In vitro study of mandibular first premolar root canals morphology using cone-beam computed tomography

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ABSTRACT

Introduction: Endodontic treatment aims to clean and shape the root canal system. Chemomechanical preparation and tridimensional (3D) filling of the root canal system are based on knowledge of internal dental anatomy. Conventional and periapical digital radiographs present limitations in image definition due to the tridimensional anatomy of the tooth to be treated. The 3D anatomy is compressed in a two-dimensional image. Cone-beam computed tomography (CBCT) is currently an interesting tool for anatomical analysis because of volumetric precision and absence of overlapping structures. **Methods:** A total of 64 (sixty-four) human mandibular first premolars were extracted for therapeutic recommendation. Then prototypes were manufactured with artificial gingiva made of silicone, positioning the teeth in a format similar to the arches. They were subjected to CBCT examination and analyzed by an experienced endodontist. The number of canals per root was quantified for each tooth, and their anatomical configurations were described following Vertucci's classification. **Results:** The following were found: Type I (n = 38) 59%; Type II (n = 0); Type III (n = 6) 9%; Type IV (n = 4) 6%; Type V (n = 10) 16%; Type VI (n = 2) 3%; Type VII (n = 3) 5%; Type VIII (n = 0) and C-shaped 2%. **Conclusion:** CBCT image reveals tridimensional anatomy on the basis of which endodontic therapy is planned. It maps internal morphology in detail. Knowledge of micro-endodontics allows for greater predictability in treatment as well as prognosis, in addition to improving decontamination of complex anatomical areas.

Keywords: Cone-beam computed tomography. In vitro techniques. Endodontics. Pulp chamber.

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Introduction

Endodontic treatment aims at cleaning root canals by means of biomechanical preparation. It consists in cleaning and shaping root canals with the aid of tools and supplementary chemical solutions.[1] Proper chemomechanical preparation and tridimensional filling of the root canal system are based on knowledge of internal dental anatomy and its structural variations. The latter can be analyzed on the basis of radiographic images aimed at thorough root morphology analysis. Anatomical complexity of different root canal shapes is a clinical challenge often leading to endodontic treatment failure.[2]

Issues related to definition of radiographic examination taken for certain groups of teeth result from root canals morphology.[3] Conventional and digital periapical radiographs have technical limitations due to tridimensional (3D) anatomy of the area subjected to radiographic examination. The 3D anatomy is compressed in a two-dimensional (2D) image due to buccolingual plane overlap.[4] As a non-invasive examination, cone-beam computed tomography (CBCT) has currently been considered an interesting tool for anatomical analysis. This is because of volumetric precision and absence of overlapping structures, which allows for accurate analysis of internal tooth morphology and external anatomy.[5] CBCT is a method capable of assessing variations in internal morphology of mandibular first premolars.

Root canals can vary in number, with branches and fusions; as well as in direction, appearance, diameter, division, and accessibility. With advances in Endodontics, a number of researches have been developed to improve knowledge of root canal system topography. Thus, new resources are available to dental surgeons, such as computer tomography and operating microscope. They allow for easier understanding of internal dental anatomy variations which, whenever unidentified, enable infection to remain untreated inside dentinal walls, thus leading to complete damage.[1]

The Brazilian overall population is one of the most heterogeneous of the world, which makes it difficult to be grouped according to ethnic groups. There is important genetic contribution provided by the following groups: African, Asian, European and Native American. The present study aimed at assessing mandibular first premolar root canals morphology and describing CBCT imaging according to Vertucci[7] while analyzing the anatomy of teeth in detail. Mandibular first premolar varies significantly in number of roots and canals. Therefore, thorough study carried out by means of cone-beam computed tomography is necessary. As a result, tridimensional information will be provided with improved precision regarding internal morphology, thus evincing normality and potential anatomical variations with a view to achieving satisfactory endodontic treatment. CBCT was used in the present in vitro study on mandibular first premolar internal anatomy to assess root morphology and the number of canals in each specific root. Images were taken in axial, coronal and sagittal views with slices and tridimensional (3D) reconstruction.

