Use of cone-beam volumetric tomography in the diagnosis of root fractures

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Objectives. The diagnosis of root fractures by conventional radiographs is still difficult because of limitations of 2D images. Cone-beam volumetric tomography improves the diagnosis capacity in dentistry, such as increased radiation dose to the patient and presence of artifacts on the image.
Study design. This study compared the images obtained on conventional periapical radiographs and 3D scans (Accuitomo 3DX) for the diagnosis of root fractures. Twenty patients with suspected root fractures were submitted to examination by periapical radiography and CBCT. Two professionals, unaware of the symptomatology, examined these radiographs and CBCT images according to pre-established scores, which were later checked against the signs and symptoms.
Results. The results revealed statistical difference for cone-beam volumetric tomography compared with conventional radiographs in the diagnosis of root fractures.
Conclusion. It could be concluded that cone-beam volumetric tomography was better than conventional radiography in the diagnosis of root fractures, thereby constituting an excellent alternative for diagnosis in general practice. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:270-277)**

Since the discovery of x-rays in 1895 by Roentgen and their use in dentistry by Kells, diagnosis by radiographic images has been widely employed in endodontics.[1]

Conventional radiography is adequate for examination of structures such as the tooth crown, root, and surrounding structures; however, difficulties are faced in the diagnosis of root fractures and internal and external resorptions.[2-4]

In 1972, Hounsfield and Cormack revolutionized the field of medical imaging with the advent of computed tomography (CT). Computed tomography is a technique of image acquisition that combines use of x-rays and computer technology, directing the x-ray beams from different angles for achievement of axial section images of the object analyzed. Those images are reconstructed and then reformatted in different planes (axial, coronal, sagittal) or as a 3-dimensional (3D) image. Soft and hard tissues can be displayed with great detail.[5]

The CT scanners currently available include the helical, and helical or spiral multislice CT. Despite the improvement of these systems, the main deficiencies for use in dentistry include the increased radiation dose to the patient compared with conventional radiographs, presence of artifacts, relatively low spatial resolution ,and difficulty to visualize incipient diseases.[6] Another important factor was the need for large space for the scanner, not suitable for dental offices.[7]

Cone-beam technology was adapted for dental applications by Arai and colleagues in 1997, who modified an existing conventional machine (Scanora, Soredex) into a small field of view (FOV), high-resolution, and low-dose CT apparatus called ORTHO CT, which later became known as Accuitomo 3DX (Morita Co., Kyoto, Japan).[8,9] It is equipped with a rotational C-arm device, similar to a panoramic machine. The C-arm rotates around the patient's head acquiring images in 360-

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Table I. Scores assigned by examiners during analysis of conventional radiographs and 3D tomographs

	First examiner	*Second examiner*	*Confirmation by symptomatology*		
#Case	*Periapical radiograph*	*Tomograph*	*Periapical radiograph*	*Tomograph*	
1	0	2	0	2	No
2	0	2	0	2	No
3	0	2	0	1	Yes
4	0	2	0	1	Yes
5	2	2	2	2	Yes
6	1	2	0	1	Yes
7	0	2	0	2	Yes
8	1	2	0	2	Yes
9	0	2	1	2	Yes
10	1	2	1	2	Yes
11	1	2	1	2	Yes
12	1	2	1	2	Yes
13	1	2	0	2	Yes
14	0	2	0	2	No
15	0	2	0	2	Yes
16	0	2	0	2	Yes
17	0	2	0	2	Yes
18	2	2	2	2	Yes
19	0	0	0	0	Yes
20	0	0	0	0	Yes

0, absent; 1, present, yet poorly defined; 2, present, and well defined.

