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Method to Determine the Root Canal Anatomic Dimension by using a New Cone-Beam Computed Tomography Software

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This study discusses a method to determine the root canal anatomic dimension by using e-Vol DX software. The methodology consists in initially establishes the correct positions which will be measured, define the point on the edge of the anatomical structure, and next adjust the intermediate position in the grayscale of CBCT image. Thin sections (0.10 mm) are obtained from 3D reconstructed slices in the filter for the measurements, in order to determine the edge of the anatomical surface in the axial plane. A replication of positions in 3D mode is done in multiplanar reconstruction (MPR) of CBCT images, where the correct position is established with the aid of a positioning guide. The 3D density is adjusted so that it is in the same dimension as the 2D image, and a dimension calibration occurs to the point where there is a coincidence between 3D and 2D. This calibration is done only at the beginning of the measurement. Next, the intermediate position of the division between the grayscale is verified in the CBCT scan. Once one side has been completed, it is moved to the other side and follows the same guidelines described above. When setting the position of the courses in the other margin, being that 2D mode is used as reference. Thus, one obtains the required measure, being checked in the two points. The creation of this filter in the e-Vol DX software for measurement, and its appropriate management, allows more effective applications when it is desired to obtain diameters of anatomical structures.

Key Words: Root canal anatomy, root canal preparation, cone beam computed tomography, e-Vol DX.

Introduction

Root canal treatment involves the removal of inflamed or infected pulp tissue, or even healthy. Particularly, the root canal preparation and filling and coronal sealing constitutes important phases which collaborate with high rates of success (1, 2). Among the operative procedures include the mechanical action of endodontic instruments during emptying and shaping, the microbial control carried out by irrigation substances and intracanal dressing, and sealing of the spaces present with filling materials (3,4).

The planning and execution of root canal treatment requires the valuable assistance of imaging exams that identify the anatomical structures that escape the direct vision of the professional. The identification of different aspects may be observed in radiographic images, such as anatomic complexity, apical limit for root canal preparation and filling, presence of material in the root canal, dental development disturbances, and progression, regression and maintenance of apical periodontitis (AP). Conventionally, the periapical radiography have been used in the endodontic routine (4), even with its known limitations of visualization of structures in two-dimensional planes (5,6).

The incorporation of cone-beam computed tomography (CBCT) in dental practice (7,8), and in special in endodontic clinical as an additional resource in the diagnosis, planning and follow-up has contributed significantly to the establishment of more efficient protocols. The accuracy of CBCT images to identify anatomic and pathologic alterations compared to panoramic and periapical radiographs has been shown to reduce the incidence of false-negative results (6).

During root canal instrumentation, the enlargement of root canal space favor the sanitization process with better access to the action of irrigating agents, intracanal medications, and root canal filling, altering the internal geometry of the root canal (2, 4).

A contemporary discussion has emphasized that even using flexible motor-driven instruments, untouched areas have been identified during the preparation of root canals (9-11). At the same way, studies have shown imprecision to determine the anatomical diameter by endodontic instrument at apical length (12,13); however, the cervical preparation may allow establishing the anatomical diameter with smaller discrepancy values between file size and the anatomical diameter (13).

The achievement of an ideal form after completion of root canal preparation is challenging to the endodontist, and it requires a thorough knowledge of the internal anatomy, the characteristics of the endodontic instruments, and a psychomotor ability of professional for proper instrumentation (4).

Root canals anatomy complex prevents the appropriate access of endodontic instruments on root canal wall, which interfere on the quality of bacterial decontamination. Previous knowledge of the root canal dimension may favor a better and more precise planning for root canal preparation, considering the characteristics and dimensions of the endodontic instruments and which instrument diameter the root canal can be enlarged. Thus, this article describes and discusses a method to determine the root canal anatomic dimension by using a new cone-beam computed tomography software (e-Vol DX).

Material and Methods

The development of the e-Vol DX software (CDT Software, Bauru, SP, Brazil) enables high quality CBCT images, visualization of complex anatomical structures, precise identification of occult lesions (possibly undetected), reduction of artifacts with capability to import, work with DICOM files, and standardize image adjustments to analyze CBCT volumes from different sources (14).

An operational tool of this new software was developed to obtain measurements of anatomical structures with real dimensions, in an approximation equivalent to 0.001 mm.