Material And Methods

This study followed resolution #466, December 2012, issued by the National Health Council (Brazilian Conselho Nacional de Saúde). It was previously subjected to the Institutional Review Board (CEP) at Faculdade Integral Diferencial (FACID), being approved under CAAE #58454316.0.0000.5211 as in APPENDIX A. CEP approval was followed by research onset. All 64 teeth were obtained by the dental surgeon in private dental offices located in Teresina, Piauí, Brazil before Human Teeth Donation Term signature, as in APPENDIX A. The dental surgeon was given permission of teeth donation by patients. The present study did not present any risks to patients, given that they were not directly involved. Research was limited to handling teeth previously extracted for therapeutic recommendation and further donated by patients and dental surgeons to be studied. This was mentioned on the informed consent form absence justification as in APPENDIX B.

Research was of an applied nature, classified as quantitative in terms of approach, descriptive in terms of objectives, and laboratory in terms of technical procedures.

Study was carried out at a university multidisciplinary laboratory and at a private image examination office both located in Teresina, Piauí, Brazil. It began after CEP approval and subsequent permission granted by those responsible for research scenarios, as in APPENDIX C and APPENDIX B. Total of research subjects was 64 (sixty-four) human mandibular first premolars of health structure, previously extracted by professional recommendation and further donated by dental surgeons through patients' permission.

Data were collected between September and December, 2016 when patients filled the Human Teeth Donation Term to grant permission for donation of the extracted tooth. This term was forwarded to the dental surgeon responsible for treatment who also signed the Human Teeth Donation Term claiming the donated tooth would be used for scientific research and the donor's identity would not be revealed, thus reinforcing the fact that donation would not cause patients any harm. After extraction, the tooth was stored in a closed container filled with saline solution until artificial dental arches were manufactured.

Prototypes were prepared at university multidisciplinary laboratory III located in Teresina, Piauí, Brazil where all 64 teeth were cleaned with copious distilled water for 10 minutes and then dried. Teeth were stored in 2.5% sodium hypochlorite solution for 24 hours with the aid of Gracey curettes. Subsequently, curettage was carried out with a view to removing periodontal ligament fibers remnants. Specimens were then washed in running water for five minutes and left to dry naturally over a workbench. With samples in hand, four arch prototypes were manufactured with 16 teeth each. Prototypes were made of artificial silicone gingiva (PRODENS) where specimens were inserted into sockets, and secured inside the arch with utility wax (DENTBRAS), as shown in Figure 1. Specimens were placed over the silicone gingiva. All of them had the buccal surface facing the arch outer side.

The aforementioned step was performed at a private imaging diagnosis laboratory office located in Teresina, Piauí, Brazil. For tomographic examination, two prototypes were overlaid, so as to simulate mandibular and maxillary joints, as shown in Figure 2. Initially, examination was performed with SIRONA ORTHOPHOS XG scanner, with 0.2-mm voxels of overlaid arches, thus totaling 32 mandibular first premolars. Subsequently, examinations were performed on the other two arches. Examinations were stored in two CDs (CD 1 and CD 2), and the software of choice for image analysis was GALILEOS IMPLANT.

At university multidisciplinary laboratory III located in Teresina, Piauí, Brazil, tomographic examinations were analyzed by one single experienced examiner. Analysis was carried out as follows: teeth were categorized from n = 1 to n = 64. CD 1 containing the prototype of specimens from n = 1 to n = 32, as seen in Figure 3, was assessed. Then, the same procedure was followed with CD 2 containing the prototype of specimens from n = 33 to n = 64, as seen in Figure 4. All images were assessed in axial, sagittal and coronal views by the examiner. With a view to enhancing visualization, zoom and brightness adjustment, as well as contrast and sharpness tools were used. Additionally, the toolbar was moved from the pulp chamber floor to the apex, so as to have the number of roots and their morphology determined. Findings were processed in Microsoft Office Excel 2016™ spreadsheet, as in APPENDIX D, and the following were considered, according to Vertucci's classification: assessed tooth, number of roots and type of canal.

Tomographic imaging examinations assessment method followed Vertucci's classification (1984):

» Type I: one single canal runs from pulp chamber to apex;

» Type II: two canals arise from pulp chamber and during their course unite into one at the apex;

» Type III: one single canal runs separately from pulp chamber and during its course becomes bifurcated, then again they unite into one at the apex;

» Type IV: two canals arise from pulp chamber to apex, always running separately;

» Type V: one canal arises at pulp chamber and before reaching the apex undergoes bifurcation;

» Type VI: two canals arise at pulp chamber and unite into one along the root and then again undergo bifurcation, running separately until they reach the apex;

» Type VII: one canal arises at pulp chamber, it undergoes bifurcation, and then again unite into one canal which before reaching the apex undergoes bifurcation to end as two canals;

» Type VIII: three canals arise at pulp chamber and run independently towards the apex.

