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Prospect of endodontic success

A successful endodontic treatment partially represents a qualitative reward of correctly performed operational procedures.

Endodontic treatment provides innumerable challenges, among which the following may be highlighted: the need for reaching complex inner anatomy, understanding the strategies to control the microbiota of the infected root canal and perceiving treatment outcome on the basis of each individual's immunologic response. The clinician's knowledge and psychomotor ability are essential for this process.

When properly used, the new technology available is considered a valuable tool and may influence the quality of endodontic treatment. Some examples include cone beam computed tomography (carried out at different treatment stages) and the use of nickel-titanium rotary instruments during root canal preparation.

Following and valuing the criteria established for each step results in discipline and decreases any potential difficulties. Scientific and technological knowledge as well as psychomotor ability (training), all together, reinforce the need for a professional who is focused and always eager to acquire excellence in endodontic treatment.

Carlos Estrela
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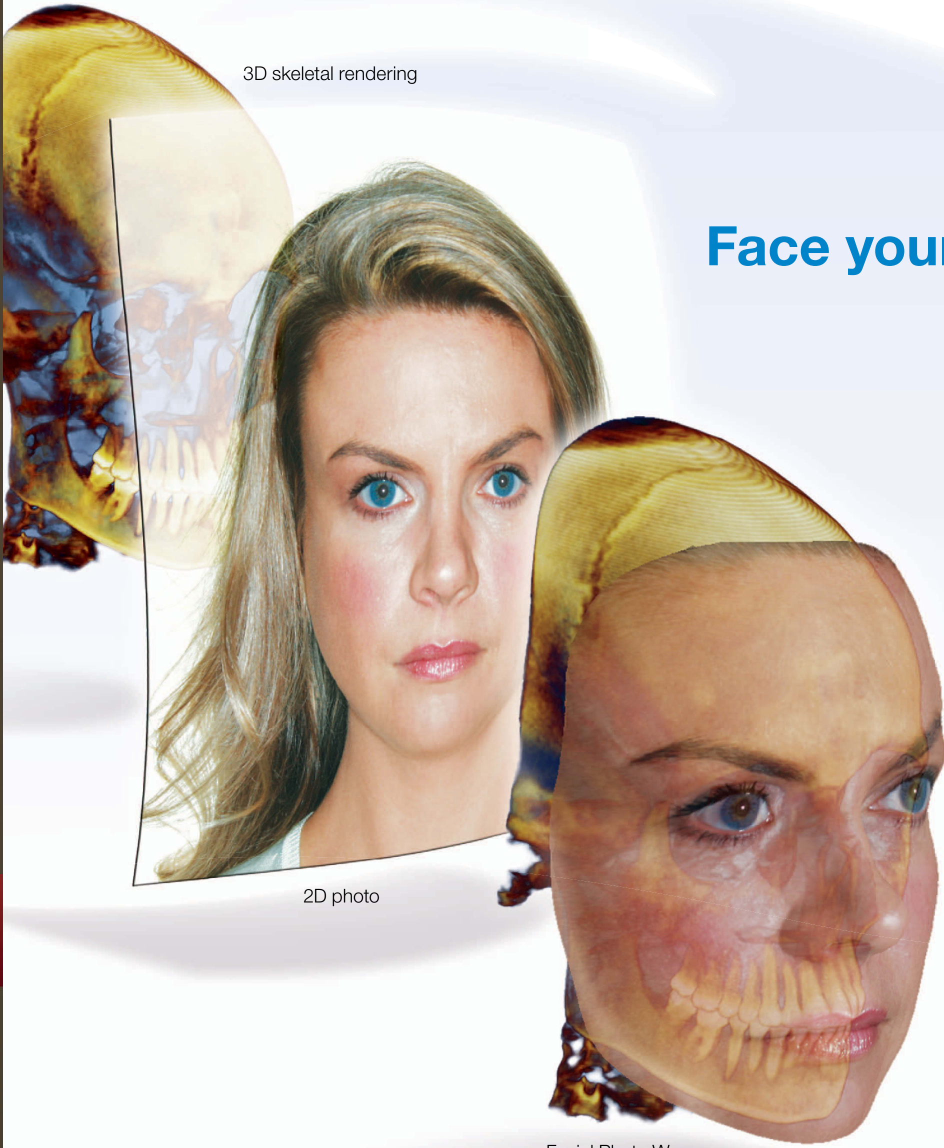