Table II. Wilcoxon test for comparison between periapical radiographs and tomographs

	Periapical radiograph	*Tomograph*
Change	0.82	1.92 median
Difference	1.00	2.00 median

Number of pairs of values: 40
Number of pairs with null difference: 3
Sum = 703.000000, Rank sum (-) = 0.00000000
Normal approximation: Z = 5.68, Probability = 0.00000001 (significant)
Alternative hypothesis: Tomograph <> Periapical radiograph
Reveals significant difference

Table III. Kendall test for analysis of inter-examiner agreement

Coefficient (Kendall) = 0.87
Chi-square = 68.38
Degrees of freedom = 39
Probability = 0.002
Number of cases = 20
Alpha (Cronbach) = 0.86

degree rotation. Data are then transferred to a computer and reconstructed. The voxel sizes can vary from 0.125 to 2.000 mm. Multiplanar reconstruction (MPR) displays the volume in high resolution in 3 planes, namely axial, sagittal, and coronal, with very little interference from artifacts.[10-12]

The diagnosis of some root fractures on conventional radiographs may be complicated, also because of the lack of specific clinical signs and symptoms.[13,14]

One limitation of intraoral radiographs is the absence of radiographic signs when the x-ray beam is not parallel to the plane of the fracture.[15] The superimposition of other structures further limits the sensitivity of radiographs for the detection of longitudinal fractures. The 2-dimensional nature of conventional radiographs with superimposition of other structures limits its ability to reveal longitudinal fractures. It was demonstrated that high-resolution images providing a 3D view of the root can improve the detection rate.[16]

Cone beam has been a great aid in endodontic diagnosis; however, little research is available on its advantages over conventional radiographs for the diagnosis of root fractures.[15,16] This study comparatively analyzed images obtained by conventional radiography and cone-beam CT (CBCT; Accuitomo 3DX) for the diagnosis of root fractures.

MATERIAL AND METHODS

Before onset, the study was revised and approved by the Institutional Review Board of Bauru Dental School, University of São Paulo. All patients were informed on the study objectives and signed an informed consent form.

The study was conducted on 20 patients with endodontically treated teeth. Some patients had suspected root fracture and reported slight discomfort, yet presented teeth with no or few specific signs and symptoms, such as extensive radiolucent images,

