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Study of Root Canal Anatomy in Human Permanent Teeth in A Subpopulation of Brazil's Center Region Using Cone-Beam Computed Tomography - Part 1

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The aim of this study was to evaluate the frequency of roots, root canals and apical foramina in human permanent teeth using cone beam computed tomography (CBCT). CBCT images of 1,400 teeth from database previously evaluated were used to determine the frequency of number of roots, root canals and apical foramina. All teeth were evaluated by preview of the planes sagittal, axial, and coronal. Navigation in axial slices of 0.1 mm/0.1 mm followed the coronal to apical direction, as well as the apical to coronal direction. Two examiners assessed all CBCT images. Statistical data were analyzed including frequency distribution and cross-tabulation. The highest frequency of four root canals and four apical foramina was found in maxillary first molars (76%, 33%, respectively), followed by maxillary second molars (41%, 25%, respectively). The frequency of four root canals in mandibular first molars was 51%. Mandibular first premolars had two root canals and two apical foramina in 29% and 20% of the cases, respectively. Mandibular central and lateral incisors and canines presented two root canals in 35%, 42% and 22% of the cases, respectively. The navigation strategy in CBCT images favors a better identification of frequency and position of roots, root canals and apical foramina in human permanent teeth.

Key Words: Anatomy, root canal, root canal morphology, root canal treatment, root canal failure, cone beam computed tomography.

Introduction

Root canal treatment involves different operative steps, and one of the great challenges is to know the details against the internal spaces individual of each human tooth. The success of cleaning, shaping and root canal filling depend of full access of root canals. Difficulties during the root canal preparation are responsible for the lack of information of internal dental anatomy (1).

The anatomic structures of human teeth (number of roots, root canals, apical foramina, root canal isthmuses, root ramifications, root curvatures, developmental disturbances), which constitute its micromorphology have been evaluated by destructive and non-destructive methodologies (1-7). Among the methods described in the literature include decalcification, radiography, vertical and cross-sectional cutting, histological evaluation, stereomicroscopy analysis, surgical microscopy, plastic casts, scanning electronic microscopy, cone beam computed tomography (CBCT) and micro-computed tomography (MCT) (2-11).

Periapical radiography (PR) represents a method to study the root canal anatomy most used in research and clinical Endodontics. However, the real multi-dimensional of teeth structures viewed in only two dimensions leaves vulnerable this method featuring an important limitation (1,6-8,10,11). Innovative alternatives to study internal root canal anatomy, such as CBCT and MCT have been proposed (1,6-12).

Matherne et al. (10) evaluated the use of CBCT as a diagnostic tool to define the number of root canals and compared findings with the analysis of images obtained by using digital radiographs with charged coupled devices (CCD) and photostimulable phosphor plates (PSP). Seventy-two extracted teeth (maxillary molars, mandibular premolars and mandibular incisors) were evaluated using CCD, PSP and CBCT scans. Three board-certified endodontists evaluated CCD and PSP images to determine the number of root canals. CBCT images were used to establish a parameter for the comparisons. When using CCD, the number of root canals was correctly identified in 80%, 78%, and 77% of the cases when compared with CBCT, whereas when using PSP, the number of root canals was correctly identified in 81%, 76%, and 84% of the cases, when compared with CBCT. Baratto-Filho et al. (11) compared the internal anatomy of maxillary first molars using extracted teeth, clinical factors and CBCT analysis. Microscopy and CBCT are important tools that may be used to locate and identify root canals.

Clinical implications of knowledge of root canal anatomy have been related with the successful treatment obtaining full access to tooth internal areas during the sanitization process and root canal filling. Thus, based on the lack of studies using tridimensional imaging methods (with non-destructive features) to evaluate the human permanent teeth new directions of investigations must be required. The aim of this study was to evaluate the number of roots, root canals, and apical foramina in human permanent teeth in a subpopulation of Brazil´s Center by using CBCT images.

Material and Methods

Sample

The CBCT databases selected in the present study was used previously to evaluate the frequency of root canal isthmuses in human permanent teeth (1). CBCT images of 1,400 human teeth (618 white patients; 224 men; mean age of 43.4 years) was selected from January 2012 to August 2014, who were referred to the dental radiology service due to different diagnoses.

The cases included in the study were teeth without RCT, post or crowns; root canal with absence of calcification, internal or external root resorption, fully formed apex, absence of orthodontic treatment, developmental disorders and no pathologies. The study design was approved by Institutional Ethics Committee (#7968214.8.0000.5083).

