

PANORAMIC RADIOGRAPHY AND CONE-BEAM COMPUTED TOMOGRAPHY TO MEASURE DISTANCES BETWEEN ROOT APEXES AND ANATOMICAL STRUCTURES.

Radiografía panorámica y tomografía computarizada de haz cónico para medir distancias entre ápices radiculares y estructuras anatómicas.

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ABSTRACT:

Aim: To compare the accuracy of the panoramic radiography with cone-beam computed tomography (CBCT) scans in measuring the distances between root apexes and the adjacent anatomical structures including the maxillary sinus and the mandibular canal.

Material and Methods: A total of 200 CBCT scans (100 maxillary and 100 mandibular) from patients who also had corresponding panoramic radiography were selected. Linear measurements (in mm) presenting centralized image were made between the apexes of the maxillary teeth and the inferior wall of the maxillary sinus, and between the apexes of the mandibular teeth and the superior border of the mandibular canal by using specific software for panoramic radiography and the measurements on the coronal sections in CBCT scans. Data were submitted to inferential statistical analysis and Student's t-test for comparison between measurements.

Results: CBCT scans were significantly more accurate than panoramic radiography to measure the distances between the apexes of the maxillary teeth and the inferior wall of the maxillary sinus ($p < 0.05$) and between the apexes of the mandibular teeth and the superior border of the mandibular canal or mental foramen ($p < 0.05$).

Conclusion: CBCT scans present more accurate measurements than panoramic radiography.

KEYWORDS:

Cone-beam computed tomography; Maxillary sinus; Mandibular canal; Radiography, panoramic; Tooth apex; Anatomy, regional.

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RESUMEN:

Objetivo: Comparar la precisión de la radiografía panorámica con las exploraciones de la tomografía computarizada dental de haz en cónico (CBCT) para medir las distancias entre los vértices radiculares y las estructuras anatómicas adyacentes, incluidos el seno maxilar y el canal mandibular.

Material y Métodos: Se seleccionaron un total de 200 tomografías CBCT (100 maxilares y 100 mandibulares) de pacientes que además tenían la correspondiente radiografía panorámica. Se realizaron mediciones lineales (en mm) que presentaban imagen centralizada entre los ápices de los dientes maxilares y la pared inferior del seno maxilar, y entre los ápices de los dientes mandibulares y el borde superior del canal mandibular mediante software específico para radiografía panorámica. y las mediciones en las secciones

coronales en escaneos CBCT. Los datos se sometieron a análisis estadístico inferencial y prueba t de Student para comparación entre mediciones.

Resultados: Las exploraciones CBCT fueron significativamente más precisas que la radiografía panorámica para medir las distancias entre los ápices de los dientes maxilares y la pared inferior del seno maxilar ($p < 0,05$) y entre los ápices de los dientes mandibulares y el borde superior de los dientes mandibulares. canal o agujero mentoniano ($p < 0,05$).

Conclusión: Las exploraciones CBCT presentan mediciones más precisas que la radiografía panorámica.

PALABRAS CLAVE:

Tomografía computarizada de haz cónico; Seno maxilar; Canal mandibular; Radiografía panorámica; Ápice del diente; Anatomía regional.

INTRODUCTION.

The root canal anatomy influences the success of the endodontic treatment as it affects the quality of the instrumentation and obturation of the root canal system,¹ thus, the practitioner must be constantly updated about its variants.² However, the treatment planning and execution demands an adequate diagnosis³ using periapical and panoramic radiography or cone-beam computed tomography (CBCT) scans.⁴

Panoramic radiography is a basic diagnostic exam for endodontic treatments and periapical surgery, because of its low cost, easy access and the possibility of observing several structures simultaneously.⁵ However, it has some disadvantages such as overlapping of anatomical structures and dimensional distortion, in vertical and horizontal directions because of its two-dimensional images.⁶

Conversely, CBCT images are three-dimensional, offer an accurate diagnosis of the anatomical struc-

tures and periapical region without overlapping and dimensional distortions.⁷ Still, the use of CBCT in endodontics is limited because of its high cost, high radiation dose, and poor soft tissue contrast and artefacts.^{8,9}

The proximity between maxillary and mandibular teeth apices and the adjacent anatomical structures including the maxillary sinus and the mandibular canal should be carefully measured⁷ to prevent physical, chemical and biological injuries to these structures during the root canal treatment or periapical surgery.¹⁰⁻¹² Therefore, the objective of the present study was to compare the accuracy of the panoramic radiography in measuring the distance between root apices and the adjacent anatomical structures with CBCT scans measurement. The null hypothesis was that there is no difference between CBCT scans and panoramic radiography in assessment of the measurement of distances between root apices and the adjacent anatomical structures.