Counts were performed by one single experienced examiner. Data from each count were processed in Microsoft Office Excel 2016™ spreadsheet (APPENDIX D), with specifications of amount and percentage of the number of canals found in each root.

Figure 1. Over view of teeth on artificial gingiva.

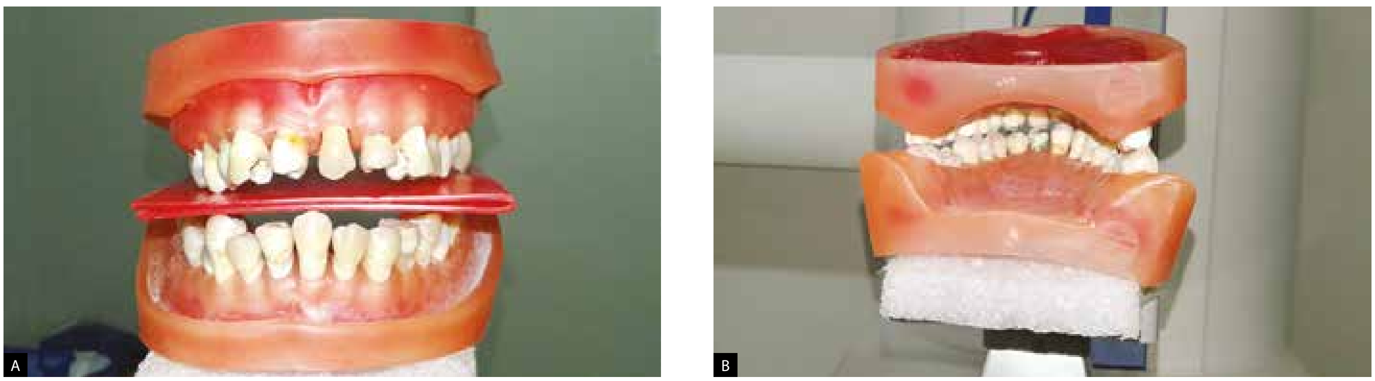

Figure 2. Frontal view (**A**) and posterior view (**B**) of prototypes on the scanner.

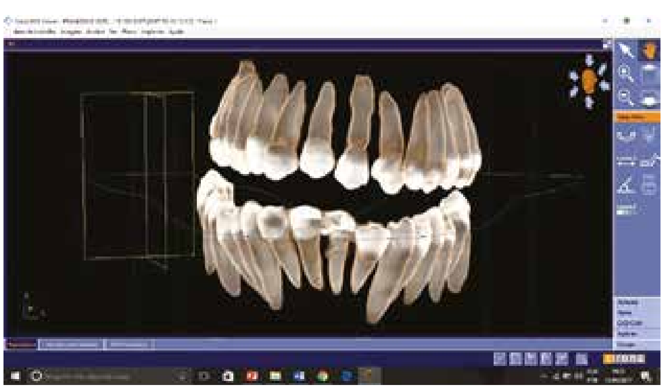

Figure 3. 3D reconstruction of teeth from n = 1 to n = 32 (CD 1) produced by GALILEOS IMPLANT.

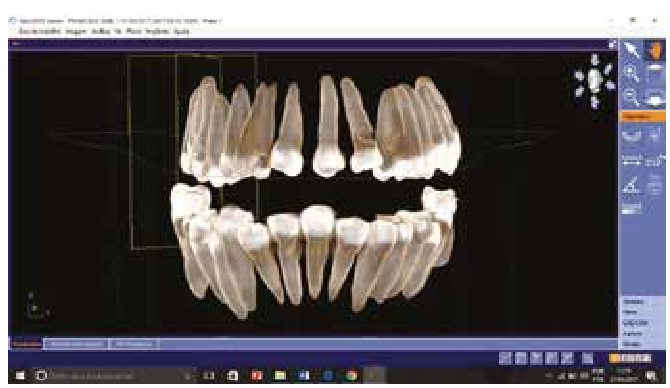

Figure 4. 3D reconstruction of teeth from n = 33 to n = 64 (CD 2) produced by GALILEOS IMPLANT.

Results

The types of canals found in the present study followed Vertucci's classification described in the literature, and an atypical configuration, as shown in Figure 5.