The measuring instrument was developed based on the difficulties of performing precise measurements of anatomical structures, of defining points on dental surfaces, and of adjusting the correct positions to establish the measurements. The major challenge is the demarcation of

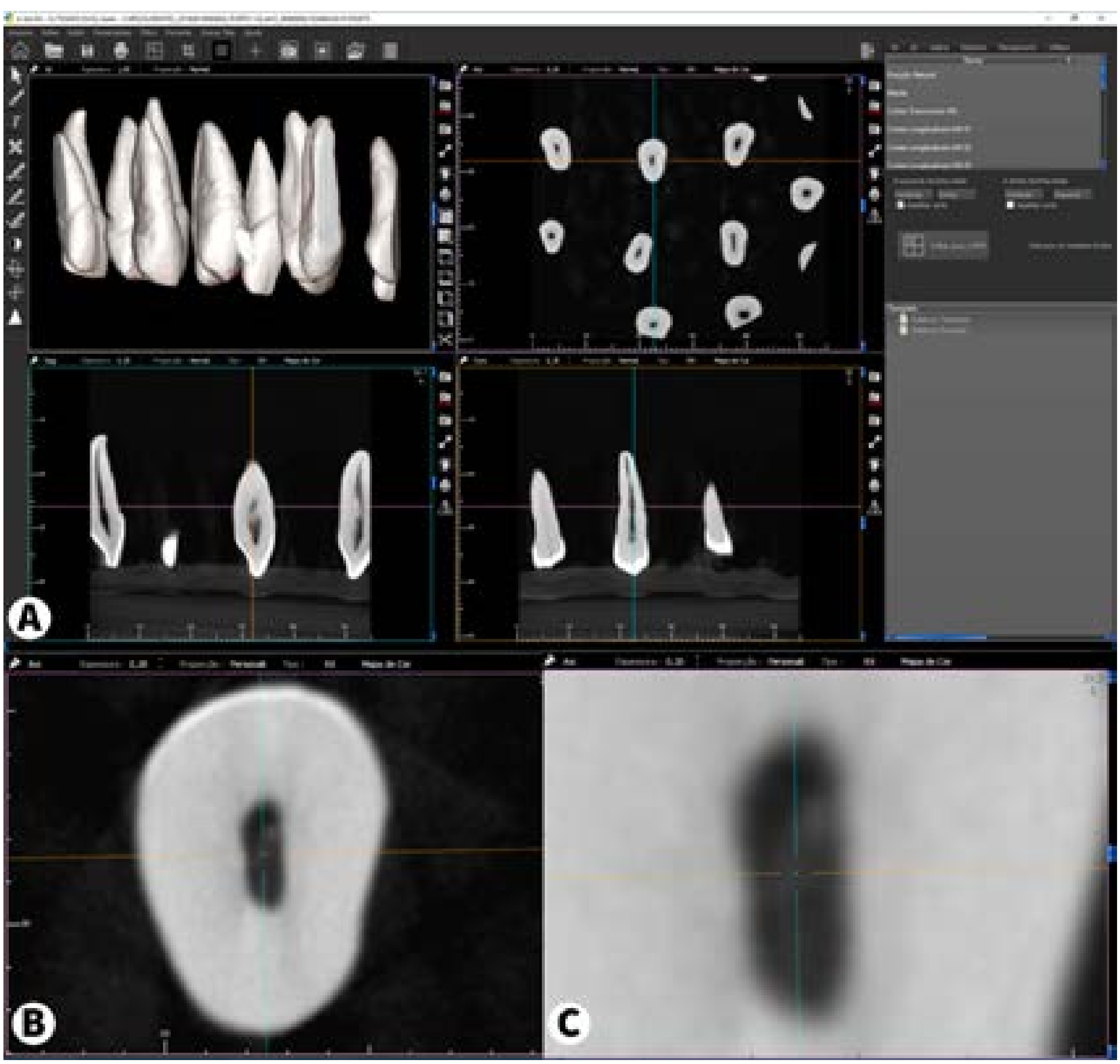

Figure 1. (A) Initial presentation of CBCT reports with slices in multiplanar reconstruction (MPR); (B,C) greater magnification of the image A in axial slice.

the boundary surface to be measured, and the midpoint between the grayscale in CBCT images. It should be considered that the images are very small dimensions, which makes it difficult to repeat the measurements, besides establishing confounding variables (biases) for the correct delimitation of the reference point.

The presented method to determine the root canal anatomic dimension was developed with a new e-Vol DX software, from a CBCT image, and with the use of a specific filter made in 3 dimensional (Fig. 1).