MATERIALS AND METHODS.

The present study was approved by the research ethics committee of the Institute of Science and Technology, São Paulo State University (no. 1.079.312), and in compliance with the Helsinki Declaration.

Inclusion criteria

- Patients with at least eight teeth per dental arch;
- Patients at least 21 years old;
- CBCT scans and panoramic radiography without image distortions or technique errors.

Exclusion criteria

- Patients with fewer than eight teeth per dental arch;
- Patients younger than 21 years old;
- CBCT scans and panoramic radiography with image distortions or technique errors;
- Patients with teeth presenting apical resorption, root dilaceration, root anomalies, root fracture, periapical bone rarefaction and absence of crown;
- CBCT scans and panoramic radiography with dental implants regions.

Panoramic radiography

For analysis of panoramic radiography, 200 digital examinations were selected from patients indicated for several treatments who also had CBCT exams corresponding to 100 maxillary and 100 mandibular exams.

All panoramic radiographs were acquired with the same equipment (Pax400®, Vatech/Gnatus, Suwon, South Korea). All the measurements were performed by only one professional (dentist, radiologist and endodontist).

Linear measurements (in mm) presenting centralized image were made

I) between the apices of the maxillary posterior teeth and the inferior wall of the maxillary sinus (Figure 1A);

II) between the apices of the mandibular 2nd premolars, 1st and 2nd molars and the superior border of the mandibular canal, and

III) between the apex of mandibular 1st premolar and the mental foramen (Figure. 1B) using specific

software (Image Tool 3.0®, UTHSCSA, San Antonio, TX, USA). All the radiographies were standardized at 100-percent size.

The measurements were performed considering the shortest distances between the radiographic apex points and the anatomical structure. Each measurement session lasted 4 hours to study 20 pairs of exams (Figure 2).

CBCT scans

A total of 200 CBCT scans (100 maxillary and 100 mandibular) from patients who also had corresponding panoramic radiography were obtained using the same volumetric CT machine (GX CB 500, Gendex/Kavo, Biebrach, Germany) operating at a voxel of 0.20 mm, FOV of 14 cm x 8 cm, 120 kVp, 36.15 mAs and 12 bits of grayscale depth.

The image data were recorded in DICOM (Digital Image and Communication in Medicine) format and reconstructed with specific imaging software (Image Studio® (AnneSolutions, São Paulo, Brazil), so that coronal sections could be obtained at a standard distance of 1.0 mm.