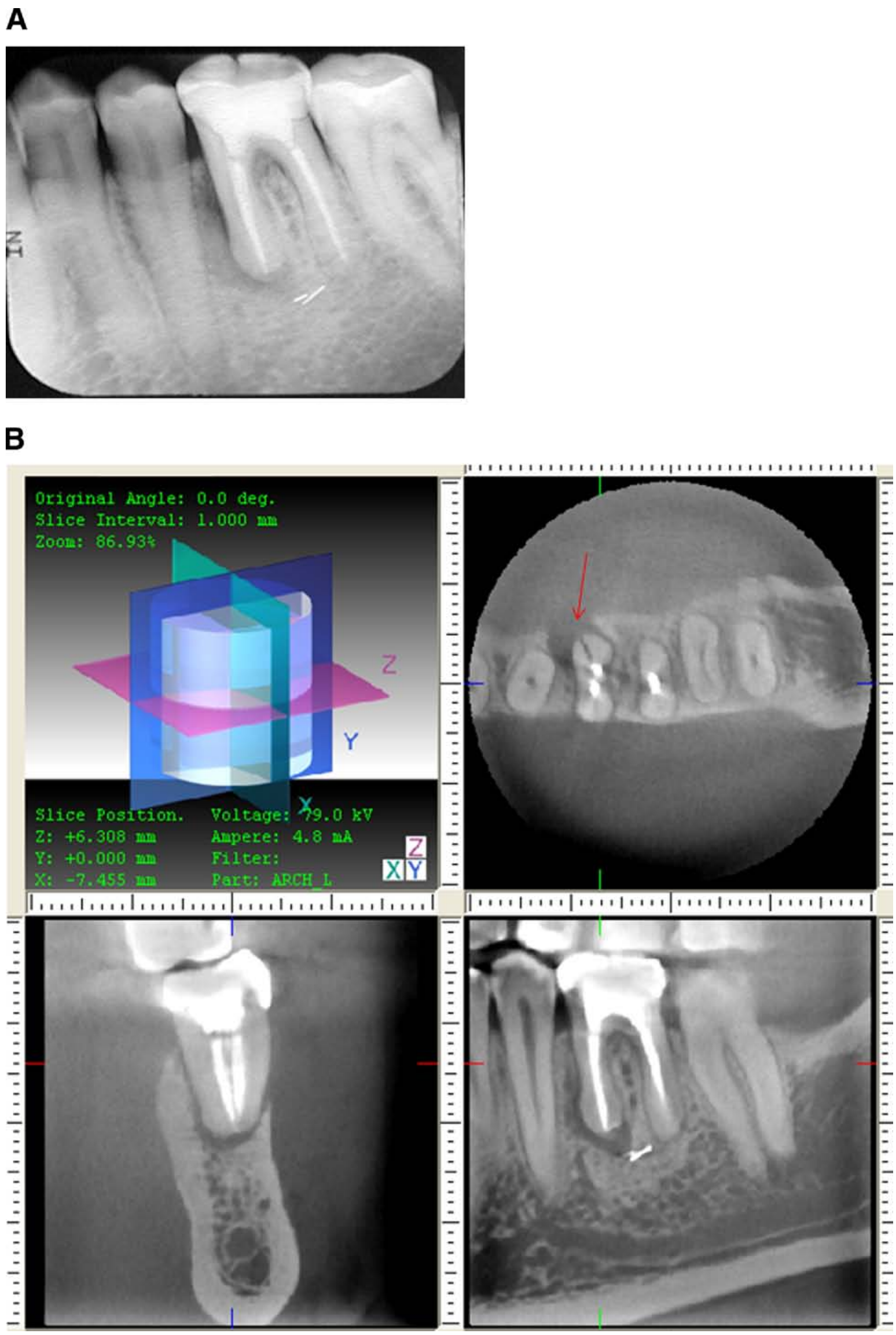

Fig 1. **A,** Images obtained by conventional periapical radiograph. **B,** Images obtained by 3D volumetric tomography (*arrow* indicates the fracture) was confirmed by checking against the symptomatology.

pain on percussion or palpation, presence of abscess and/or sinus tract, and periodontal pockets. Periapical radiographs and 3D volumetric scans were obtained from the reported regions of all patients.

Periapical radiographs were obtained with a periapical film (Kodak Insight, Eastman Kodak, Rochester, NY) using an x-ray machine Max F1 (J. Morita Mfg Corp, Kyoto, Japan) set at 58 Kv and 10 mA. Radiographs were obtained by the paralleling periapical technique with the aid of film holders (Indusbelo, Londrina Pr, Brazil). During the acquisition of radiographs, the patients were protected with lead aprons and thyroid collars.

