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Method to Identify Accessory Root Canals using a New CBCT Software

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This study describes a methodology to identify accessory root canals using the e-Vol DX software in CBCT scans. Accessory root canals are strategic shelters for microorganisms present in root canal infections. The identification of these small canals in periapical radiographic exams has limitations, besides being markedly limited accessibility to the action of endodontic instruments and to the antimicrobial agents. A significant number of accessory canals have sufficient diameters to be visible on cone-beam computed tomography (CBCT) images of high spatial resolution. Therefore, it may go unnoticed or even confused when there is no specific training for this type of diagnosis. The methodology consists in establishing thin slices (0.1mm or smaller) obtained from coronal, sagittal and axial slices. The method consists of the following steps: during navigation along the long axis of a root canal when finding a possible hypodense line of main root canal in a tomographic section (axial, sagittal or coronal), the navigation software lines of the multiplanar reconstruction (MPR) must be adjusted so that they are parallel and perpendicular to the hypodense line (parallax correction). Then, after judiciously adjusted, the accessory canal image will invariably appear as a line on one of the MPR tomographic slices, another line on another slice, and a dot on the third slice. The three sections of the MPR present images with the "line-line-dot" sequence. In this way, it is possible to identify an accessory root canal and also visualize it in volumetric reconstruction in a specific filter. The application of this method is easy to employed and may benefit the diagnosis when you want to visualize accessory root canals and distinguish it from root fracture line.

Key Words: Accessory root canal, apical periodontitis, cone-beam computed tomography, diagnosis, imaging method, root canal anatomy.

Introduction

Successful root canal treatment is dependent on the professional mastering and overcoming the challenges of the complex internal anatomy of the root canal system (1). The steps of emptying, shaping, sanitization and filling of the root canal system have the internal anatomical scenario as their field of action. The sanitization process of infected root canal implies accessing all internal spaces of the tooth, which may represent obstacles that are difficult to overcome and determinants of success (1-3). Knowledge of the details of the internal anatomy regarding the dental group, number of roots, number of canals, apical foramina, root canal shapes, accessory root canals, root isthmus, developmental disorders are important for endodontic planning and clinical decision-making (3 -6).

An imaging exam that is routinely still used in endodontic diagnosis is periapical radiography (1,5-7). The endodontic planning and the operative procedures involve the identification of different aspects observed in radiographic images, including internal morphology complex, presence of root canal sealing material, dental development disturbances, and progression, regression and maintenance of apical periodontitis (1-3).

The limitations of two-dimensional imaging exams such as periapical radiography have been frequently exposed, such as the overlapping of important anatomical structures and occult periapical lesions, anatomical structures of clinical importance such as the root ramifications. The conventional imaging exams are two-dimensional representations of three-dimensional structures whose morphological features may not be reflected in radiographic images (7-11).

Based on the technological advances of recent years, new imaging modalities have been added to endodontic clinical application as viable diagnostic tools the cone-beam computed tomography (CBCT) (9-13). This multidimensional imaging exams provides detailed high-resolution images which has been used in clinical practice and endodontics researches. The accuracy of CBCT images to identify anatomic structures and pathologic alterations compared to panoramic and periapical radiographs has been shown to reduce the incidence of false-negative results (12,13).

Accessory root canals may serve as a safe haven for microorganisms in infected root canals (14-17), with improbable access to endodontic instruments and antimicrobial agents (14-20). The frequency of accessory root canals varies, depending on the methodology and the dental group analyzed (diaphanized teeth, periapical radiographs, microtomography, CBCT) (14-20).

The use of periapical radiographic exam to determining the presence of accessory root canals expresses another limitation of this type of conventional imaging exam (12). However, even with the use of CBCT scans, it is essential to navigate through the image and carefully investigate the existence of an accessory root canal, as it is not a simple and common task. This article presents and describes a method to determine accessory root canals analyzed by a new CBCT software.

