REVISTA DE ODONTOLOGIA DA UNESP
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Original Article

Analysis of the obliteration of the root canal: an investigation with Micro-CT

Análise da obliteração do canal radicular: uma investigação com Micro-CT

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How to cite: Victorino MLZ, Seron MA, Santin G, Jussiani EI, Andrello AC, Vistorino FR. Analysis of the obliteration of the root canal: an investigation with Micro-CT. Rev Odontol UNESP. 2024;53:e20240011. https://doi.org/10.1590/1807-2577.01124

Resumo

Introdução: Dentes traumatizados podem sofrer com metamorfose cálcica da polpa, fator que dificulta o tratamento endodôntico devido à obliteração total ou parcial do canal radicular. **Objetivo:** Comparar a existência de luz do canal radicular entre a Tomografia Computadorizada Cone Beam e a Microtomografia de Raios-X em dentes humanos. **Material e método:** Foram selecionados dez dentes permanentes unirradiculares com algum grau de obliteração observada em imagem radiográfica 2D. Foi realizada a Tomografia Computadorizada de Feixe Cônico, e analisado o perfil tomográfico da calcificação dos canais radiculares. A presença da luz do canal radicular foi observada nos terços cervical, médio, apical e na câmara pulpar, utilizando escores de 1 a 5. Os dentes foram analisados usando Microtomografia de Raios-X e reconstruções foram feitas com o software NRecon. O teste de Friedman foi utilizado com significância de 5%. **Resultado:** Notavelmente, na região cervical, foi observada pelos avaliadores uma baixa probabilidade de existência do lúmen do canal pela Tomografia Cone Beam. No entanto, a Micro-CT consistentemente identificou a presença de lúmen do canal nessa região. Nas regiões média e apical, a probabilidade de existência do lúmen do canal radicular entre os avaliadores foi confirmada em 100% com a Microtomografia. Foi observado ainda, em todos os espécimes um padrão de obliteração do canal radicular da coroa ao ápice, e o lúmen do canal confirmado com imagens de Microtomografia. **Conclusão:** Ficou evidente que, para o tratamento endodôntico de casos com canais pouco visíveis na Tomografia, a probabilidade de sua existência é alta.

Descritores: Endodontia; tomografia computadorizada de feixe cônico espiral; patologia.

Abstract

Introduction: Traumatized teeth may undergo calcific metamorphosis of the pulp, a factor which makes endodontic treatment difficult due to the total or partial obliteration of the root canal. **Objective:** To compare the existence of root canal lumen between Cone Beam Computerized Tomography and X-ray Microtomography in human teeth. **Material and method:** Ten single-rooted permanent teeth with some degree of obliteration observed in 2D radiographic images were selected. Cone Beam Computerized Tomography was performed, and the tomographic profile of root canal calcification was analyzed. The presence of root canal lumen was observed in the in the cervical, middle and apical thirds, and in the pulpal chamber, using scores from 1 to 5. The teeth were analyzed using X-ray Microtomography, and reconstructions were made using the NRecon software. The Friedman test with a significance level of 5% was used. **Results:** Notably, in the cervical region, the evaluators observed a low probability of the existence of lumen in the canal, using Cone Beam Tomography. However, the Micro-CT consistently identified the presence of canal lumen in this region. In the middle and apical regions, the probability of the existence of root canal lumen was confirmed among the evaluators at 100%, using Microtomography. A pattern of root

canal obliteration from the crown to the apex was also observed in all specimens, and the canal lumen was confirmed using Microtomography images. **Conclusion:** It was evident that, for the endodontic treatment of cases with canals barely visible in the tomography, the probability of their existence is high.

Descriptors: Endodontics; cone beam spiral computerized tomography; pathology.

INTRODUCTION

Following a trauma, the tooth may develop Calcific Metamorphosis of the Pulp, a pulp alteration that results in the partial or complete obliteration of the root canal due to the deposition of mineralized tissue in this area[1]. This occurs due to the reduction of the vascular and nervous supply of the pulp. This occurrence is more frequent in the anterior teeth of young adults, since this area is more vulnerable due to its location in the anterior region[2], and can be identified up to three months following the injury. However, in some cases, it may not be detected for up to a year[3].

Teeth with pulpal obliteration generally do not present symptoms. The most common clinical characteristics include negative responses to sensitivity tests, changes in the color of the crown to a yellowish or grayish hue due to the deposition of dentin, and difficulty in accessing and locating the root canal of the affected tooth[2-6]. Using a radiographic exam, pulp obliteration may be seen as a reduction in the size of the pulp chamber and narrowing of the root canal. Partial obliteration may occur when part of the pulp chamber or root canal are not seen. Total obliteration may occur when both are not seen[4,7].