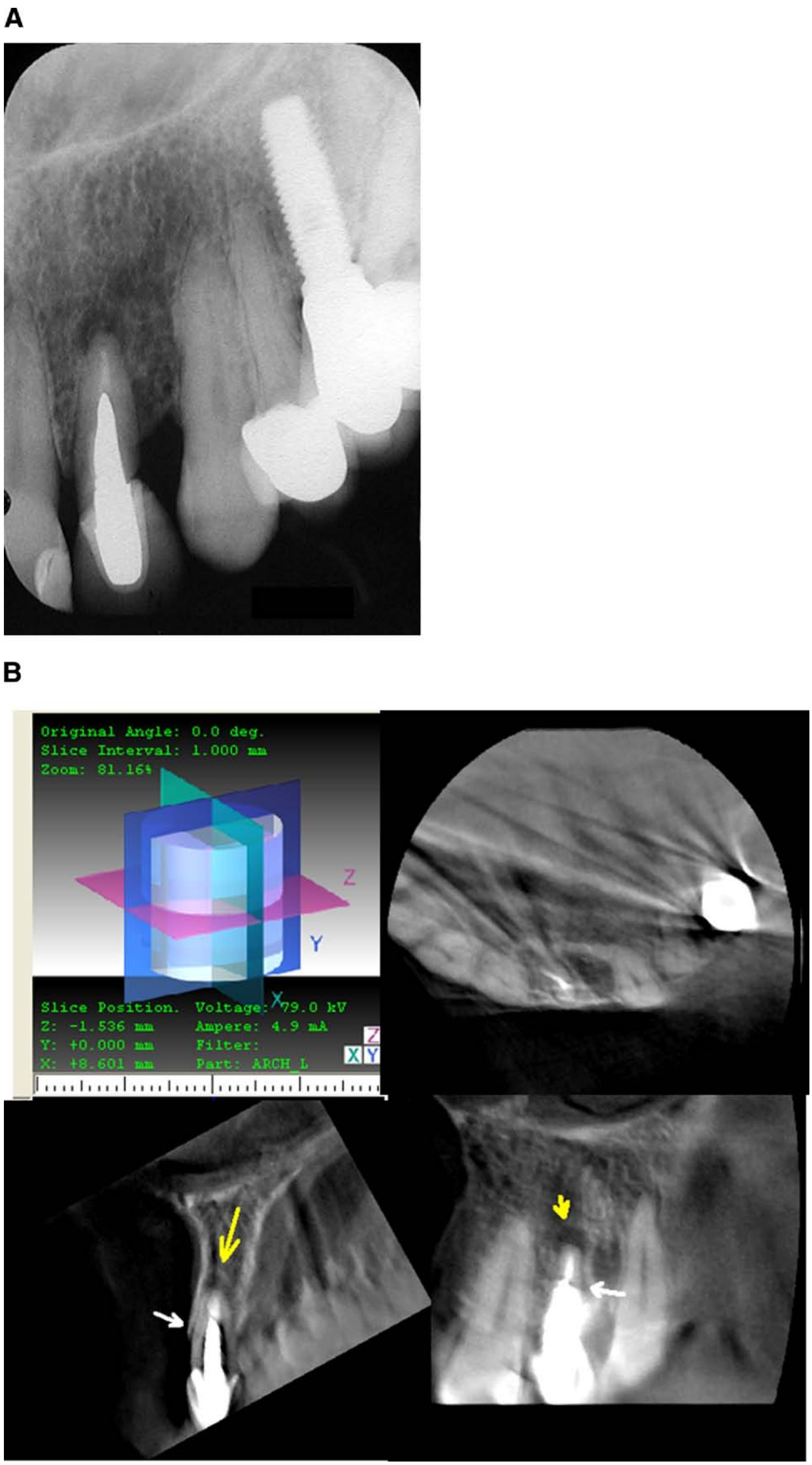

Fig 2. **A,** Images obtained by conventional periapical radiograph. **B,** Images obtained by 3D volumetric tomography (*arrows* indicate the fracture) not seen in the x-rays was not confirmed by checking against the symptomatology. **C,** Photograph shows the tooth without symptomatology.

C

Fig. 2. (Continued)

Radiographs were automatically processed in a developing automatic processor (Kodak, Eastman Kodak) and digitized on a scanner Scanjet G4050 (Hewlett-Packard Development Company, Beijing, China) at 1200 dpi.

The exposure time for periapical radiographs was 0.42 seconds for maxillary incisors, 0.53 seconds for maxillary premolars, and 0.62 seconds for maxillary molars; 0.25 seconds for mandibular incisors, 0.35 seconds for mandibular premolars, and 0.42 seconds for mandibular molars.

The 3D scan images were obtained with the Accuitomo 3DX set at 80 Kv and 5.6 mA. Two scout images were obtained for optimal scanner position, and a 17-second, 360-degree scan was acquired. Volume reconstruction was performed on dedicated software (I-dixel, J. Morita, Kyoto, Japan) with an approximate reconstruction time of 2 minutes. After reconstruction, the volumes were saved in a CD-Rom and loaded into a viewing software 3D Tomo X (IORB, Brasilia DF Brazil) for MPR evaluation.

Evaluation of radiographs and scans was performed by 2 examiners, 1 radiologist, and 1 endodontist (both specialists for more than 20 years) in a blinded manner (i.e., unaware of the symptomatology) who recorded the characteristics of root fracture on a specific form, assigning scores from 0 to 2, as follows:

0: absent
1: present, yet poorly defined
2: present, and well defined

Periapical radiographs were initially analyzed with the aid of magnifying glasses on a light box, with control of external lighting. They were scanned and visualized using the software Adobe Photoshop (Adobe Systems Inc., San Jose, CA, USA). The 3D images were analyzed on the software 3D Tomo X. The observer was able to align the 3 planes at any point by clicking a location of interest in any one of the planes. All images were displayed on a 19-inch LCD monitor (Samsung, Samsung Electronics Co., Ltd, Ridgefield Park, NJ) at their native resolution of 1600 × 1200 pixels under dimmed ambient light.

The results between images were compared by the Wilcoxon test at a significance level of 5%. The intra-reader variability was analyzed by the Kendall test.