- Type I: 59%;
- Type II: 0%;
- Type III: 9%;
- Type IV: 6%;
- Type V: 16%;
- Type VI: 3%;
- Type VII: 5%;
- Type VIII: 0%; and
- C-shaped 2%.

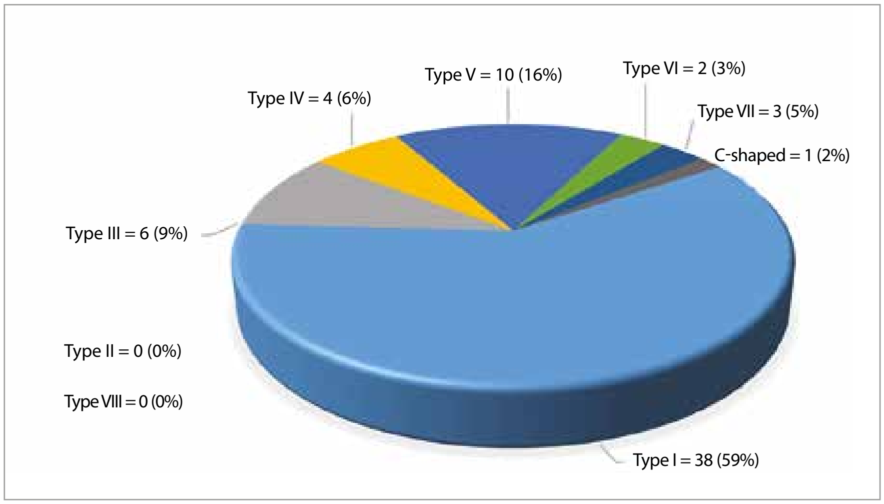

Figure 5. Distribution of types of root canals found in the 64 mandibular first pre-molars analyzed.

Discussion

Endodontic treatment success is multifactorial. Among those factors, knowledge and mastering of dental anatomy are highlighted. Thus, over the years, researches have been carried out with a view to demonstrating variations in root canals morphology and, as a result, deepening studies on internal dental anatomy and providing greater predictability of treatment and prognosis. The variety of methods that can be found might also be one of the factors related to different study results. Some techniques, such as the clearing technique and root section, can promote abrasion of dental structures, causing modifications to the results.[6-9] At present, CBCT has proved to be an interesting tool for anatomical studies due to volumetric precision and absence of overlapping structures, allowing for accurate analysis of internal tooth morphology and external anatomy, thus resulting in intact and feasible dental structure.[5] In the present study, priority was given to describing extracted teeth root canal system morphology, with no need for statistical inter-relations.

The present study outcomes revealed roots of the 64 mandibular first pre-molars presented with one single root. This result was similar to previous studies;[2,5,8,10-12] however, mandibular first pre-molars vary significantly: having one single root is not the rule. Therefore, examinations aiding studies on thorough anatomy of the tooth only contribute to endodontic treatment success, since morphology of the tooth is unpredictable. Those findings corroborate a number of previous researches found in the literature, regardless of methods.

Type I

Of the teeth studied, those of Type I configuration (n = 38) were 59%. Figure 6 reveals slices of one of those cases. Type I has one single canal running from canal opening to apex. Vertucci,[7] in his traditional study, which guides the present research, used 400 mandibular first pre-molars and the clearing technique. The author concluded the following: 70% of teeth were Type I. With radiographic and tomographic examinations as methods, of 10 mandibular first pre-molars assessed in a Brazilian population, 40% were Type I[3]. Of 598 mandibular first pre-molars assessed in a Turkish population by CBCT, 94.2% were Type I[4]. In an Indian population, 94% of canals were Type I[11]. In a study performed with 83 mandibular first pre-molars (n = 41), 50% were Type I.[13] The literature shows Type I was the most frequently found in all reviewed studies: 75,8%;[14] 60.7%;[15] 80%;[5] 76.14%;[8] 78.1%.[16]

Type II

In the present study, there were no mandibular first pre-molars with Vertucci's[7] Type II. The study was used as reference and did not found Type II for this tooth either. In Type II, two canals arise separately from canal opening and during their course unite into one at the apex (2-1). In the literature, the follow-