Imaging Method

The specifications of acquire of the images used in this study were the same used in previous study (1,6). CBCT images were obtained using a PreXion 3D Inc. (San Mateo, CA); thickness: 0.100 mm; dimensions: 1.170 mm x 1.570 mm x 1.925 mm; FOV: 56.00 mm; voxel: 0.100 mm, 33.5 s (1,024 views). Tube voltage was 90 kVp, and tube current was 4 mA. Exposure time was 33.5 s. Images were examined using the scanner's proprietary software PreXion 3D Viewer (TeraRecon Inc, Foster City, CA) in a PC workstation with Intel Core 2 Duo-6300 processor, 1.86 Ghz (Intel Corp., Santa Clara, CA), NVIDIA GeForce 6200 turbo cache videocard (NVIDIA Corporation, Santa Clara, CA), EIZO-Flexscan S2000 monitor at a resolution of 1600X1200 pixels (EIZO NANAO Corp., Hakusan, Japan), running Windows XP professional SP-2 (Microsoft Corp., Redmond, WA).

Determination of Roots, Root Canals and Apical Foramina

The frequency of number of roots, root canals and apical foramina in all teeth was evaluated by preview of the planes sagittal, axial, and coronal. Navigation in axial slices of 0.1 mm/0.1 mm followed the coronal to apical direction, as well as the apical to coronal direction. In the teeth with three or more roots, axial navigation was personalized for each root. In maxillary molars, axial navigation started in the mesiobuccal root and was followed by analysis of distobuccal and palatal roots; in mandibular molars, the axial navigation started in the mesial root, followed by analysis of the distal root. When there were bifurcated roots, the axial navigation was concomitant in these two roots. All CBCT images were assessed by two examiners (one endodontist and one radiologist, both with 10 or more years of experience), calibrated by assessing 10% of the sample. When differences were found, a consensus was reached by discussing results with a third examiner. Statistical data were analyzed including frequency distribution and cross-tabulation.

Results

Table 1 shows the distribution of roots, root canals and apical foramina in all groups of human permanent teeth. In maxillary first molars, three roots were found in 93% of the cases, two in 6% and one root in only 1% of the cases. In maxillary second molars, three roots were observed in 69% of the cases, two roots in 29%, and only two teeth had one root. Root fusions were found in several cases.

The highest frequency of four root canals and four apical foramina was found in maxillary first molars (76%, 33%, respectively), followed by maxillary second molars (41%, 25%, respectively). Two root canals were found in the mesiobuccal roots of these teeth.

Maxillary first and second premolars had two roots in 66% and 17% of the cases, respectively, and one root in 32% and 83% of the cases, respectively. As much as 88% of maxillary first premolars and 73% of maxillary second premolars had two root canals. Six percent of maxillary first premolars presented three root canals.

Mandibular first and second molars had two roots in 95% and 91%, of the cases, respectively. The highest frequency of four root canals and four apical foramina was found in mandibular first molars (51%, 15%, respectively) while in mandibular second molars this frequency was 4% and 1%, respectively. Mandibular second molars had three root canals in 87% of the cases.

Mandibular first premolars had two root canals and two apical foramina in 29% and 20% of the cases, respectively. All mandibular second premolars presented one root and 97% of them presented one root canal. In mandibular central and lateral incisors and canines, two root canals were identified in 35%, 42% and 22% of the sample.

This map-reading technique in CBCT images provided valuable information for a better visualization and identification of frequency and position of roots, root canals and apical foramina (Figs. 1-3).

Discussion

Negligence, lack of planning, and knowledge of internal anatomy contributes significantly to the failure of root canal treatment. Each patient must be judiciously analyzed, how much the anatomic, ethnic and genetic features. The populations around the world have some peculiarities that must be respected. Anatomical variations are identified in the literature (1-5). Reports have published of a maxillary first molar presenting 7 (13) and 8 root canals (14), and a mandibular first molar with 6 root canals (15). However, the distribution and frequency of the number of roots, root canals and apical foramina in the studies of anatomy may vary depending on the sample size, the methodology used, knowledge of the tooth age, and the aspects associated with ethnic factors of the population.

In previous study, Silva et al. (16) analyzing root canal morphology of mandibular molars by using CBCT mentioned the diversity of ethnic community in Brazilian population, which derives of important genetic contributions from four continental groups, including Europeans, Africans, Asians, and Native Americans. Different characteristics of canal morphology have been also found in Indian maxillary molars from both Caucasian and Mongoloid traits (17).