Cone Beam Computerized Tomography (CBCT) has been used broadly in endodontic treatment since its development in the 1990s, due to the possibility of analyzing teeth three-dimensionally, in addition to the quality and better resolution of the images. It is a resource that is also widely used in studies of endodontic anatomy for the same reasons, as well as enabling *in vivo* studies in different populations, addressing the influence of characteristics such as ethnicity, sex and age[8]. There is also X-ray computerized microtomography, a technique broadly utilized for internal, three-dimensional anatomic analysis[9,10] with better resolution[11]. This permits the detection of smaller structures which are not visible in other types of imaging exams. However, extraction of the tooth is necessary to perform this exam[12].

The treatment of Calcific Metamorphosis involves the endodontist directly, who has the specialized training, appropriate equipment and detailed knowledge of the internal anatomy of the tooth. The decision regarding endodontic treatment is debated broadly. Some authors recommend intervention immediately following diagnosis, while others prefer radiographic monitoring, performing the intervention only when the apical injury is detected. When intervention is chosen, the success rate is about 89%, with responsibility for keeping the tooth in the mouth[13]. Regardless of the moment chosen for treatment, dealing with Calcific Metamorphosis is a challenge in endodontics[3,6].

Therefore, the objective of the present study was to evaluate the existence of root canal lumen using Micro-CT when not observed in CBCT images.

MATERIAL AND METHOD

The present study is experimental, conducted with permanent, single-root teeth extracted due to periodontal disease at the UniCesumar Dental Clinic. The research protocol was approved by the Committee for Ethics in Research with Human Beings at UniCesumar, in accordance with Resolution 466/12 of the National Health Council/MS, n° 12994219.7.0000.5539. As inclusion criteria, the teeth had to present total or partial root canal obliteration, confirmed by radiography, in addition to being permanent and single-root. Among the 90 teeth analyzed, only 10 were included in the sample (Figure 1A).