Material and Methods

The identification of anatomical microstructures such as accessory root canals, the exact visualization of occult periapical lesions and inflammatory root resorptions, added to the absence of compromise of the undesirable effects of white contrast artifacts has highlighted the potential of the e-Vol DX CBCT software (CDT Software, São José dos Campos, SP, Brazil) (12). This software presents compatibility with all current CBCT scanners with the capacity to export DICOM Data, with a more comprehensive brightness and contrast library; custom slice thickness adjustment, custom sharpening adjustment; advanced noise reduction algorithm that enhances image quality; preset imaging filters, dedicated endodontic volume rendering filters with the ability to zoom the image over zoom in the image of hundreds of times (3D reconstructions) without loss of resolution and automatic imaging parameters customization for better standardization and opportunities for research; capture screen resolution of 384 dpi. The presented method to determine accessory root canals was proposed using this new e-Vol DX software from a CBCT scan and with the developed of a specific filter may visualize this anatomic structure in volumetric reconstruction.

This method proposed was tested in a sample of more than 500 CBCT scans of patients with different diagnoses who were referred to the dental radiology service of private clinics (Radiological Center of Orofacial Images (CROIF, Cuiabá, Brazil). The methodology consists in locating the accessory canals from longitudinal navigation on 0.1-mm/0.1-mm tomographic slices of CBCT scans, from the pulp orifice to the apical foramen and from the root apex to the coronal region. The reference is the main canal with the use of multiplanar reconstruction (MPR) adjusted so that all 3 planes remain parallel and perpendicular to the analyzed canal, with corrections according to the curvature of the canal. In teeth with more than one canal, each canal has to be analyzed individually. Considering the location of a hypodense line of the main canal in a tomographic slice, the navigation line with multiplanar reconstruction (MPR) must be adjusted so that it is parallel and perpendicular to this hypodense line (parallax correction). After this image adjustment, during navigating at the main canal will appear a line on one of the tomographic slices of the MPR, another line on another slice, and a point on the third slice will appear as a form. The three sections of the MPR present images with the line-line-dot sequence. In this mode, it is possible to identify the accessory canals and visualize it in volumetric reconstruction using another specific filter (Figure 1-3).

Care should be taken when finding the presence of a lateral hypodense area in the root (osteolysis area). In this case, the described procedure is repeated, the cursor is tilted until it is parallel to the hypodense line of the main canal and perpendicular to this line (to the reference areas - interest) (parallax adjustment), and the navigation proceeds, where the presence of a line in a tomographic slice, another line in another tomographic slice and a point in the third tomographic slice defines the identification of an accessory canals. In the presence of metallic artifacts, the Blooming Artifact Reduction (BAR) filter is used. When the shapes of line, line and an amorphous image appear in tomographic sections, they do not fit as accessory canals. In the clinical cases presented (Fig. 1-3) here, the use of methodology increased the amount of information for detection of accessory root canals. The use of volumetric reconstruction filter significantly improved the visualization of the accessory canal in areas of difficult perception.