The methodology used in the present study was discussed previously and appears suitable to identify the anatomic particularities of root canals (1,6,10-12). An important aspect of this study was the possibility of identify precisely anatomical details associated with the possibility of being developed in vivo without destruction of the samples and with knowledge of the tooth age, the

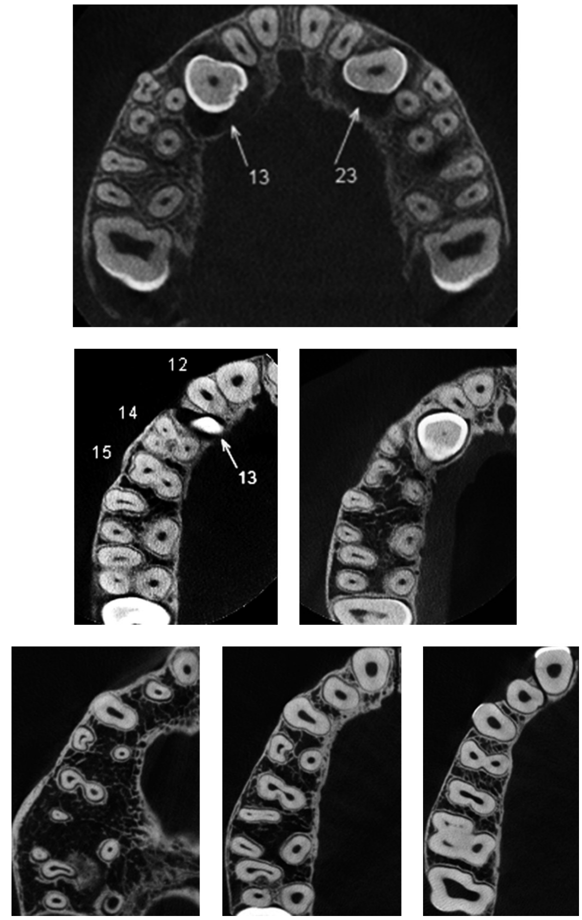

Figure 1. CBCT images of human maxillary incisors, canines, premolars and molars in axial planes.

Table 1. Distribution of frequencies (%) of roots, root canals and apical foramina in human permanent teeth

	Number of roots			Number of root canals					Number of apical foramina				
Maxillary teeth (n=700)	1	2	3	1	2	3	4	5	1	2	3	4	5
Central incisors	100	-	-	100	-	-	-	-	100	-	-	-	-
Lateral incisors	100	-	-	100	-	-	-	-	100	-	-	-	-
Canines	100	-	-	97	3	-	-	-	100	-	-	-	-
First premolars	32	66	2	6	88	6	-	-	16	81	3	-	-
Second premolars	83	17	-	25	73	2	-	-	56	43	1	-	-
First molars	1	6	93	-	1	21	76	2	-	1	64	33	5
Second molars	2	29	69	1	5	54	41	-	2	8	65	25	-
Mandibular teeth (n=700)	1	2	3	1	2	3	4	5	1	2	3	4	5
Central incisors	100	-	-	65	35	-	-	-	100	-	-	-	-
Lateral incisors	100	-	-	58	42	-	-	-	100	-	-	-	-
Canines	97	3	-	78	22	-	-	-	97	3	-	-	-
First premolars	99	1	-	70	29	1	-	-	80	20	-	-	-
Second premolars	100	-	-	97	3	-	-	-	99	1	-	-	-
First molars	2	95	3	-	3	45	51	1	-	36	49	15	-
Second molars	7	91	2	1	8	87	4	-	5	54	40	1	-

gender of the individuals selected. The sample size involved 1,400 teeth with 2,046 roots. Map-reading strategy with sequential axial slices of each root and image navigation in the coronal to apical (or in the apical to coronal) direction was used with 0.1-mm/0.1-mm axial slices (voxel size of 100 µm, PreXion 3D Inc.). However, the teeth were analyzed in all planes. Furthermore, this method overcomes the two dimensions limits of periapical radiography. The focus of the present study was to evaluate the frequency of roots, root canals and apical foramina.