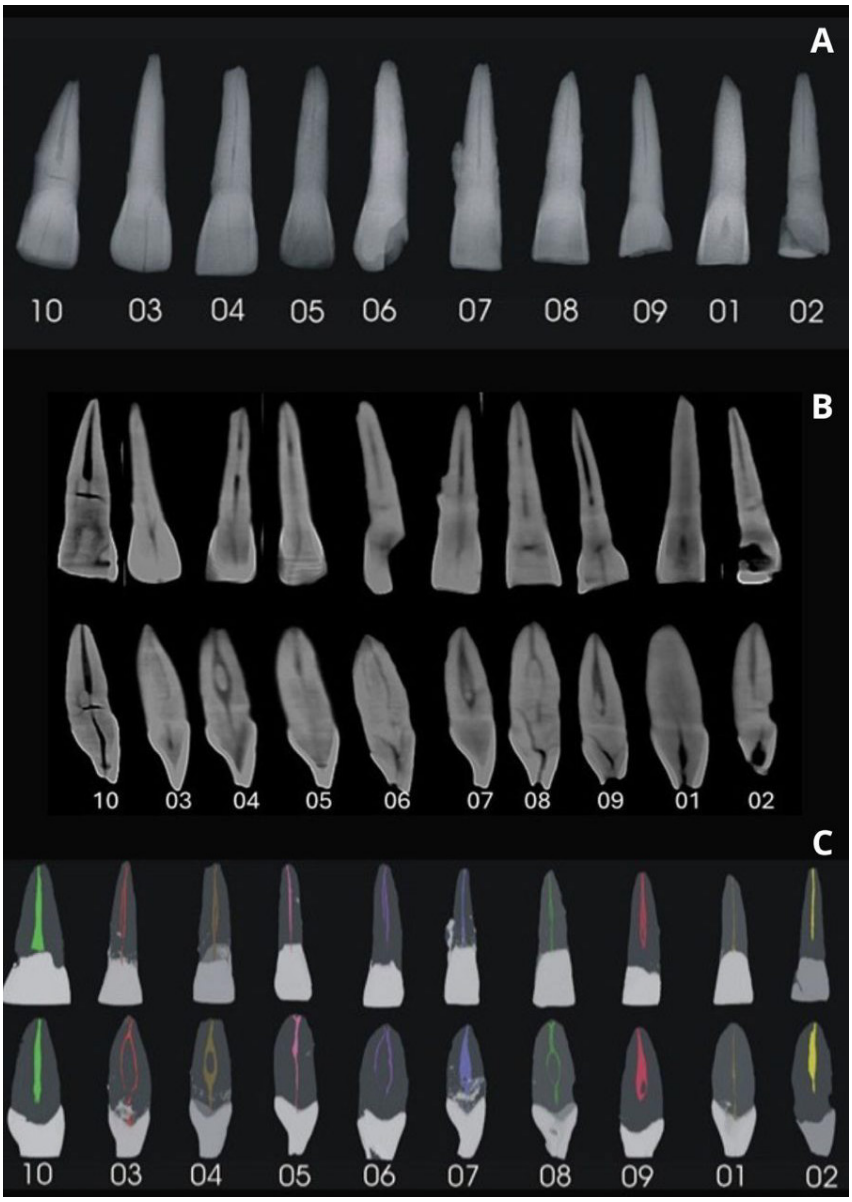

Figure 1. (A) Radiography of the selected teeth; (B) Tomographies; (C) Micro-CT.

Radiograph/X-Ray

To obtain the radiographic images of the sample, the Timex 70 Gnatus Dental X-ray, 70KVp, with a maximum tube current of 7mA (Gnatus, Equipamentos Médicos-Odontológicos Ltda, Ribeirão Preto. SP, Brazil) with SAEVO Sensor T1 digital sensor, 25pl/mm resolution, 1.50 MegaPixels, 4096 degrees of gray and 12-bit image resolution (Alliage S/A Indústrias Médico Odontológica, Ribeirão Preto, SP, Brasil) was used. The exposures were performed at 70 kVp and 7 mA, with a focal distance of 4 cm and an exposure time of 0.18 seconds. The teeth were positioned with the vestibular surface facing the X-ray beam, with the aid of a utility wax. The radiographic images were analyzed using a 17-inch Dell monitor - E1715S - with high-definition resolution of 1280 × 1024.

Cone Beam Computerized Tomography

CBCT was performed using the KAVO OP 3D Pro CT scanner (Instrumentarium Dental PaloDex Group, Finland), with a voltage of 90 kV and current of 8.0 mA, to generate images having 85 µm and FOV of 61x41mm (Figure 1B).

Computerized Microtomography

The sample was also analyzed using X-Ray Computerized Microtomography. The Skyscan-Bruker model 1173 equipment was used, at a voltage of 100kV and current of 80µA to generate images with 8.5µm resolution. The time for obtaining each projection was 600ms, with an angular step of 0.3° at 180°. The projections were reconstructed using the NRecon software. On average, 1500 axial, coronal and sagittal sections were generated (Figure 1C). The teeth were positioned on a dental mannequin. Quantification of the areas by section and 3D models of the canals were made using the CTan software; 3D images were visualized using the CTvol software. In the axial sections, measurements were made of the largest and smallest diameter at the beginning of the canals at the cementoenamel junction, using the Data Viewer software, release 1.6.

Data Analysis

Three specialists in endodontia were previously calibrated with 10 teeth that were not part of the present study, resulting in a Kappa value of 0.82. The CBCT and Micro-CT images of the 10 teeth selected for the sample were evaluated independently, for the presence or absence of root canal lumen. Originally, the sample was verified for the profile of calcification of the root canals followed by the presence of canal lumen, in the cervical, middle and apical thirds, in addition to the pulp chamber. Scores from 1 to 5 were used for classification, in which 1 represented the total absence of canal lumen and 5 represented the total presence.

Statistical Analysis

Friedman's non-parametric test was used to verify if there were differences among the evaluators in the observation of the presence of canal lumen at the level of the crown and the cervical, middle and apical thirds. When there was no agreement about the presence of canal lumen among the evaluators on the tomographic and Micro-TC exams, measurements were made of the largest and smallest diameters at the beginning of the root canals, at the cementoenamel junction, through axial slices using the Data Viewer software, release 1.6. Values from $p<0.05$ were considered significant.

RESULT

Pulp Obliteration Patterns

Following tomographic evaluations, a consistent pattern of partial pulp obliteration was observed in all specimens selected. This pattern extended from the crown to the apex of the tooth, as illustrated in (Figure 2), through CBCT images.

Probability of Existence of Canal Lumen

Table 1 presents the distribution, perceived among the evaluators, in the percentage of the probability of existence of canal lumen, based on the CBCT and Micro-CT examinations.

CBCT examination showed a low probability of existence of canal lumen in the pulp chamber, but the Micro-CT confirmed its presence in 70% of the cases, with a statistically significant difference.