RESULTS

Table I presents the scores assigned by examiners to root fractures observed on conventional radiographs and 3D tomographs, as well as the comparison checked against the symptomatology.

These data were statistically analyzed by the Wilcoxon test for comparison between radiographic methods, as presented in Table II. The results revealed statistically significant difference between conventional radiography compared with 3D computerized tomography in the diagnosis of root fracture.

Analysis between examiners revealed inter-examiner agreement according to the Kendall test (Table III).

Fig 1 exhibits fractures observed on 3D scans that could not be detected on conventional radiographs.

DISCUSSION

The results revealed that examiners could detect fractures on conventional radiographs in 8 and 6 cases, respectively; images were clearly observed in 2 cases and confirmed by the professional aware of the symptomatology, which was enhanced because these patients exhibited horizontal fractures and reported pain on mastication. In 6 cases with poor definition, enlarged periodontal space was observed on periapical radiographs (Table I). In 18 cases, CBCT clearly revealed the fracture, which was confirmed by checking against the symptomatology in 15 cases (Figs. 1 and 2). In the remaining 2 cases, no examiner was able to detect the root fracture using 3D imaging (Fig. 3). This discrepancy may be related to the metallic artifacts produced on the scans.

According to Meister et al.,[14] vertical fractures may cause abscesses due to bone loss and exacerbation of chronic inflammation caused by a fracture. These data were also reported by Tamse[17] and Testori et al.[18] in 58% of fracture cases.

None of the present cases exhibited abscess; 6 patients reported pressure and moderate pain on mastication.

Rud and Ormnell[19] reported that, when these signals are not clearly observed, periapical radiographs are limited for diagnosis. Moule and Kahler[3] diagnosed root fractures in 35.7% of cases when there was sepa-