Recent classical studies (4,5) addressing the distribution of the number of roots and root canals differ in some values, due the type of study used, the sample size and the population studied. In our study, three separate roots were found in 93% of maxillary first molars and 69% of second molars (Table 1). Root fusions were found in several cases. It was found in root and canal morphology of maxillary first and second molars in an Indian population a frequency of 3 separate roots in both the first (96.8%) and second molars (93.1%) (17). It was observed in our study that maxillary first molars had higher frequency of four root canals (76%) than maxillary second molars (41%), however the location of two root canals of these were in mesiobuccal root. Roots with four apical foramina were also identified in maxillary first and second molars in 33% and 25% of the cases, respectively. In North American population (18) the number of roots and canal morphology of maxillary permanent first molars found in the bilateral additional mesiobuccal canal (MB2) was 65.6%, with significant differences among age groups. The prevalence of 3-rooted maxillary first molars was higher on the right side (100%) compared with the left side (98.1%) (18). In Korean Population, additional canals were found in 63.59% of the mesiobuccal of maxillary first molars and in 34.39% of maxillary second molars (19).

In the present study, 95% and 91% of mandibular first and second molars, respectively, were found to have two roots. The frequency of four root canals and apical foramina was 51% and 15%, respectively, in the first molars, and 4%

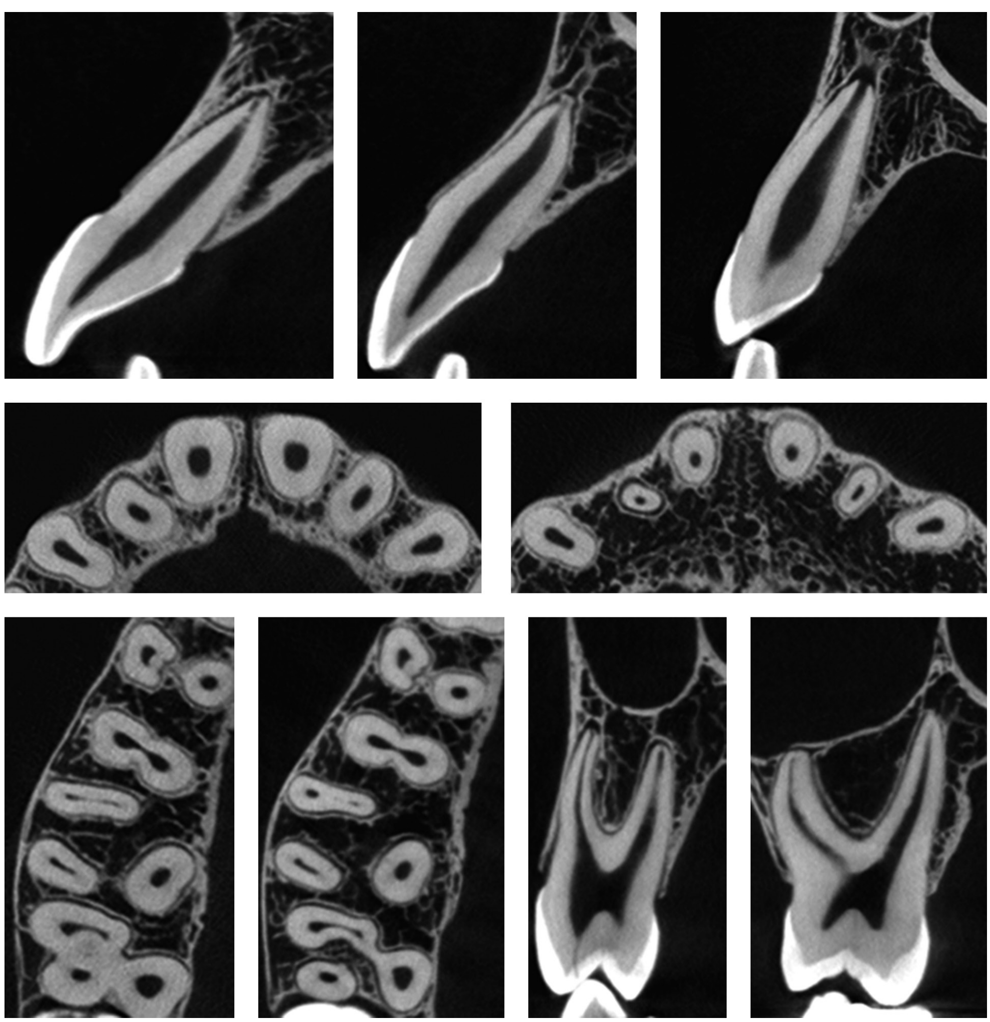

Figure 2. CBCT images of human maxillary incisors, canines, premolars and molars in different planes.