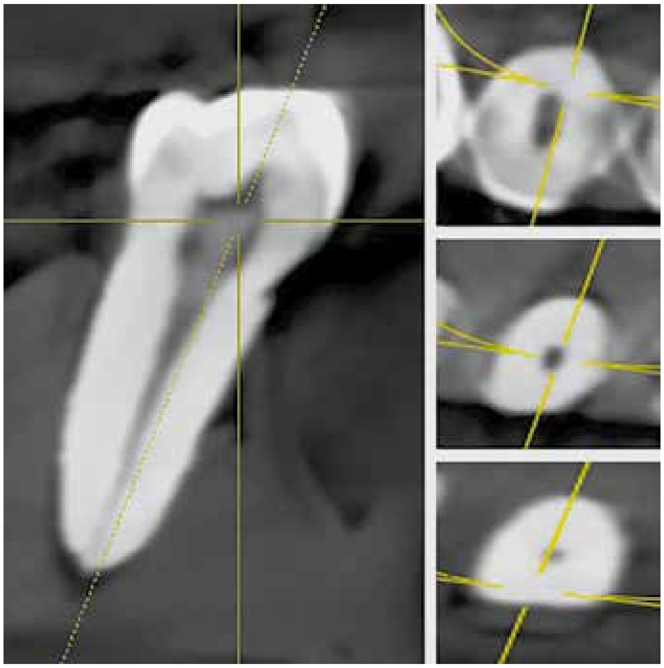

Figure 6. Tomographic examination image of Type I tooth #57. Axial and sagittal slices.

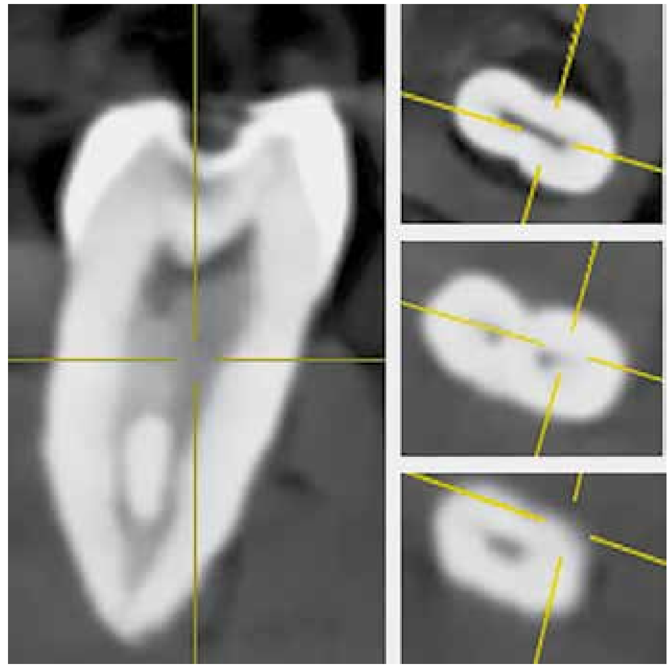

Figure 7. Tomographic examination image of Type III tooth #32. Axial and sagittal slices.

ing data are found: 24.2%;[17] 78.9%;[14] 11.2%;[15] 3.41%;[8] Type II in 8.2%;[16] Type II in 0.6%;[4] 1.3%.[11] Type II is the most rare to be found in mandibular first pre-molars; however, examination on dentinal walls seeking Type II should be performed during endodontic treatment. After all, the goal of Endodontics is disinfection. If the main root canal is partially hidden and not decontaminated, humidity can interfere in treatment results, despite this canal ending in one single foramen. In other words, necrotic remnants left inside the canal, even in the middle third, can infiltrate in apical direction and reach periapical tissues, thus causing periapical infection.

Type III

Of the 64 teeth studied, 9% (n = 6) were of Type III. Figure 7 reveals slices of one of those cases. Type III has one single canal at canal opening. During its course, the canal becomes bifurcated, then before reaching the apex, they unite into one. Previous research concluded 4% of mandibular first pre-molars are Type III, and this was revealed by the clearing technique.[7] In a study carried out with 83 mandibular first pre-molars, 9.8% (n = 8) were Type III.[13] In Brazil, 31.6% of mandibular first pre-molars were Type III, as revealed by CBCT.[5] Mandibular first pre-molars assessed by CBCT in a Turkish population were Type III in 1% of the sample.[4] This is a complex configuration; for this reason, the endodontist is required to be skillful in order to achieve satisfactory endodontic treatment.