The methodology consists in initially establishes the correct positions which will be measured, and defines the point on the edge of the anatomical structure and next adjust in intermediate position in the grayscale of CBCT image (Fig. 2). Thin sections (0.10 mm) are obtained from 3D reconstructed slices in the filter for the measurements, in order to determine initially the edge of the anatomical surface in the axial plane. The positions delimited with markings are checked in other planes in CBCT scans. A replication of positions in 3D mode is done in multiplanar reconstruction (MPR) of CBCT images (present in an access box in the e-Vol DX), where the correct position is established with the aid of a positioning guide. When it is observed that the positioning guide is not in the correct position of the margin to be measured, the adjustment is made until to obtain this position, and there is coincidence of the edge line with the center of the guide. The 3D density is adjusted so that it is in the same dimension as the 2D image, and a dimension calibration occurs to the point where there is a coincidence between 3D and 2D (2D is used as a reference). This calibration is done only at the beginning of the measurement process, once it is repeated posteriorly (Fig. 3). Next, the intermediate position of the division between the grayscale is verified in the CBCT scan. Once one side has been completed, it is moved to the other side and follows the same guidelines described. When setting the position of the courses in the other margin (another border, point to be measured), the 2D mode present in an e-Vol DX box is used as reference. Thus, one obtains the required measure, being checked in the two points (edges).

The Figure 1 characterize the initial presentation of CBCT reports with slices in multiplanar reconstruction (MPR). The Figure 2 shows the position which will be measured, and defines the point on the edge of the root canal after adjustment in intermediate position in the grayscale. The Figure 3 present the initial synchronization process of the marker in multiplanar reconstruction (MPR). The 3D density is adjusted so that it is in the same dimension as the 2D image, and a dimension calibration occurs to the point

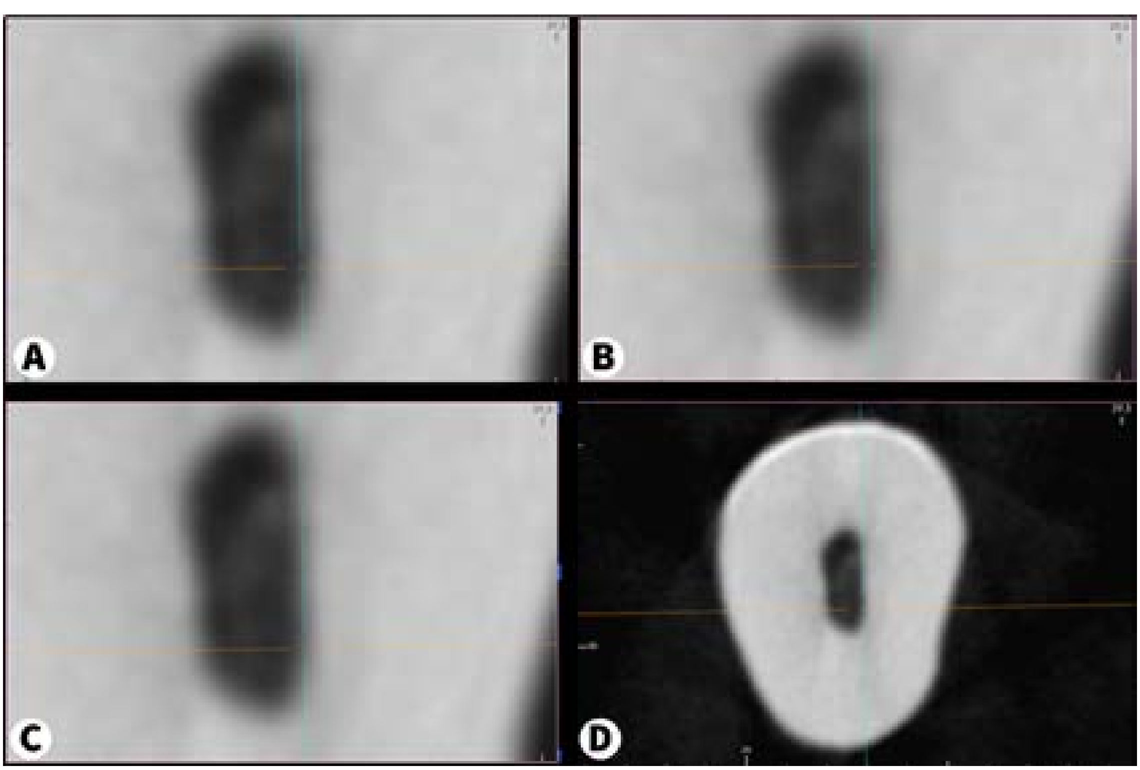

Figure 2. (A-D) CBCT report showing the position which will be measured, and defines the point on the edge of the root canal after adjustment in intermediate position in the grayscale.