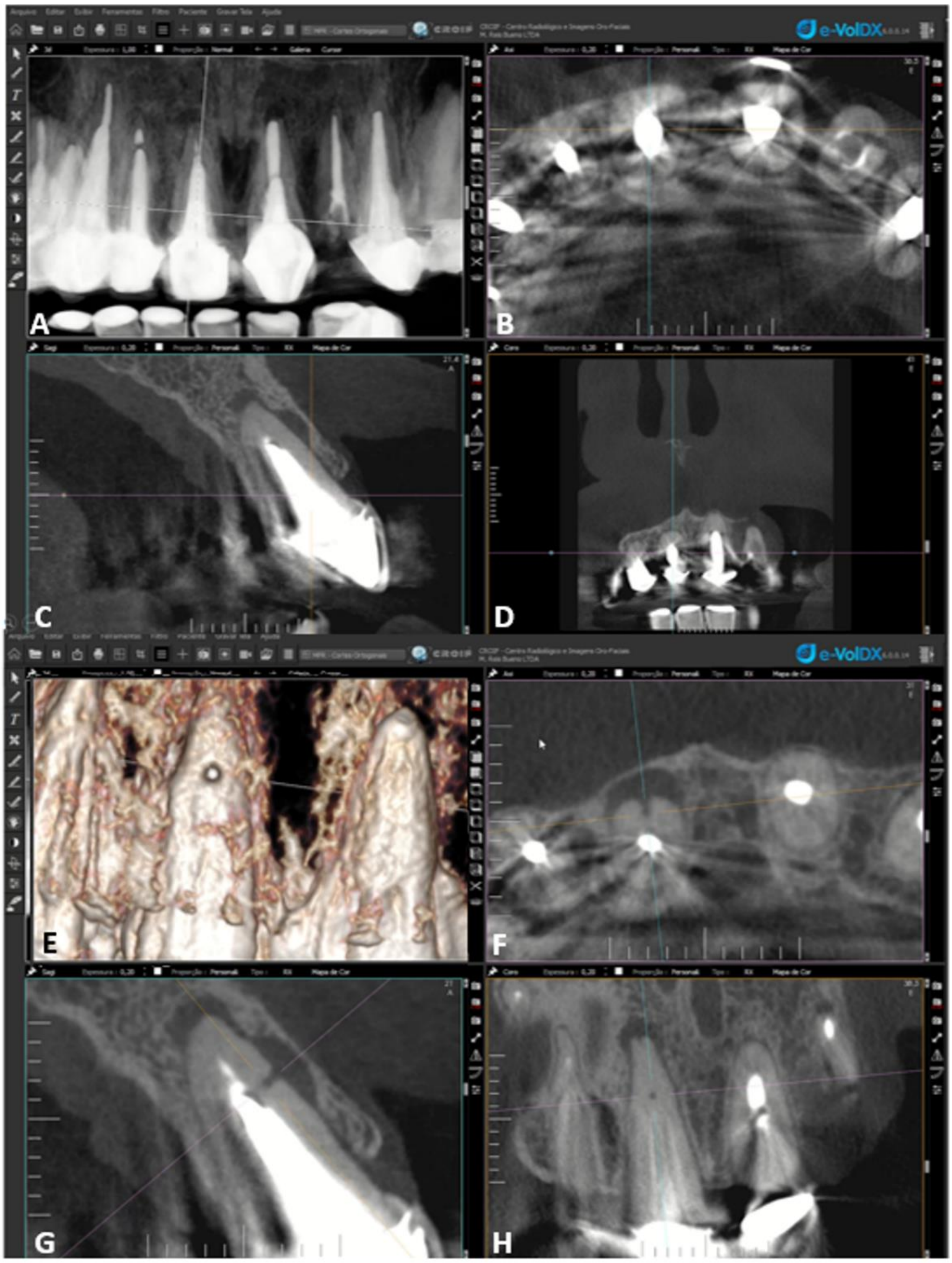

Figure 1 (A-H). Characterization of the described methodology for identification of accessory root canal in apical third and buccal surface of a maxillary central incisor visible in tomographic slices in multiplanar reconstructions (MPR). MPR (F, G and H) in the form of a line in a tomographic slice (F); in the form of a line in second tomographic slice (H), and in form of point (3) in third tomographic slice. The sequence in tomographic slices, line-line-point, characterizes the presence of accessory root canal. Accessory canal image visible in volumetric reconstruction filter (E).