Table 1. Distribution of the probability of the presence of canal lumen in the crown, cervical, middle and apical thirds presented by those evaluated (Ev) and by microtomography

	CBCT*	Micro-CT	Statistic**	P value
Crown				
Sp 1	10%	40%	1.071	0.294
Sp 2	20%	40%	0.119	0.906
Sp 3	40%	40%	0.000	1.000
Cervical				
Sp 1	20%	70%	5.169	< .001
Sp 2	20%	70%	3.345	0.002
Sp 3	20%	70%	6.082	< .001
Middle				
Sp 1	70%	100%	2.629	0.014
Sp 2	80%	100%	1.214	0.235
Sp 3	80%	100%	1.820	0.080
Apical				
Sp 1	80%	100%	1.614	0.118
Sp 2	90%	100%	0.922	0.365
Sp 3	80%	100%	2.075	0.048

*Percentage of teeth root canal lumen (sample of 10 teeth). **Non-parametric Friedman test; Sp = Endodontics specialist.

In the cervical region, the probability of existence of space in the root canal was low, 20%, according to tomography. However, its presence was confirmed by in 100% of cases, with a significant difference. In the middle and apical regions, the probability of existence of lumen in the root canal, verified by the evaluators, was confirmed with Microtomography in 100% of cases. A pattern of root canal obliteration was observed from the crown to the apex, and the presence of lumen was confirmed with Micro-CT images.

Measurements of Canal Diameter

To characterize the canal even more, we measured the largest and smallest diameters in the cervical region, specifically at the cementoenamel junction. These measurements are detailed in Table 2.

Table 2. Values of the largest and smallest diameter of the canal lumen at the cement/enamel level in mm

Tooth	Largest Diameter	Smallest diameter
1	0.32	0.20
2	0.03	0.03
3	0.22	0.20
4	0.14	0.12
5	0.10	0.09
6	0.32	0.26
7	0.10	0.09
8	0.04	0.04
9	0.03	0.03
10	0.03	0.03
Mean (SD)*	0.13 (±0.11)	0.11 (±0.08)

The smallest and largest diameters observed in this region varied between 0.11 (±0.08) mm and 0.13 (±0.11) mm, respectively.

It is important to note that, despite radiographic indications of complete obliteration, in most of the cases our measurements revealed the presence of a residual canal with reduced diameter.

DISCUSSION

The present study aimed to verify whether teeth with pulp calcification, identified by the 2D radiographic technique, are really totally or partially lacking root canal lumen, using imaging tools such as tomography and microtomography.

Root canal obliteration is a well-known phenomenon, identified as Calcific Metamorphosis of the Pulp[14]. Its diagnosis is based on the clinical appearance of a yellowish color in the tooth crown and in the radiographic image of a reduction in the root canal lumen[15,16]. Most teeth presenting pulp calcification, following clinical examination, are considered healthy and functional. Teeth presenting pulp obliteration are generally asymptomatic and, frequently, are diagnosed accidentally[13]. It was not possible to verify the real etiology of the obliteration of the teeth used in the present study, as this was not the focus of the study and did not interfere with the results.

Some authors argue that endodontic treatment should only be performed when there are clinical symptoms. For teeth that do not present symptoms and have no apical pathology, they recommend clinical control consultations and periodic imaging examinations[13,17]. Thus, the best therapeutic approach remains a dilemma for the professional, since the decision to perform endodontic treatment, or not, depends on specific clinical situations and is a difficult task[18]. For this reason, the use of auxiliary tools, such as more sensitive imaging equipment, may help the professional in the decision-making process.

Regarding to the results of the present study, it can be observed that there is no total root canal obliteration since, in all Micro-CT images, there was root canal presence in the cervical region in 70% of the cases. This is where the probability of the existence of the root canal, in the CBCT, was 20%. It can be affirmed that this region is the most critical, because it was more difficult and presented a dubious interpretation on the CBCT. Also, the smallest and largest diameters in this region were extremely reduced, varying between 0.11 and 0.13mm, on average. There was greater agreement between the CBCT and the Micro-CT in the middle and apical thirds, due to the larger diameter of the canal lumen. This profile of obliteration and reduction in the diameter of the root canals in the crown and the cervical third complicates the coronal opening and increases the risk of iatrogenic damage during this phase of treatment, which corroborates the studies by Kiefner et al.[17], McCabe, Dummer[13], and Jain et al.[18]. When verifying the diameter of this lumen using Micro-CT, the smallest and largest diameters in this region were extremely reduced, varying between 0.11 (±0.08)mm at the smallest diameter and 0.13 (±0.11)mm at the largest diameter, respectively, at the level of the cementoenamel junction. It is known that, although the root canal is not visible radiographically in obliterated teeth, there is always a residual canal that shelters a dental pulp having a normal aspect[3]. In spite of this, such teeth may, after many years, present signs and symptoms of pulp necrosis for no apparent reason. This profile of obliteration and reduction in the diameter of the root canals, in the crown and the cervical third, makes coronal opening difficult and increases the risk of iatrogenic events during this treatment phase, according to Kiefner et al.[17], McCabe, Dummer[13], and Jain et al.[18].