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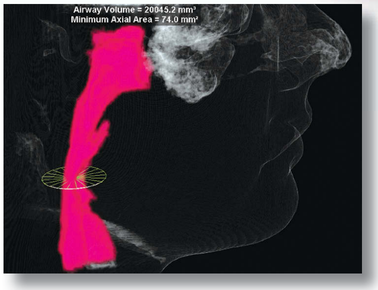

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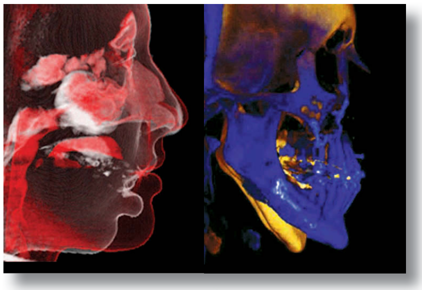

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Foraminal debridement: reflections and insight

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ABSTRACT

One of the procedures employed for canal treatment during endodontic therapy, be it performed by manual technique or with rotary instruments, is the foraminal debridement, in which the first tool is used beyond the foraminal opening (0.5 to 1 mm). Some reflections on the clinical implications of these procedures include the real dimension of periodontal ligament thickness and its inflammatory and connective tissue reactive characteristics. These reflections and an insight for future studies are presented here.

Keywords: Instrumentation. Rotary instruments. Apical repair. Periapical repair.

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The foraminal patency concept is based on the insertion of an endodontic instrument with small diameter (not greater than #25) in the apical foramen. For some authors, the patency instrument should surpass, on average, 1 mm of the foraminal opening, being in intimate relation with the periodontal ligament.[1,4,5] However, for a sterile instrument with small diameter, this fact does not cause any clinical problems.[5] This protocol leads to some reflections on the clinical implications of these procedures:

1. The periodontal ligament will be completely surpassed by the instrument, given that its thickness varies from 0.2 to 0.4 mm, 0.25 mm on average. "Completely" means that the instrument will surpass the most apical limit of the cementum and will reach the bundle bone beyond the cortical alveolar bone, also known as lamina dura.

2. As it is a highly organized fibrous connective tissue of which half consists of blood vessels, the onset of an acute, inflammatory process, with the concentration of substances (exudate) and cells (infiltrate), especially, neutrophils,[2] is inevitable. In two or three days, if the cells and the substances do not meet a significant amount of bacteria, they will migrate and be reabsorbed, preventing the serous exudate from becoming purulent.[2] This can be named as chronic apical serous pericementitis (periodontitis) physically induced by endodontic instruments and which will develop into repair, once its cause will be removed by canal obturation.

3. If the tooth under treatment is with pulp necrosis and the root canal is contaminated, but with no periapical lesion, a significant increase in the possibility of periodontal ligament contamination is expected, thus, requiring greater need for care.

4. Should the tooth present chronic periodontal lesion — including chronic apical pericementitis, periapical granuloma, root cyst and chronic dentoalveolar abscess — surpassing the instruments beyond 1 mm will not cause damage to the periodontal ligament, since an inflammatory process has started in this region and the ligament structure has been almost completely lost.

But there will be greater risks of causing the process to become more severe by accidentally "pushing" isolated or clustered bacteria to apical tissues previously contaminated, in cases of chronic periapical lesion.[3] Great care should be taken in this sense.

5. If the objective of surpassing these limits is to standardize the cemental canal walls and put them in continuity with the main canal walls, in cases of biopulpotomy, there would be no need for instrumentation beyond the apical foramen, given that the cemental walls are neither contaminated nor reabsorbed.

6. In spite of the fact that pain threshold and discomfort varies from patient to patient, there will inevitably be an initial acute inflammatory process for two or three days in the protocols in which the instrument surpasses the apical foramen limits and passes through the apical periodontal ligament. This may bring discomfort characterized by spontaneous or painful sensibility to mastication. The professional must be prepared to administer analgesic and anti-inflammatory drugs during this period, should the patient complain. Moreover, the professional may even assume that, for better comfort of the patient, he will administer these drugs in all cases in which this protocol is employed.