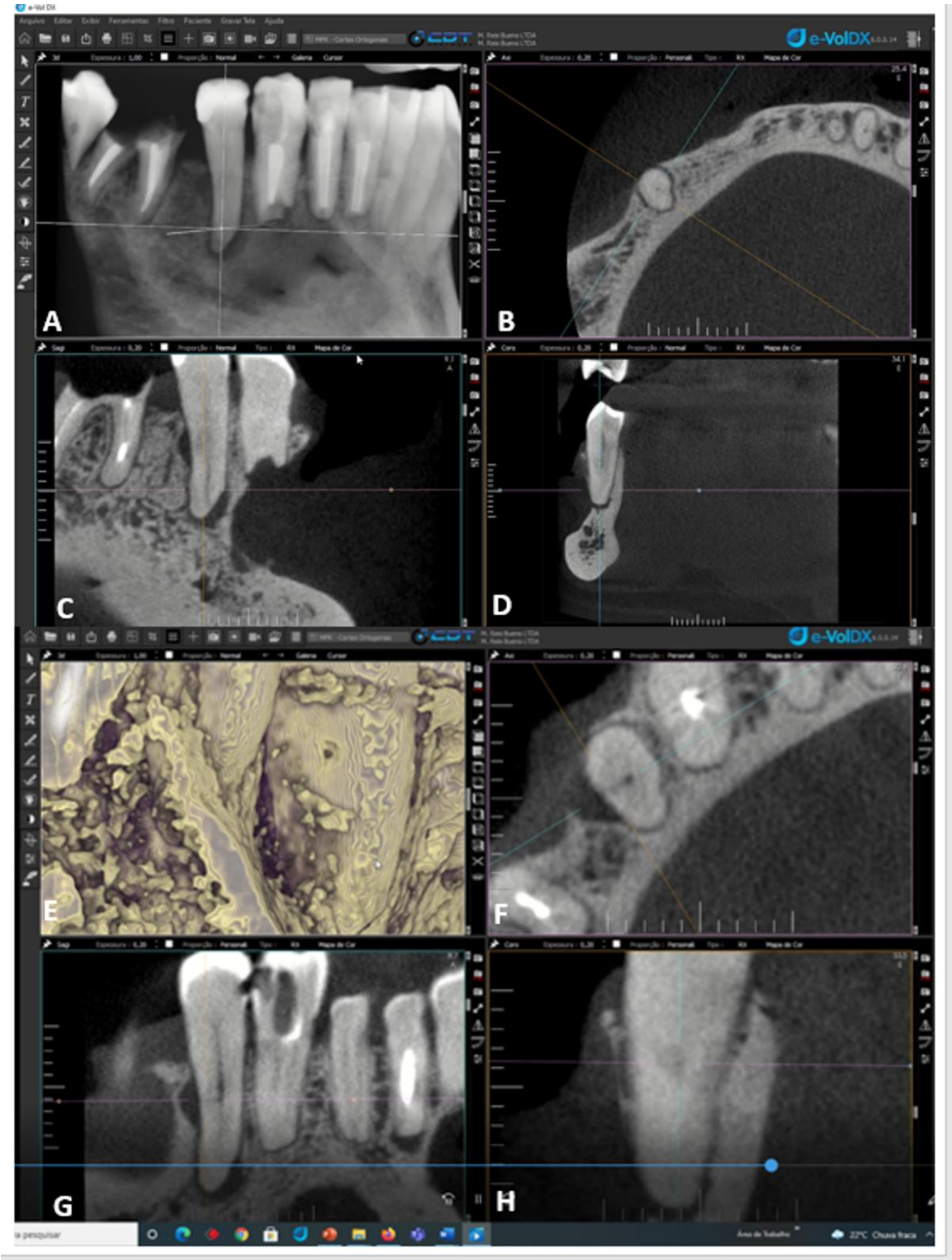

Figure 2 (A-H). Identification accessory root canal in apical third and distal surface of a mandibular first premolar incisor visible in tomographic slices in multiplanar reconstructions (MPR). MPR (F, G and H) in the form of a line in a tomographic slice (F); in the form of a line in second tomographic slice (G), and in form of point (H) in third tomographic slice. The sequence in tomographic slices, line-line-point, characterizes the presence of accessory root canal. Accessory canal image visible in volumetric reconstruction filter (E).