where there is a coincidence between 3D and 2D (2D is used as a reference). This calibration is done only at the beginning of the measurement process, once it is repeated. Figure 4 shows the synchronization process in MPR mode, and the conference of calibration on other edges of the root canal. Figure 5 presents the determination of the actual position of the edges of the root canal to be dimensioned with the visualization measured in micrometers. The measurements are checked on both sides of the root canal surfaces. Figure 6 show other positions of the tooth that can be measured. The 3D image dimension is not determined by the software, the reference decision was selected by the

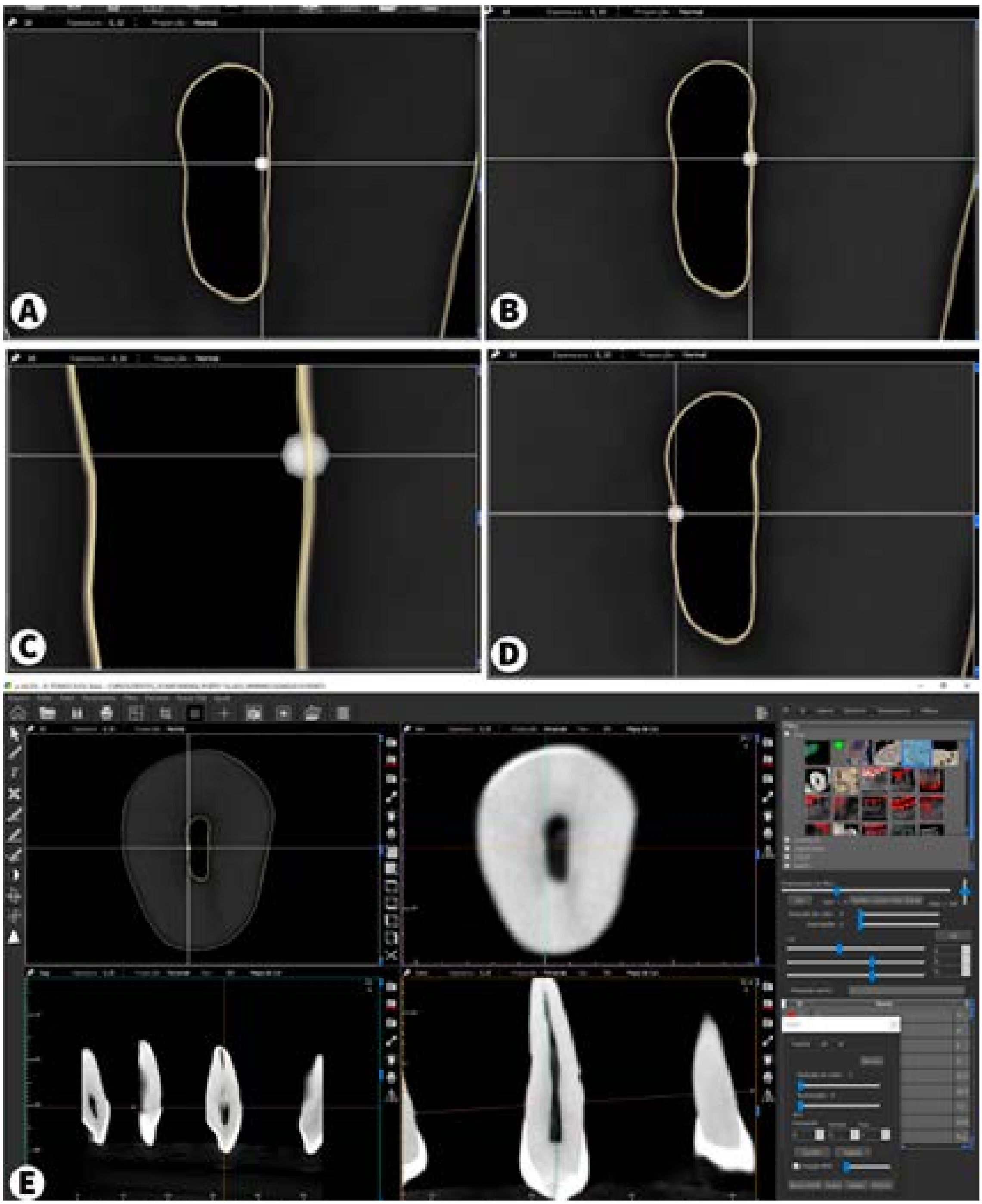

Figure 3. View of the initial synchronization process of the marker in multiplanar reconstruction (MPR). (A) 3D image without synchronization; (B-E) images with marker (guide) of synchronization; (C) greater magnification for conferring at the other edge (margin) of the root canal; The 3D density is adjusted so that it is in the same dimension as the 2D image, and a dimension calibration occurs to the point where there is a coincidence between 3D and 2D (2D is used as a reference). This calibration is done only at the beginning of the measurement process, once it is repeated.

operator. After the operator calibrates, the software repeats in other positions.