Type IV

In the present study, 6% (n = 4) of teeth were Type IV. Figure 8 reveals slices of one of those cases in which mandibular first pre-molars were Type IV. Type IV has two canals arising from canal opening to apex, always running separately. According to the literature, in a study performed with 83 mandibular first pre-molars, 7.3% (n = 6) were Type IV.[13] Another study concluded 0.8% of canals were Type IV. A different study used CBCT[4] to assess teeth in an Indian population and concluded 2.7% were Type IV.[11] This configuration requires attention to tomographic diagnostic studies before endodontic treatment onset. Oftentimes, depending on the number of canals, we should enlarge the access cavity to pulp chamber in buccolingual direction with a view to making root canal instrumentation and filling easier.

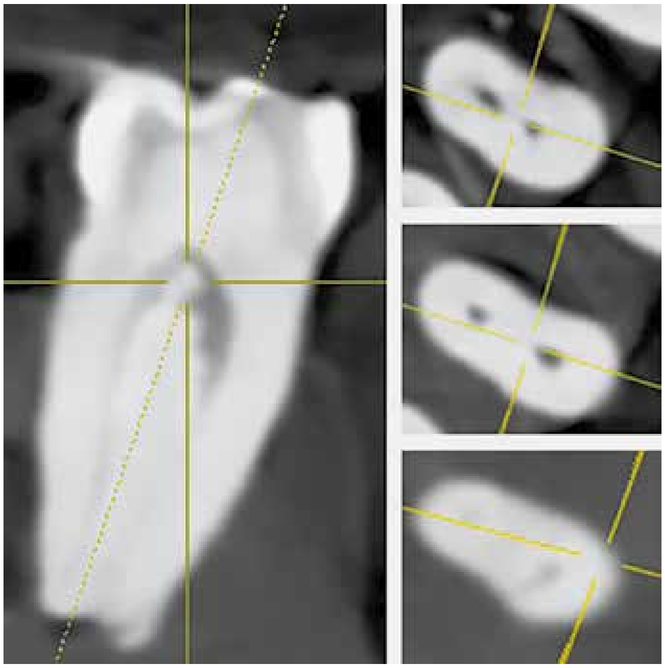

Figure 8. Tomographic examination image of Type IV tooth #53. Axial and sagittal slices.

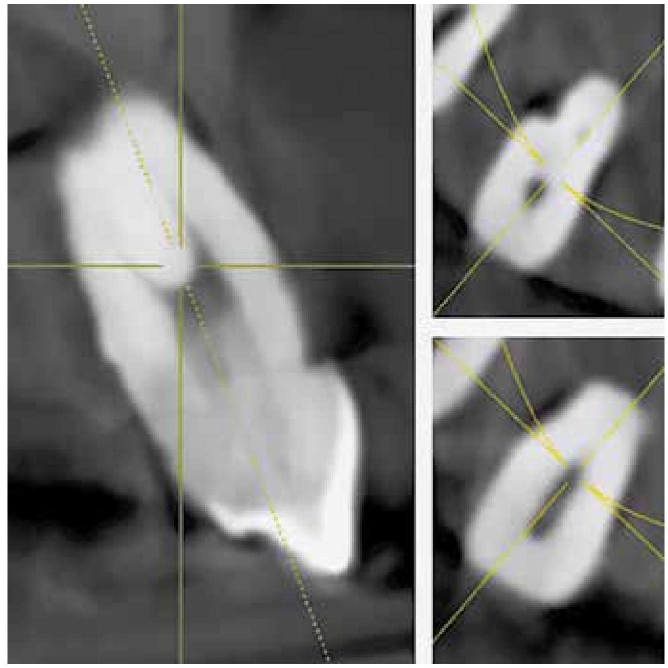

Figure 9. Tomographic examination image of Type V tooth #07. Axial and sagittal slices.

Type V

In the present study, 16% (n = 10) of canals were Type V. Figure 9 revels slices of one of those cases. This anatomical configuration consists in one canal in cervical and middle thirds, and before reaching the apex, the canal undergoes bifurcation. Previous studies also reveal this type of canal is present. In the study by Vertucci,[7] 24% of teeth were Type V. Other studies carried out with mandibular first pre-molars revealed teeth were Type V: 28%;[13] 9.32%;[8] 20%;[4] 12.3%;[16] 60%;[3] 6.5%;[5] 1.3%.[11] This is the second most frequent configuration. Therefore, the clinician must pay attention not to treat Type V teeth, with a single canal, which would lead to treatment failure.