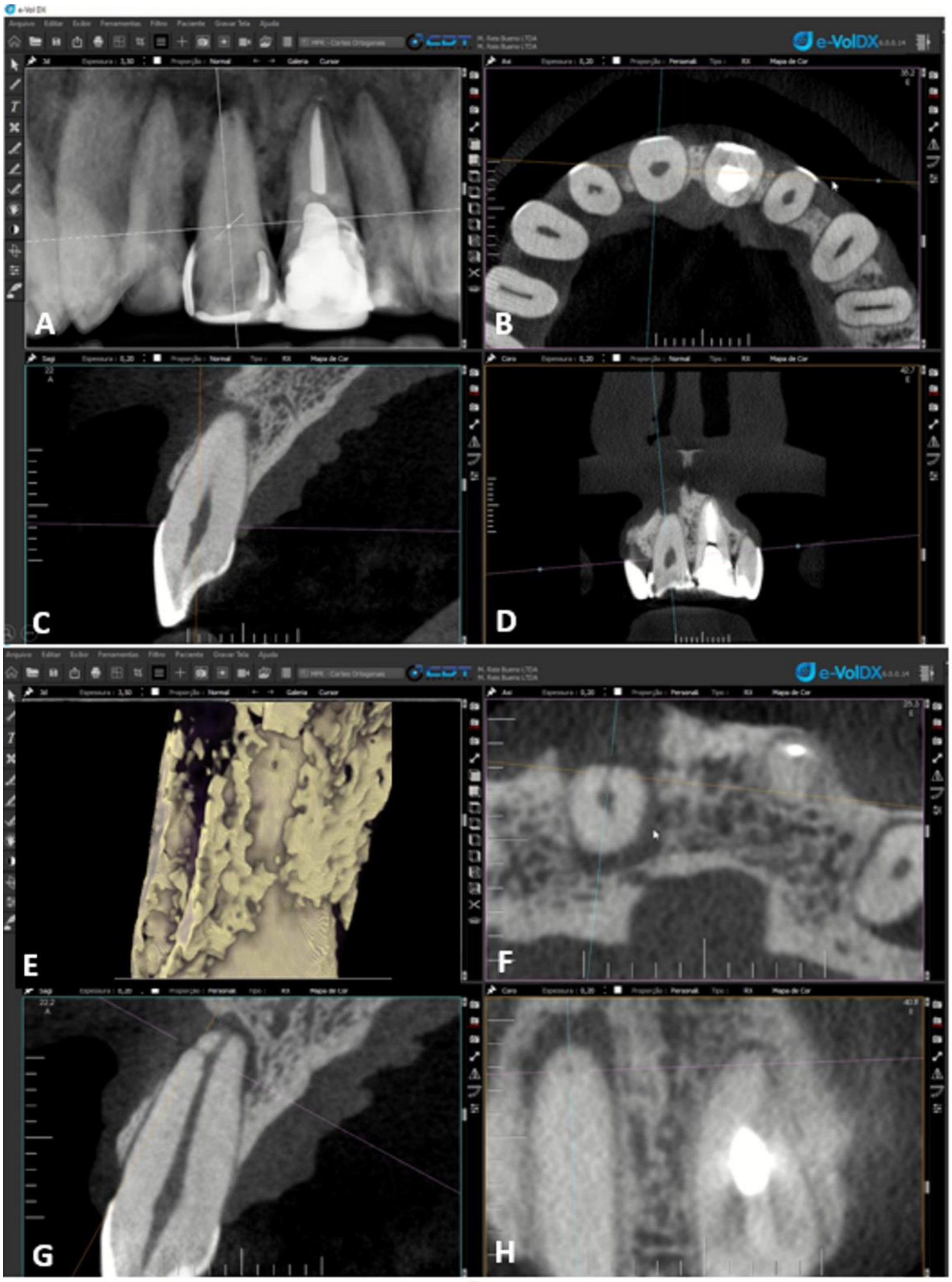

Figure 3 (A-H). Description of methodology for visualization of accessory root canal in apical third and buccal surface of a maxillary central incisor visible in tomographic slices in multiplanar reconstructions (MPR). MPR (F, G and H) in the form of a line in a tomographic slice (F); in the form of a line in second tomographic slice (G), and in form of point (H) in third tomographic slice. The sequence in tomographic slices, line-line-point, characterizes the presence of accessory root canal. Accessory canal image visible in volumetric reconstruction filter (E).

Discussion

The method to visualize accessory root canals through the CBCT e-Vol DX software brings benefits for the clinical practice of root canals treatment. It has the ability to define the sanitization process in a more hard-hitting way, thus preventing future problems of maintenance of root infection. This type of root ramifications may routinely go unnoticed, both on periapical radiographs and even on CBCT exams. The professional must have good training and master the technique to correctly handle 3D images, with the perspective of dynamic navigation, domain and rational use of the tools in the e-Vol DX software package.

The greatest impact on endodontics obtained with the incorporation of CBCT in clinical practice was the greater assertiveness in clinical decision-making. The accurate diagnosis of microstructures and anatomical details that escaped the usual visibility and detection due to their subtleties could now be identified. In this sense, a greater number of information can be acquired for the management of the diagnosis, with the addition of expressive benefits such as predictability of results in complex clinical cases (11-13).