Discussion

This method to determine the root canal anatomic dimension by using a CBCT e-Vol DX software can bring benefits in several moments of the root canal treatment, highlighting a more effective planning in determining the longitudinal and transverse limits of root canal preparation. An important impact observed in contemporary endodontics was the incorporation of CBCT on diagnoses and clinical decision-making, represented by expressive benefits as predictability in complex cases.

Bueno et al. (14) reviewed the current limitations of CBCT and presented the potential of a new CBCT software package (e-Vol DX, CDT- Brazil) with the ability to assist diagnosing, planning and managing of complex endodontic cases. The authors described that the differences between e-Vol DX and other software packages include: compatibility with all current CBCT scanners with the capacity to export DICOM Data, a more comprehensive brightness and contrast library, as other applications, in which adjustments are

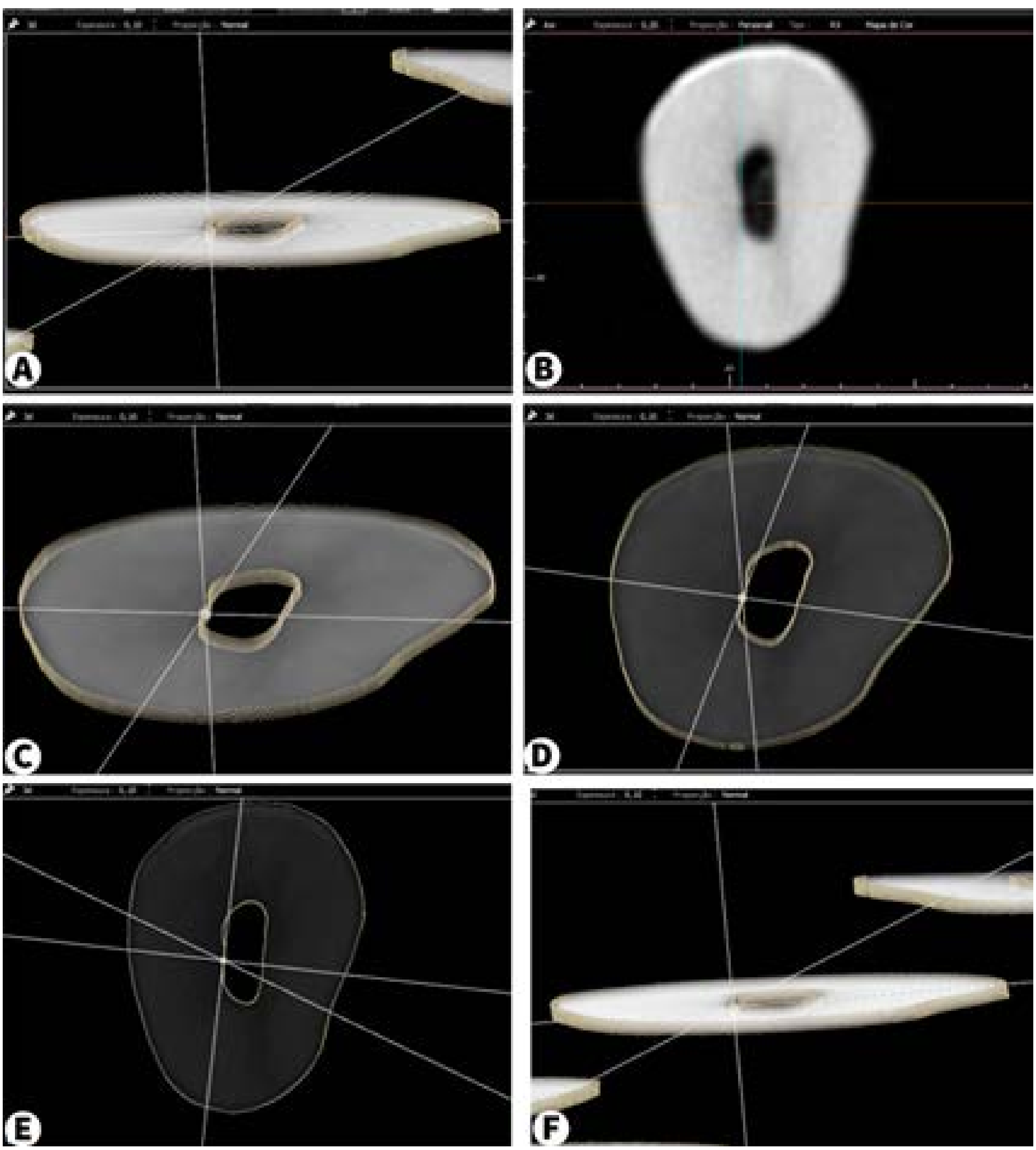

Figure 4. View of the synchronization process in MPR mode. (A) 3D image without synchronization; (B-F) 3D images with synchronization; (F) Conference of calibration on other edges of the root canal.

limited, do not usually support all the DICOM dynamic range features; custom slice thickness adjustment, often limited and pre-defined in other applications; custom sharpening adjustment, often limited in other applications; advanced noise reduction algorithm that enhances image quality; capture screen resolution of 192 dpi, with a 384 dpi option, in contrast to the 96 dpi of most similar applications. Thus, this imaging method provide high resolution images due to submillimeter voxel sizes, dynamic multi-plane imaging navigation and ability to change the volume parameters such as slice thickness and slice intervals and data correction applying imaging filters and manipulating brightness and contrast. This new software also preset imaging filters, dedicated endodontic volume rendering filters with the ability to zoom the image over 1000x (3D reconstructions) without loss of resolution and automatic imaging parameters customization for better standardization and opportunities for research.

An operational tool using the e-Vol DX with endodontic filter was developed to obtain measurements of anatomical structures of small dimensions, in an approximation equivalent to 0.001 mm. The protocol for obtaining