7. In cases in which inflammatory symptoms persist, the possibility of greater bacterial presence, taken or pushed by the instruments to the apical region, must be considered. The process may develop into abscessation. In cases of greater sensibility, the possibility of an antibiotic therapy must be considered in order to avoid bacterial proliferation in the apical tissues, aborting any possible abscessation focus.

8. If we consider that the inflammation induced in the apical region is inevitable when the instrumentation is adopted beyond the apical foramen, the possibility of having bacteria in the periapical tissues, "taken or pushed" by the instruments to the apical periodontal ligament, increases. Thus, the preventive administration of medication right after endodontic treatment of special patients, such as cardiac, renal and immuno-compromised patients, should be emphasized.

9. Even if the filling material is expected to greatly adapt itself to the walls of the instrumented canal with this protocol, it must be emphasized that there will be no hermetic closure and perfect adaptation in the material-canal interface at the enlarged apical foramen, due to the irregularity of its anatomy (Fig 1) and uniformity of its walls, in terms of space and surface.

10. Inflammation represents a very efficient mechanism of local defense that is able to easily eliminate isolated bacteria. In the first two or three days, the neutrophils, arriving 90 minutes after the physical aggression, phagocyte the bacteria and even though they release enzymes and anti-bacterial substances that are toxic to the tissues, they prevent abscessation or microabscesses