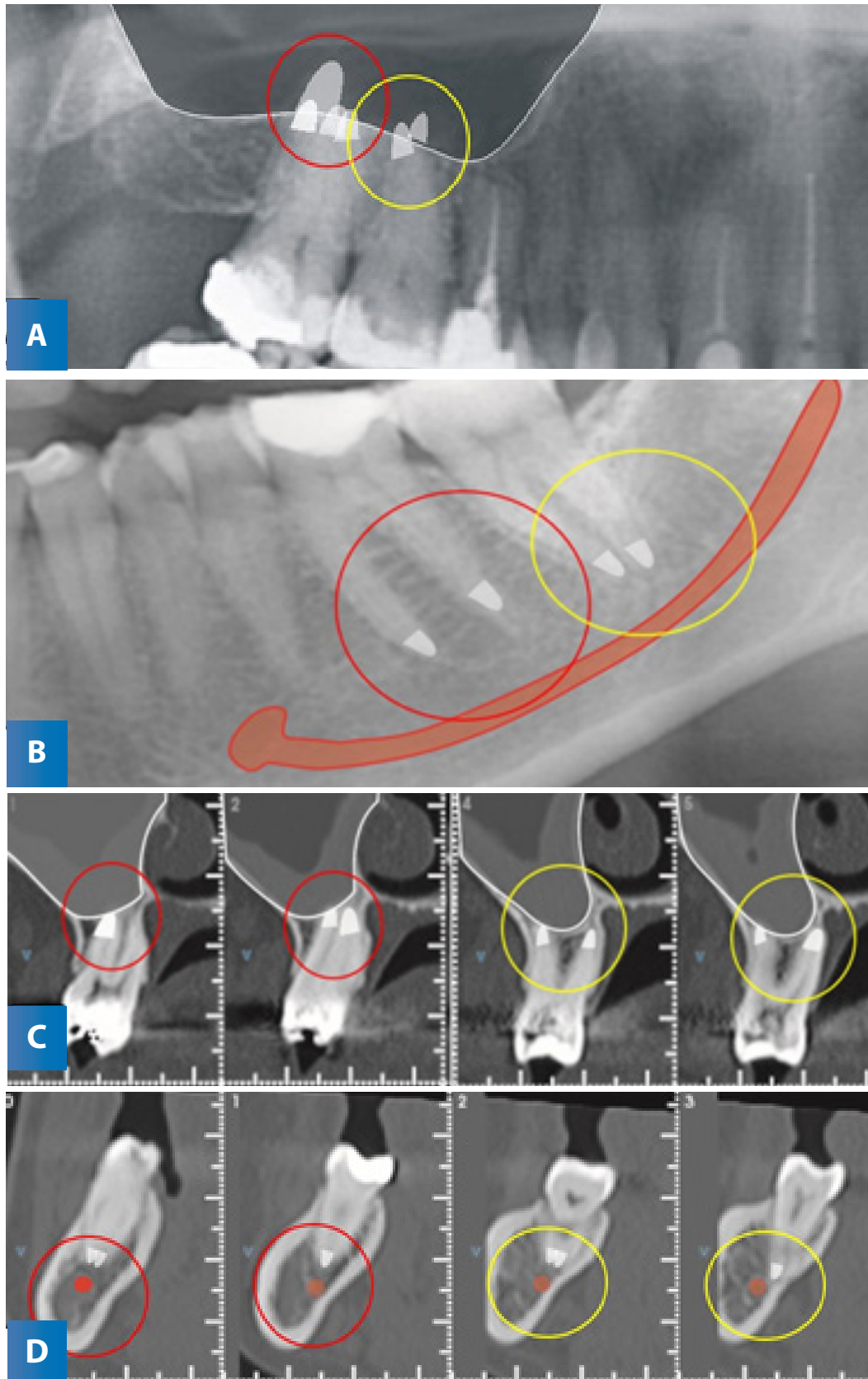
Linear measurements (in mm) on the coronal sections presenting centralized image were made between the apices of the maxillary teeth and the inferior wall of the maxillary sinus (Figure 1C), and between the apices of the mandibular teeth and the superior border of the mandibular canal or mental foramen (Figure 1D).⁷

The measurements were performed between the shortest distances between the radiographic apex points and the anatomical structure. The measurements were performed in 20 pairs of exams per study session that lasted 4 hours each (Figure 2).