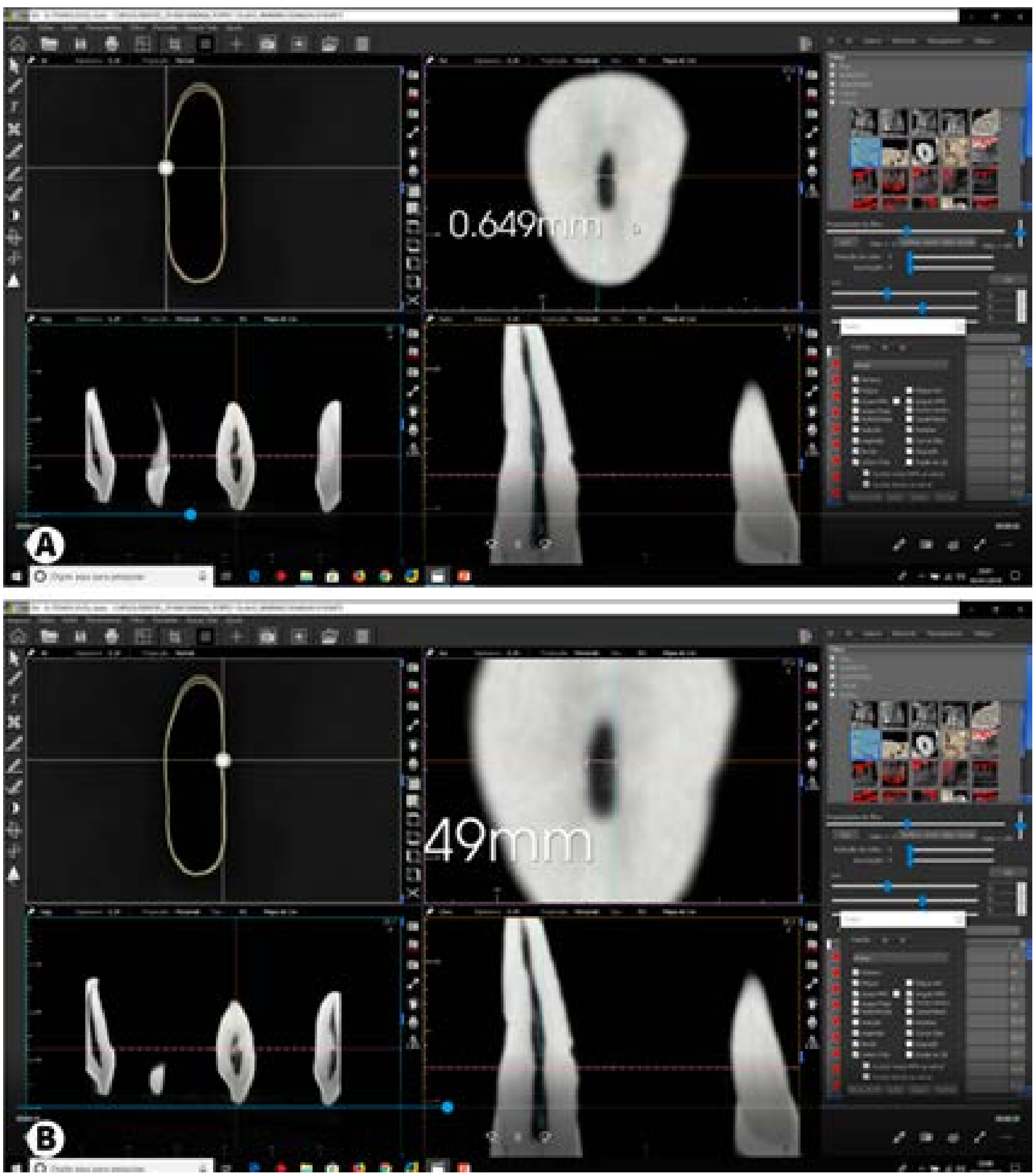

Figure 5. (A-B) CBCT report show the determination of the actual position of the edges of the root canal to be dimensioned with the visualization measured in micrometers. The measurements are checked on both sides of the root canal surfaces.

measurements is simple, easy to apply, and avoids operator interference in the selection of points which will be measured. During the determination of an intermediate point between grayscales, errors can easily be induced because the positioning of the marker (guide) may be out of the correct position (below or beyond the midpoint). Once the measurement is repeated it hardly fits in the correct position. This method allows the calibration conference between the edges to be measured (Fig. 5). The margin delimitation of an anatomical structure to be measured in the multiplanar reconstruction (MPR) mode becomes more evident to the operator. It is important to emphasize