Endodontic treatment aims to treat diseases of the dental pulp, permitting functional maintenance of the teeth in the oral cavity. The success of this treatment depends on appropriate chemical-mechanical preparation, disinfection and obturation of the root canals. These procedures can be made more difficult when the main canal presents calcification or narrowing, complicating access, as occurs in cases of root canal obliteration. In this situation, this condition presents a tremendous challenge for the professional because it can increase the level of difficulty of the treatment, increasing the risk of iatrogenesis and treatment failure[18,19].

When an endodontic approach is necessary, that is, in cases of painful symptomology, apical lesions and bone loss, in teeth with calcific metamorphosis of the pulp, the biggest problem of the professional is the possibility of endodontic access via the coronal route in a conventional way, due to the reduction of the lumen of the main canal. However, Kiefner et al.[17] and de Toubes et al.[19] demonstrated that it is possible to access root canals that showed partial or total obliteration radiographically, by using the operating microscope.

Thus, it is evident that computerized tomography by CBCT is an indispensable planning resource in these cases, associated with mastery of knowledge of internal and external tooth anatomy, combined with technologies such as operating microscopy and ultrasound, may result in a good protocol for locating calcified canals[17,20].

X-ray computerized microtomography was used in the present study to analyze the three-dimensional, internal anatomy of extracted teeth. This is a non-destructive, 3D imaging technique that evolved from computerized tomography and has been applied broadly in several fields of knowledge[21].

Although it is a gold standard imaging tool, its use in patients is not feasible[9-12].

As shown in the results, it is still possible to work in diameters between 0.11mm and 0.13mm, using a #10 hand file, that has a diameter of 0.10 mm. However, in some specimens, the largest diameter observed was 0.03 mm, making it impossible to work with the thinnest hand file, #6, of 0.06mm. Therefore, clinically it is necessary to perform, with the aid of the resources listed above, a slightly smaller reduction in the cervical region to locate the root canal lumen. To do so, one should also consider the possibility of using an endodontic guide, EndoGuide, made through clinical workflow from CBCT and digital scanning[22], to overcome such difficulties[22,23] and reduce unnecessary wear of healthy dentin. This has been demonstrated by Connert et al.[6], although the manufacture of the guide results in a high cost to the patient and the diameter of the drills is still inappropriate for teeth with thin roots.

Therefore, treatment of cases with root canal obliteration visualized in radiographic and tomographic examinations must, necessarily, be performed using operating microscopy and ultrasound. If access is not possible, the professional can still use the EndoGuide, since the canal lumen is normally present in the middle and apical thirds.

It is important to highlight that, when necessary, endodontic treatment of cases with partial or total root canal obliteration is considered highly difficult, both in anterior teeth such as those analyzed in the present study, and in multi-rooted teeth according to the classification of the American Association of Endodontics. Therefore, it is recommended to refer the case to experienced professionals[1].

CONCLUSION

Teeth with Calcific Metamorphosis of the Pulp are easily identified in imaging exams, such as periapical radiographs and CBCT, due to the reduction of the volume of the pulp chamber and the root canals. In the present study, a pattern of obliteration was observed in the direction from the crown to the apex, with a significant reduction in the diameter of the canal lumen in the cervical third. Also, even though they were poorly visualized in the CBCT, the canals were present, as observed using Micro-CT. Therefore, clinically, the operator should not give up on cases with symptomatic root canal obliteration and with low risks of iatrogenesis.

AUTHORS' CONTRIBUTIONS

Maria Luiza Zamparoni Victorino: Original Manuscript Drafting, Review, Editing.
Marcelo Augusto Seron: Review.
Gabriela Santin: Data and Experiment Validation, Data Presentation Design.
Eduardo Inocente Jussiani: Investigation, Methodology.
Avacir Casanova Andrello: Investigation, Methodology.
Fausto Rodrigo Victorino: Project Administration, Supervision.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest related to this study.

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Received: June 4, 2024
Accepted: November 3, 2024