Statistical analysis

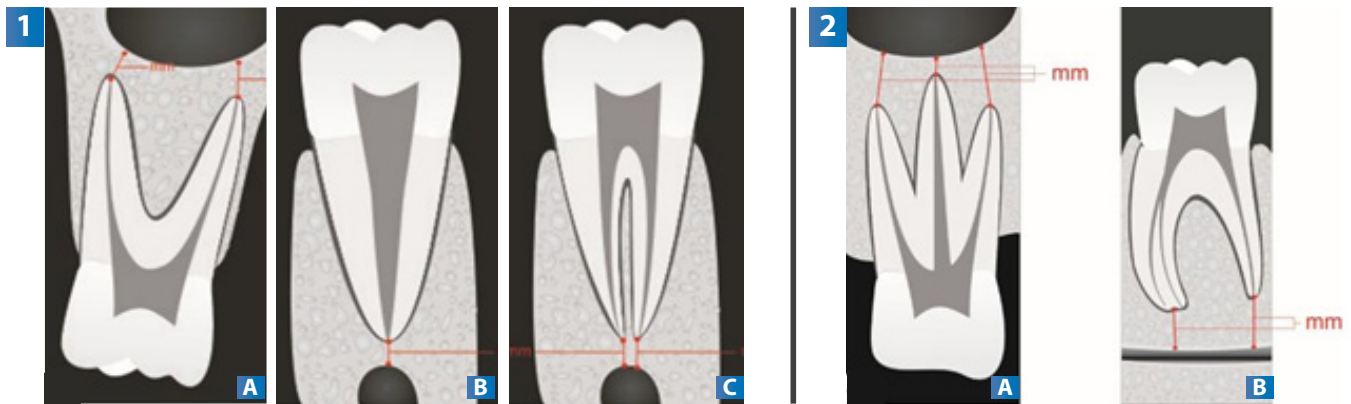
All the values obtained were submitted to descriptive statistical analysis (i.e., mean, standard deviation, minimum and maximum values). The resulting data were submitted to inferential statistical analysis and Student's t-test for comparison between measurements made on CBCT scans and panoramic radiography.

Figure 1. Linear measurements presenting centralized image were made between the apexes of the maxillary teeth and the inferior wall of the maxillary sinus in panoramic radiography .



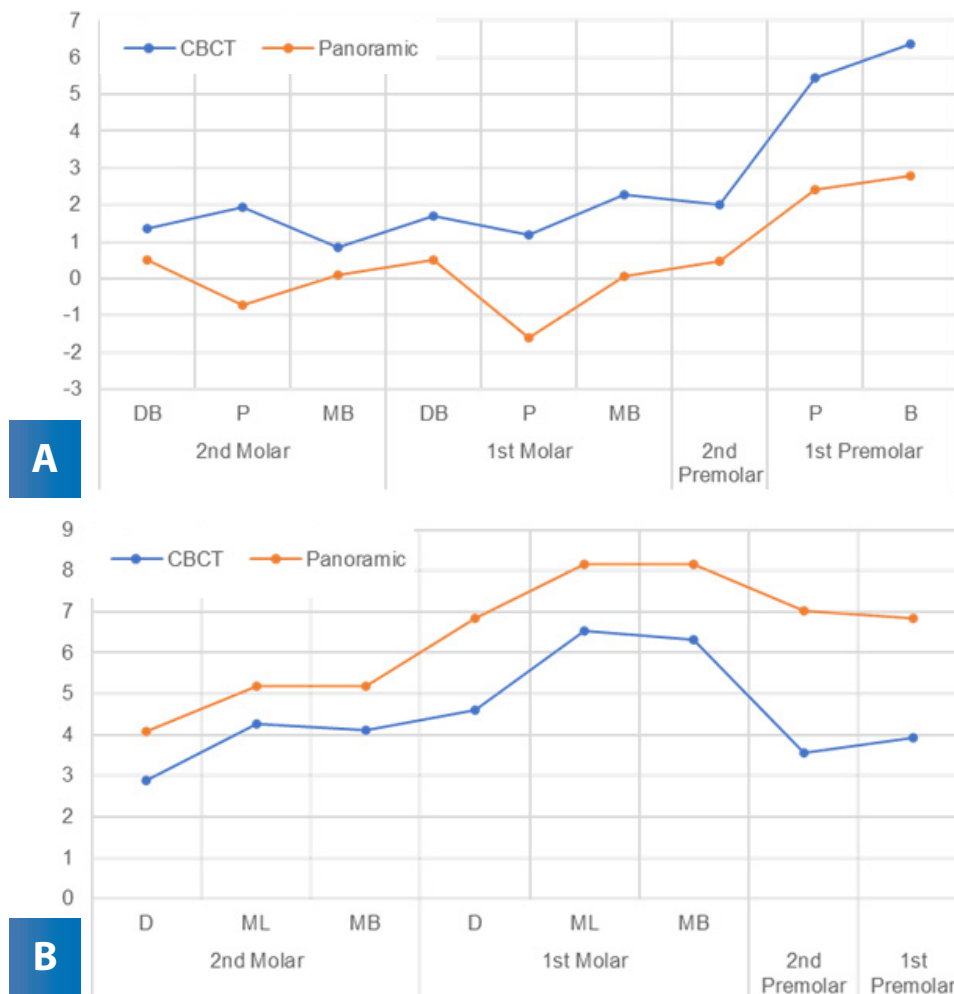
A: Between the apices of the mandibular teeth and the superior border of the mandibular canal or mental foramen in panoramic radiography. **B:** The same measurements of A but in coronal sections of CBCT scans. **C and D:** The same measurements of B but in coronal sections of CBCT scans D.