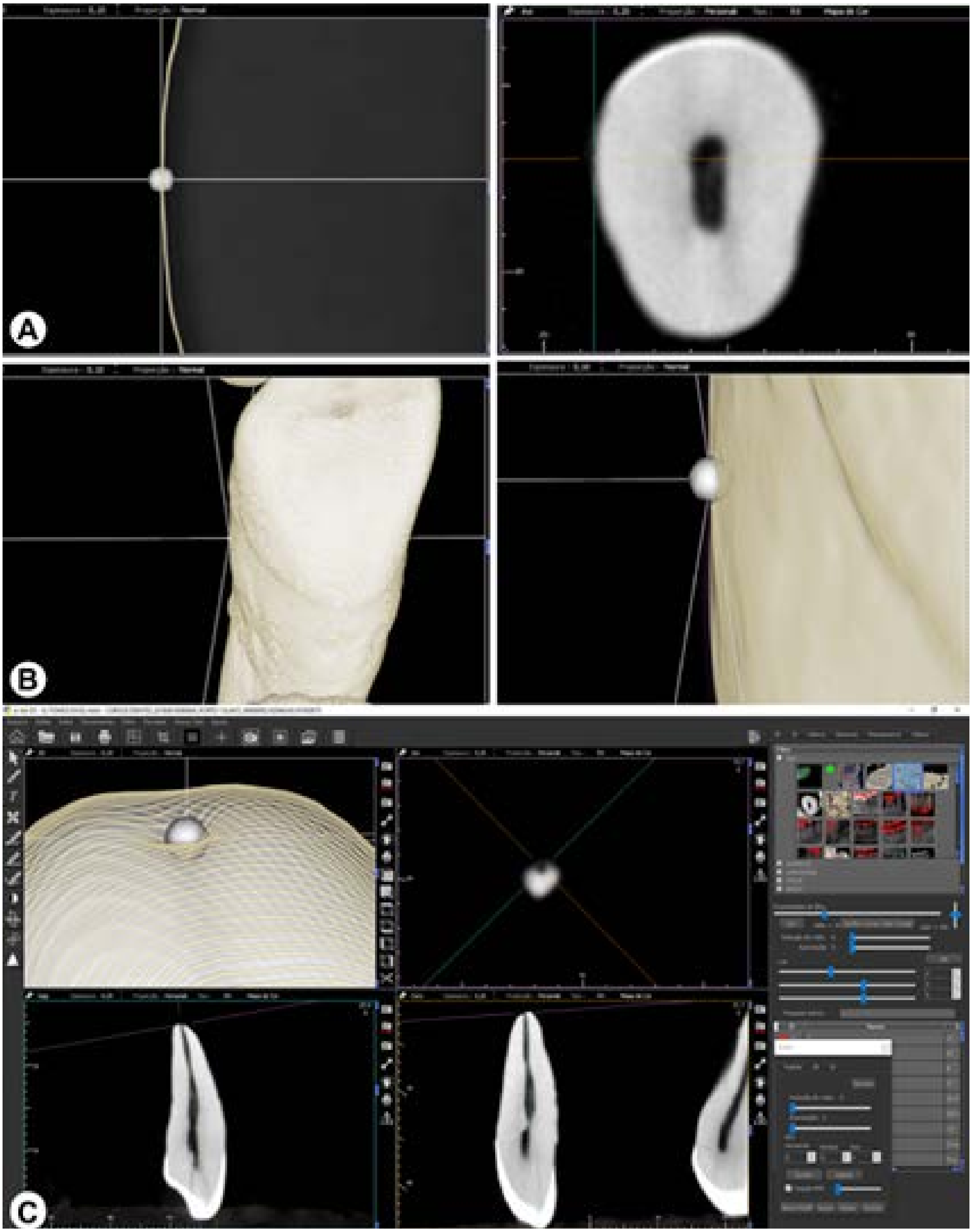

Figure 6. (A-C) Other positions of the tooth can be measured. The 3D image dimension is not determined by the software, the reference decision was selected by the operator. After the operator calibrates, the software repeats in other positions.

that the 3D decision is not determined by the software, the reference decision is selected by the operator. Once calibrated by the operator, the software repeats in other positions (Fig. 6). Another important aspect to be mentioned relates to the coincidence in size calibration between 3D and 2D, since 2D represents a reference.

The specific software developed by the various manufacturers of CBCT devices provides tools for measurements that have been used in several previous studies (15-19). These devices were useful to determine distances of anatomical structures; in the planning of guides for parendodontic surgery; guided access cavity preparation; in root length and bone level measurements, the relationship between teeth and anatomical structures, periapical lesions and root resorption, among several other alternatives which can be applied in several areas of dentistry (15-22).

Another peculiarity of the benefits that emerged after the application of CBCT in endodontics was the characterization of different methodologies of studies and researches (17-23). Thus, the 3D navigation strategies in CBCT images allowed better exploration and definition of new parameters for endodontic research (23, 24).

Among the methods of study that were developed from the use of CBCT tecnology applied to clinical resolution of endodontic problems can be found: the determination of human permanent dental development stages based on linear measurements (17); the evaluation of periapical lesions and their association with maxillary sinus abnormalities; the study of anatomical relationship between posterior teeth and maxillary sinus floor (18); the method for determination of root curvature radius (20); a new periapical index based on CBCT (21); the method to evaluate inflammatory root resorption (22); the map-reading strategy to diagnose root perforations near metallic intracanal posts (23); the frequency of root canal isthmi in human permanent teeth (24); the apical foramen position in relation to proximal root surfaces of human permanent teeth determined by using a new CBCT software (25).