and 1% in the second molars, respectively. Silva et al. (16) evaluated root canal morphology of mandibular molars of the Brazilian population by using CBCT. A higher prevalence of 2 separate roots with 2 canals in the mesial root and 1 canal in the distal root was observed in mandibular first and second molars (74% and 54%, respectively). In a systematic review (20) about root canal anatomy of the permanent mandibular first molar, 41 studies were retrieved. Three root canals were found in 61.3% of the teeth, 4 canals in 35.7%, and 5 canals in approximately 1%. Root canal configuration of the mesial root revealed 2 canals in 94.4% and 3 canals in 2.3% of the teeth. Root symmetry and root canal morphology of maxillary and mandibular molars was evaluated using CBCT by Plotino et al. (21). Maxillary first molars were symmetrical in 71.1% of the patients, whereas maxillary second molars were symmetrical in 79.6%. About 30% of the mandibular first molars and 20% of the mandibular second molars were asymmetrical. Symmetry ranges from 70% to 81%. These variations in symmetry should be taken in high consideration when

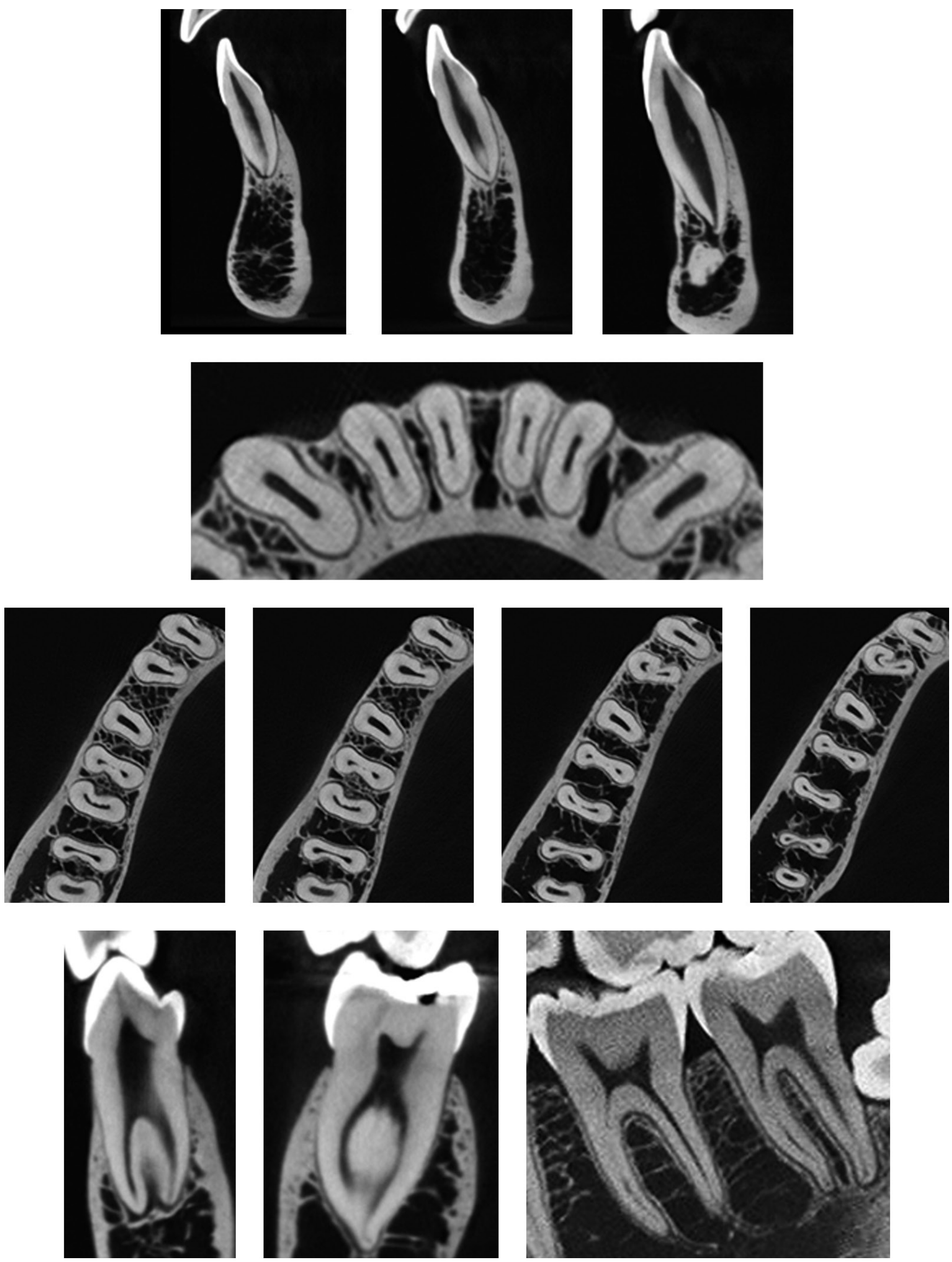

Figure 3. CBCT images of human mandibular incisors, canines, premolars and molars in different planes.

treating two opposite molars in the same patient, because their anatomy may be different in up to 30% of the cases.