Figure 2. Linear Measurement scheme.



1A: CBCT scans of maxillary molars, palatal and buccal roots. 1B: Ingle roots of premolars and distal roots of mandibular molars. 1C: Mesial roots of mandibular molars. In panoramic, 2A: CBCT scans of maxillary molars, palatal and buccal roots. 1B: Mesial and distal roots of mandibular molarZ.

Figure 3. Chart of the mean values of the measurements between the apices of the maxillary teeth and the inferior wall of the maxillary sinus (A); and between the apexes of the mandibular teeth and the superior border of the mandibular canal or mental foramen (B).



Legend: DB: Distobuccal root. P: Palatal root, MB: Mesiobuccal root, B: Buccal root, D: Distal root. ML: Mesiolingual root.

Table 1. Linear measurement (in mm) between the maxillary tooth apexes and the lower wall of the maxillary sinus in CBCT scans and panoramic radiographs.

Maxilla Tooth	2 nd Molar			1 st Molar Molar			2 nd Premolar	1 st Premolar	
	DB	P	MB	DB	P	MB		P	B
CBCT scans	1.36	1.94	0.86	1.7	1.18	2.29	2.01	5.46	6.36
Panoramic	0.49	-0.73	0.1	0.52	-1.61	0.08	0.48	2.43	2.78

DB: Distobuccal root. **P:** Palatal root. **MB:** Mesiobuccal root. **B:** Buccal root.

Table 2. Linear measurements (in mm) between the mandibular tooth apexes and the upper border of the mandibular canal or mental foramen in CBCT scans and panoramic radiographs.

Maxilla Tooth	2 nd Molar			1 st Molar Molar			2 nd Premolar	1 st Premolar
	D	ML	MB	D	ML	MB		
CBCT scans	2.9	4.25	4.11	4.61	6.52	6.31	3.56	3.94
Panoramic	4.08	5.18	5.18	6.85	8.15	8.15	7.01	6.84

D: Distal root. **ML:** Mesiolingual root. **MB:** Mesiobuccal root.

RESULTS.

Figure 3A presents a significant difference of the measurements between the apexes of the maxillary teeth and the inferior wall of the maxillary sinus when comparing the panoramic radiography with the CBCT scans ($p < 0.05$).

Figure 3B also shows a significant difference of the measurements between the apexes of the mandibular teeth and the superior border of the mandibular canal or mental foramen when comparing the panoramic radiography with the CBCT scans ($p < 0.05$).

In Table 1, it was observed that the mean measurements of the distances between the apexes of the maxillary teeth and the inferior wall of the maxillary sinus, presented by the panoramic radiography (ranging from -1.61 mm for the palatal apex of the

first molars to 2.78 mm for the buccal apex of the first premolars) are shorter in all the studied apexes, than those observed by CBCT scans (ranging from 0.86 mm for the mesiobuccal apex of the second molars to 6.36 mm for the buccal apex of the first premolars) and all differences were statistically significant ($p < 0.05$).

The most discrepant differences were found between the palatal and buccal apices of the maxillary molars.

In Table 2, it was observed that the mean measurements of the distances between the apices of the mandibular teeth and the superior border of the mandibular canal or mental foramen, presented by the panoramic radiography are greater than those observed by CBCT scans ($p < 0.05$), unlike the measurements of maxillary teeth observed in Table 1.