Type VI

2-1-2 configuration, with the apical third having two individual foramina, has a great potential for endodontic treatment failure in disinfecting the apical region. Anatomy assessed only by CBCT might be the factor responsible for endodontic treatment failure, which sometimes hinders apical lesion remission. In the present study, 3% (n = 2) of canals were Type

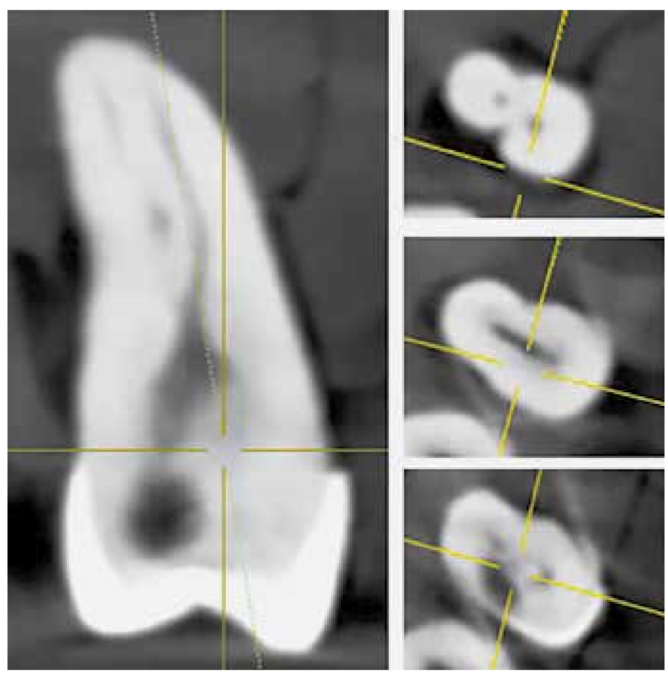

Figure 10. Tomographic examination image of Type VI tooth #45. Axial and sagittal slices.

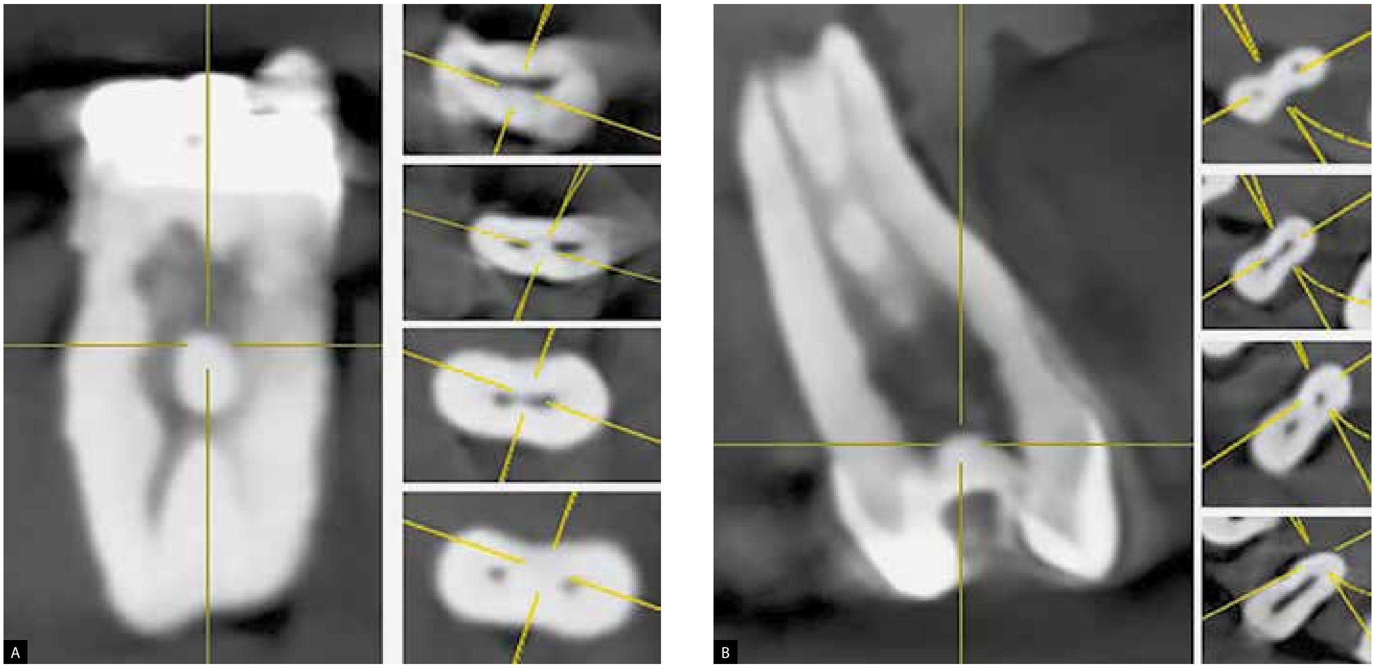

Figure 11. Tomographic examination image of Type VII tooth #51 (**A**) and #39 (**B**). Axial and sagittal slices.

