefits of the diagnosis over the possible damage that radiation exposure may cause, being essential the indication based on the history and clinical examination of each patient [12].

5. Conclusion

Measurements of the vestibule-lingual inclination of the upper and lower central incisors performed on CBCT presented clear evidence of greater efficiency and reliability compared to measurements taken on lateral skull teleradiographs.

CBCT requires a higher radiation dose compared to TeleRx, so its use must be justified so that the patient obtains a benefit greater than the risk to which he/she is exposed.

Compliance with ethical standards

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Disclosure of conflict of interest

In this research, none of the authors presented conflicts of interest.

Statement of informed consent

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

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