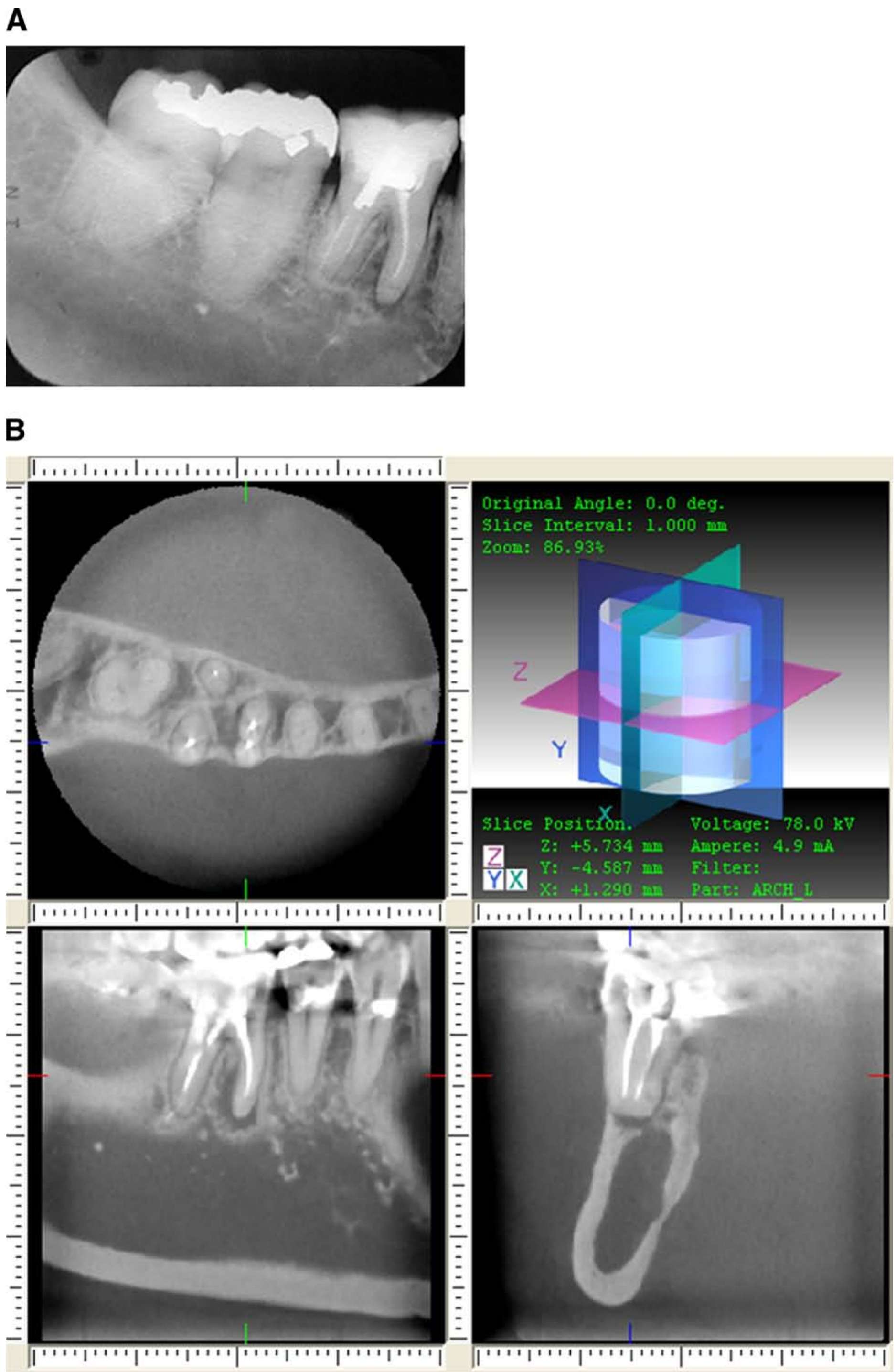

Fig 3. **A,** Images obtained by conventional periapical radiograph. **B,** Images obtained by 3D volumetric tomography , not indicates the fracture in the tomography.

ration of segments; however, it should be remembered that this separation may occur after 1 to 2 years.[15-17]

Tomography provides achievement of 3D images, thereby allowing better conclusive diagnosis. Even though Youssefzadeh et al.[15] and Mora et al.[16] observed better results in the diagnosis of root fractures by conventional tomography, false negative results were observed because of the beam hardening artifact produced between the post and gutta-percha in endodontically treated teeth.

Use of cone beam volumetric tomography has been useful for the diagnosis of fractures[15,16] and periapical lesions,[20,21] and in endodontic surgery[22] and implant planning.[23] The resolution of 3D images is also high enough for analysis of the temporomandibular joint[24] and resorptions.[25] However, few studies have addressed the diagnosis of root fractures with tomography.[15,16,26,27]

The low radiation dose to the patient should also be mentioned. The Principle of ALARA (As Low As Reasonably Achievable) should always be in consideration. Several authors had stated that CBCT scans have less radiation dosage to the patient than medical CT. Ekestubbe et al.[28] stated that the dose of 2 periapical radiographs in the molar region is 0.01/0.02 mSv and according to Ludlow et al.,[27] CBCT scans are 4 to 42 times greater than comparable panoramic examination doses and reduction in FOV (field of view) size contributes to reducing dosage to the patient. According to Hirsch et al.,[29] the Accuitomo has an effective dose of 20.02 μSv on the 4 $\times$ 4-cm FOV.

Despite the advantages provided by the CBCT technology, there are some limitations. Currently, CBCT is not found in every dental office.[30] The presence of streaking artifacts and beam hardening even in lower scale[31-33] can compromise the quality of the scan. There is still a lack of training in interpreting 3D images, thus a radiologist report is suggested for every scan because of the liability that the exam carries and that the dentists are responsible for all the information within the volume acquired.[34] According to Cotton et al.,[30] as CBCT technology evolves, clinicians will be able to adopt 3D imaging into their diagnostic repertoire. CBCT may prove to be an invaluable tool in the modern endodontic practice.[30,35]

The present results reveal that CBCT is an excellent option for detection of root fractures. It should be highlighted that, even though the CBCT reduces the presence of image artifacts compared to conventional CT, they still occur due to the presence of radiopaque materials, such as metals, gutta-percha, and sealers,[31-33] evidencing the importance of considering the signs and symptoms for diagnostic confirmation.

CONCLUSION

The CBCT provides enhanced and accurate information for the diagnosis of root fractures, thereby constituting an excellent alternative for diagnosis in the dental practice. However, clinical signs and symptoms are fundamental and very important for the diagnosis of fractures, besides auxiliary resources as the CBCT.

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