The addition of important data for diagnostic imaging, starting with the participation of 3D imaging exams (CBCT scans) has contributed in several ways to endodontics (4-6,11-13,12,21-26), such as specification of anatomical dental structures, identification of occult periapical lesions, support for the periapical lesion index (CBCTPAI) and detection of root resorption. Another particularity is in the characterization of several study and research methodologies, including: relationship of the apexes of the teeth (distances) with noble anatomical structures (arteries, maxillary sinus, mandibular canal, etc.; determination of the stages of permanent human dental development; method of identifying the radius of curvature of root canals; method for determining root canal anatomic dimension; frequency of root canal isthmus in human permanent teeth; frequency of shape of root canals; frequency of apical foramen position in relation to proximal root surfaces; navigation strategy to identify root perforations, root fractures, presence of fractured instruments; development of white contrast artifact reduction filter; in digital endodontics planning guides for access endodontic (Endoguide), and guided access in periapical surgery. Specific e-Vol DX tools have been developed and are able to support adding values and new information in the imaging exam (4-6,11-13,12,21-25). Bueno et al. (13) discussed the use of CBCT cinematic rendering for clinical decision-making, teaching, and research in endodontics. The photorealistic cinematic rendering of maxillofacial structures provided powerful details for the investigation, which certainly increased diagnostic accuracy and had an impact on clinical decision-making. High dynamic range resulting from the natural photorealistic quality of images positively affected the visualization of details used for the analysis of shape and depth.

The new perspectives with technological advances in CBCT imaging exams include (12): sharper images and higher magnification, more high-quality diagnostic tools, cleaner images, artifact reduction, mechanical movement stabilizer, radiation dose reduction, as well as sophisticated software applications for subtle 3D shape separation, shape transformation to STL, CT superposition, volume measurement, 3D functionality, full dynamic scope of the DICOM format, sub-millimeter measurements, multidirectional image tracing, tracking curved images, oblique position recorder, position indexing including 3D, sharing information with dynamic files and cloud information sharing.

The clinical benefits to be added to root canal treatment using advances in imaging techniques should be better understood. CBCT imagens provides 3D images of the anatomical structure that is more detailed and comprehensive than conventional 2D images. A better quality and number of information can be viewed with volumetric reconstruction (13).

The map-reading dynamic on CBCT images with application of specific filters might reveal essential details for a diagnosis and directing to the best treatment alternative. In summary, the application of this methodology is easy, but requires proper training and may benefit the diagnosis when you want to visualize accessory root canals. Further studies should be developed to validate this methodology presented and certify the potential clinical application of this new CBCT e-Vol DX software.

Conclusion

The suitable training and handling of CBCT scans may reveal tiny accessory root canals that may go unnoticed in 3D imaging exams. A method for manipulating CBCT images may aid in the diagnosis to identify accessory root canals, with easy application and benefits in clinical practice.

Resumo

Este estudo descreve um método para identificar canais radiculares acessórios usando o software e-Vol DX em imagens de TCFC. Os canais radiculares acessórios constituem abrigos estratégicos aos micro-organismos presentes nas infecções endodônticas. A identificação destes pequenos canais em exames radiográficos periapicais apresenta limitações, além de apresentar baixa acessibilidade natural a ação dos instrumentos endodônticos e dos agentes antimicrobianos. Os canais acessórios apresentam diâmetros suficientes para ficarem visíveis em imagens de tomografia computadorizada de feixe cônico (TCFC) de alta resolução espacial. Porém, podem passar despercebidos ou até confundidos quando não ocorrer treinamento específico para este tipo de diagnóstico. A metodologia consiste em estabelecer finos slices (0,1 mm ou menor) obtidos a partir de cortes coronal, sagital e axial. O método consiste nos seguintes passos: ao encontrar uma linha hipodensa de um canal radicular principal em um corte

tomográfico (axial, sagital ou coronal) deve-se ajustar as linhas de navegação da reconstrução multiplanar (MPR) para que fiquem paralelas ao canal principal e perpendiculares a esta linha hipodensa (correção de paralaxe). A seguir, depois de criterioso ajuste da imagem em busca do canal acessório, aparece invariavelmente como uma linha em um dos cortes tomográficos da MPR, outra linha em outro corte e um ponto no terceiro corte. Os três cortes da MPR apresentam imagens com a sequência linha-linha-ponto. Desta maneira, pode-se identificar um canal acessório e visualizá-lo em reconstrução volumétrica em filtro específico. Esta metodologia é fácil de ser aplicada e pode beneficiar o diagnóstico quando se deseja identificar canais radiculares acessórios e distingui-lo de linha de fratura radicular.

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