In the present study, it was identify two root canals and two apical foramina in mandibular first premolars in 29% and 20%, respectively. While, it was detected 100% of the mandibular second premolars with one root, and 97% with one root canal. Based on a literature review (22), approximately 98% of mandibular first premolar present single-rooted. The incidence of two roots was 1.8%. Three roots when reported were found in 0.2% of the teeth studied. Four roots were rare and were found in less than 0.1% of the teeth studied. Studies of the internal canal morphology revealed that a single canal was present in 75.8% of the teeth. Two or more canals were found in 24.2% of the teeth studied. A single apical foramen was found in 78.9% of the teeth, whereas 21.1% had two or more apical foramina. In other reviewer (23), mandibular second premolars showed single-rooted in 99.6%. The incidence of 2 roots (0.3%) and 3 roots (0.1%) was extremely rare. Anatomic studies of the internal canal morphology found that a single canal was present in 91.0% of the teeth. A single apical foramen was found in 91.8% of the teeth. The incidence of more than 1 root (0.4%), more than 1 canal (9.9%), and more than 1 foramen (8.2%) was lower than that of the mandibular first premolar tooth (2.0%, 24.2%, and 21.1%, respectively).

In the present study, two root canals were identified in 35%, 42% and 22% of mandibular central and lateral incisors and canines, respectively (Table 1). In a Chinese subpopulation, Han et al. (24) analyzed the root canal configuration of the mandibular anterior teeth using CBCT. All of the incisors in this study had 1 root, and 1.32% of the canines had 2 roots. The prevalence of 2 root canals in the lateral incisors (27.36%) was higher than that in the central incisors (15.71%) and the canines (6.27%). In this Chinese subpopulation it was verified a high frequency of 2 root canals in the mandibular anterior teeth.

Anatomical variations can occur in any tooth. This fact enhances the use of more precise technology to complete evaluation and treatment planning, as in the case of CBCT. The frequencies of root, root canals and apical foramina found in this study may be explained by differences on study method, sample size, tooth age. The sex and ethnicity are often not known in ex-vivo studies, whereas age and gender may be controlled in in-vivo studies (1).

Clinical impact of full access in all root canal walls may have influence on sanitization process and root canal filling and possibility the successful treatment (25). In summary, the navigation strategy in CBCT images is favorable for a precise identification of position of roots, frequency of root canals and apical foramina found in a subpopulation of Brazil's Center Region.

Resumo

O objetivo deste estudo foi avaliar a frequência de raízes, canais radiculares e forames apicais em dentes permanentes humanos por meio de imagens de tomografia computadorizada de feixe cônico (TCFC). Imagens de TCFC de 1.400 dentes de um banco de dados avaliadas anteriormente (1) foram usadas para determinar a frequência do número de raízes, canais radiculares e forames apicais. Em todos os dentes foi realizada avaliação por visualização em planos sagital, axial e coronal. Foram feitas navegações em cortes axiais de 0,1 mm/0,1 mm em sentido cervical para a direção apical, bem como de apical para cervical. Todas as imagens foram avaliadas por dois examinadores. Os dados estatísticos foram analisados, incluindo distribuição de frequência e tabulação cruzada. A maior frequência de quatro canais radiculares e quatro forames apicais foi encontrada em primeiros molares superiores (76%, 33%), seguido de segundos molares superiores (41%, 25%). A frequência de quatro canais radiculares nos primeiros molares inferiores foi de 51%. Primeiros pré-molares inferiores apresentaram dois canais radiculares e dois forames apicais em 29% e 20%, respectivamente. Os incisivos centrais e laterais inferiores e caninos apresentaram dois canais radiculares em 35%, 42% e 22% dos casos, respectivamente. A estratégia de navegação em imagens de TCCB favorece uma melhor identificação de frequência, posição das raízes, canais radiculares e forames apicais em dentes permanentes humanos..

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