In summary, the creation of this filter in the e-Vol DX software for measurement, and its appropriate managment allows more effective applications when it is desired to obtain diameters of anatomical structures. Further studies should be developed to validate the methodology presented and verify the potential clinical application of this new CBCT e-Vol DX software.

Resumo

Este estudo discute um método para determinar a dimensão anatômica do canal radicular usando o software e-Vol DX. A metodologia consiste em estabelecer as posições corretas que serão medidas, definir o ponto na borda da estrutura anatômica e ajustar a posição intermediária na escala de cinza na imagem em tomografia computadorizada de feixe cônico (TCFC). A seguir, slices finos (0,10mm) são obtidos a partir de cortes 3D reconstruídos no filtro para as medidas, a fim de determinar inicialmente a borda da superfície anatômica no plano axial. Uma replicação de posições no modo 3D é feita em reconstrução multiplanar (MPR) em imagens de TCFC, onde a posição correta é estabelecida com o auxílio de um guia de posicionamento. A densidade 3D é ajustada de modo a ficar na mesma dimensão da imagem 2D, e então realiza-se uma calibração de dimensão até o ponto em que há uma coincidência entre o modo 3D e 2D. Essa calibração é feita apenas no início da medição. Posteriormente, a posição intermediária da divisão entre a escala de cinza é verificada na TCFC. Uma vez que um lado tenha sido concluído, o guia é movido para o outro lado, e segue-se as mesmas diretrizes descritas. Define-se a posição do marcador na outra margem, sendo que o modo 2D usado como referência. Assim, obtém-se a medida necessária, sendo verificado nas duas margens do canal radicular. A criação deste filtro no software e-Vol DX para medição e seu uso apropriado permite aplicações eficazes quando se deseja obter diâmetros de estruturas anatômicas.

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