VI. Figure 10 reveals slices of one of those cases. In previous studies, Type VI mandibular first pre-molars were 2.45%;[13] 1.3%.[4]

Type VII

In the present study, Type VII was found only in three samples (5%). Figures 11 and 12 reveal slices of some of those cases. In Type VII, one canal arises at pulp chamber, it undergoes bifurcation in the middle third, and then again 1mm before the apex canals unite into one, and before reaching the apex, it undergoes bifurcation to end as two apical foramina (1-2-1-2). Type VII reveals anatomical complexity that hinders instrumentation. For this reason, ultrasound is recommended to aid root canal system disinfection. CBCT is of paramount importance, since one-single-canal configuration can only be assessed by the examination, which certainly interferes in endodontic treatment success.

C-shaped

In the present study carried out with 64 mandibular first pre-molars, 2% (n = 1) of specimens were C-shaped. Figure 13 reveals slices of those cases. C-shaped canals are majorly found among the Chinese[18]. Endodontic treatment of C-shaped canals pose difficulties, such as greater potential for partial removal of pulp tissues and insufficient filling (due to remaining empty spaces), in addition to higher chances of pulp chamber floor drilling. Therefore, those canals are considered root anomalies. Although rare, clinicians must be aware of their existence and be able to perform satisfactory endodontic treatment.

At present, cone-beam computed tomography shows tridimensional anatomy (3D) and should be required as prerequisite for endodontic treatment, thus improving endodontists' performance. The goal is to decontaminate microendodontics; that is, fight complex anatomical structures, so as to get the most of root canal system decontamination. Even though Types II, III, IV are rare, they must be assessed in order to be cleaned and filled, thus seeking to increase success rates in both endodontic treatment and re-treatment.

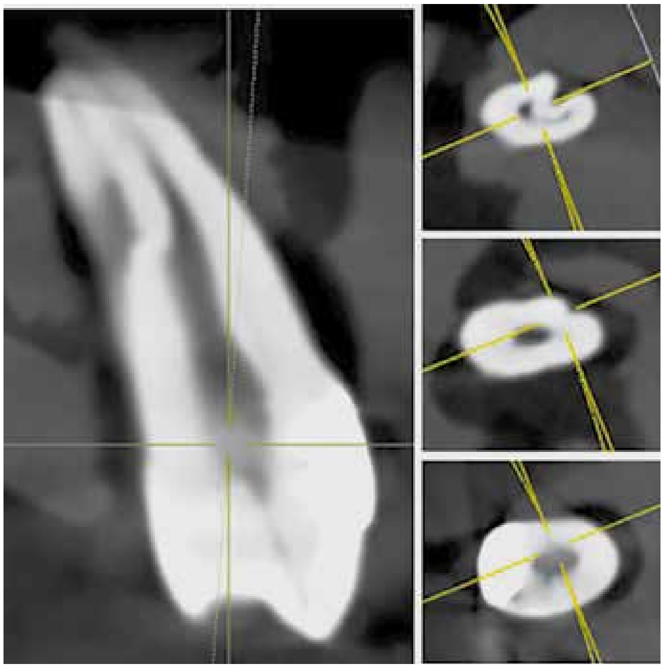

Figure 12. Tomographic examination image of C-shaped canal in tooth #1. Axial and sagittal slices.

Conclusions

The root canal system has complex anatomy, and it is clinicians' duty to always pay attention to potential variations. They should not take them for granted, thinking that a given group of teeth has always the same anatomy or internal morphology. Diagnostic thorough examination should be performed at all times.

CBCT has proved an interesting tool to determine internal dental anatomy. In more complex cases, it can be of paramount importance for diagnostic examination. In present clinical practice, new scanners have increasingly been available on the market. They aim at achieving better imaging resolution. Technology has been increasingly associated with Endodontics.

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