DISCUSSION.

The use of CBCT scans for measuring the distances between the root apices and the adjacent anatomical structures and the cortical plates was indicated in many studies related in the literature considering the CBCT as the standard gold method.^{7,13-15} However, this study tried to evaluate the accuracy of the panoramic radiography in measuring these distances when compared to the CBCT scans measurements. The null hypothesis of this study is to be rejected according to its outcomes.

In the literature, some studies aimed to compare the distances between the apices of the maxillary teeth and the inferior wall of the maxillary sinus using panoramic radiography and CBCT scans, and it was noticed discrepancies between the measurements obtained by both examination methods as the panoramic radiography presented dimensions smaller than those of CBCT scans.¹⁶⁻²⁰ Similar results were found in this study, as there was a significant difference between the CBCT scans and the panoramic radiography measurements.

The agreement between the measurements presented by both methods in the present study was greater in molars than in premolars, conversely, in other study the agreement was greater in premolars.²⁰ However, this may be related to the vertical protrusion of the roots into the maxillary sinus, as roots that did protrude into the sinus in the CT showed a protrusion length that was much shorter than the projection length appearance using panoramic radiography.^{17,19}

In the present study it was observed that the mesiobuccal root of the second molars was the closest to the floor of the maxillary sinus with mean distance of 0.86 mm (Table. 1) measured with CBCT scans, the same finding was related in other studies with mean value of 1.57-1.97 mm.^{13,21} Another finding in the present study is that the second molar presented the shortest distances between their root apices and the maxillary sinus, and this agree with the same results of other studies.^{21,22}

However, these distances are affected by patient age, sex and race.^{7,21} It should be emphasized the greater differences founded in the palatal apices of molars in relation to the buccal apices, this may be related to the negative angulation of the x-ray beam used in the panoramic examination, and the consequent application of the principle of parallax, as the negative angulation projects the image of the palatal apices (closer to the beam) above in relation to the vestibular (more distant from the beam). It is worth remembering that the beam is inserted during the examination through the patient's cervical region, through the tongue, reaching the bulkhead (sensor), which is in front of the patient.⁶

To the best of our knowledge, there are no studies in the literature that evaluated the distances between the apices of the mandibular teeth and the superior border of the mandibular canal or mental foramen. It was found in this study that the mean distances obtained in panoramic radiography are greater. This means less certainty in the estimation of this relation through this exam and indicates that, in case of proximity of the mandibular canal to the apex, even if it seems satisfactory, the planning must be carried out by means of CBCT scans for a safe estimate.

In this study, the measurements in panoramic radiography were greater in the mandible and smaller in the maxilla. This alerts to the greater proximity between the maxillary teeth and the maxillary sinus, that may cause injuries to the sinus tissues. However, despite the greater distance found in the mandible, attention must be paid too, as there is a good percentage of teeth in contact with the mandibular canal, and accidents tend to be more serious.

The importance of an adequate diagnosis and its effect on a proper treatment planning and execution cannot be overemphasized.³ However, the treatment success does not depend on the diagnosis tool but on the diagnosis accuracy.²³ CBCT is a useful tool for better diagnosis as found in the literature^{9,12,24,25} and it presents

more accurate data as found in the present study. Thus, it should be indicated the use of CBCT for more accurate diagnosis^{26,27} and to investigate the distances between the root apices and the adjacent anatomical structures which has a great relevance for root canal treatment, endodontic surgeries and surgical extractions.

CONCLUSION.

CBCT presents more accurate data about the measurements of the distances between the apexes of the maxillary teeth and the inferior wall of the maxillary sinus; and between the apexes of the mandibular teeth and the superior border of the mandibular canal or mental foramen than panoramic radiography.

Conflict of interests:

The authors declare that they have no conflict of interest.

Ethics approval:

The present study was approved by the research ethics committee of the Institute of Science and Technology, São Paulo State University (No. 1.079.312), and in compliance with the Helsinki Declaration.

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Authors' contributions:

Ferrari CH: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Validation; Visualization; Writing - original draft;

Hasna AA: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Validation; Visualization; Writing - review and editing.

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