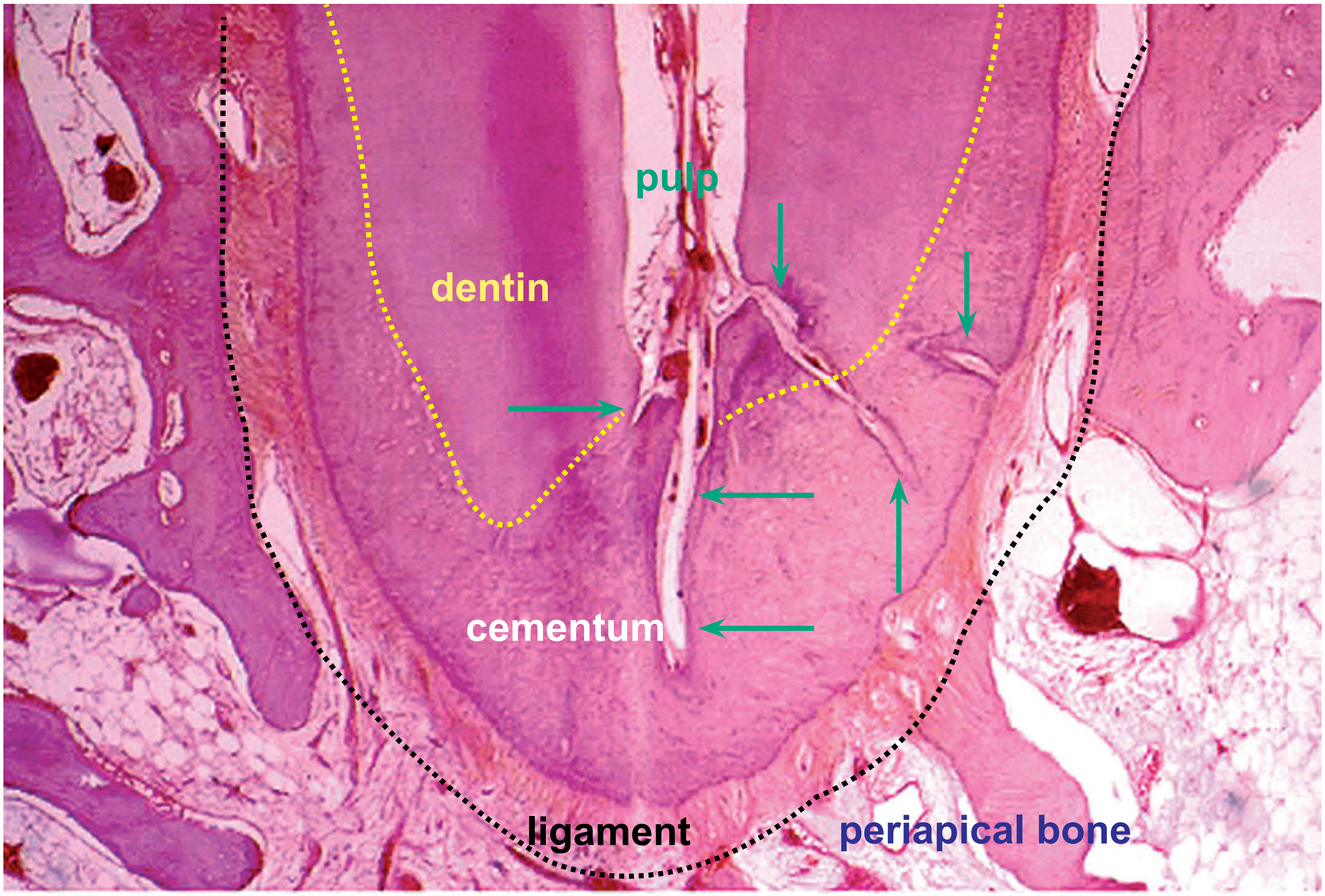

Figure 1. Microscopic morphological aspects of human dental apex and periapical region, emphasizing proportionality between the parts and irregularity of the region, especially the apical delta (arrows) (H.E. Magnification = 10X).

from being formed due to the low number of bacteria. Abscessation and exuberant pus formation occur when there is a great number of bacteria and/or when they are organized in microbial biofilms, the moment in which they assume greater resistance caused by the lack of access of cells, substances of defense, antiseptics and antibiotics.[2]

11. Despite regularizing and cleaning the cemental canal wall, instrumentation beyond the apical foramen does not eliminate the microbial biofilm adhered to the external apex surface, let alone the ones located in the anatomical irregularities, in the apical deltas and/or apical resorption areas.[3] This situation explains the persistence of a small, but significant percentage of endodontic failures when teeth with chronic periapical lesions are treated.

12. The last stage of an inflammation or repair is characterized by the reconstruction of unorganized and destroyed areas only after the local aggressor has been eliminated. The vessels and adjacent periodontal ligament cells proliferate and colonize the area, forming an immature tissue known as granulation tissue which gradually matures into connective tissue, structurally and functionally. The apical structures, such as the cement and ligament, are reestablished, and their bone limits are reinstalled from the granulation tissue, promoting complete periapical bone repair.

13. The concept of infection refers to the contact of microorganisms (bacteria, viruses and fungi) with another living organism. An infection may be characterized by: a) the latency of microorganisms without causing any aggression, or even, b) the induction of aggression and tissue reactions that characterize the diseases. Despite being technically and technologically developed, the endodontic techniques cannot ensure that all microorganisms are eliminated from the apical region after canal obturation. However, a significant reduction in the amount of microorganisms is mandatory, since it will imply in an inflammatory reaction that will eliminate and/or control this apical infection/contamination, without any clinical discomfort to the patient.

Final considerations and insight

The endodontic clinic, including the Imaging sciences, offers several parameters to establish successful and unsuccessful criteria for performed treatments. These criteria must be applied to research carried out with human beings. Researches carried out with humans are directly extrapolative and way more reliable, if the ethical principles are respected and the specificities of each species are considered.

Researches on new treatment protocols that exceed the apical limits to an extent not greater than 1 mm should assess cases in light of the following criteria: Pain and discomfort (type, intensity and duration), painful occlusion (type, intensity and duration), need for therapy with analgesic, anti-inflammatory and antibiotic drugs (time, type, costs and efficiency).

At the same time, these results should be compared by means of the same parameters used in similar cases, but using more classic protocols of endodontic therapy, in which the apical limits of work were restricted to the main and cemental canals, only.

Likewise, in the same cases, but in distinct subgroups, the previous images of the apical region, with and without chronic periapical lesions, could be studied and compared with the progress of apical and periapical repair. Digital, radiographic and tomographic images currently offer high accuracy in analysis.

The following parameters are among those that could be compared and assessed: the limits of obturation, material overflow, apical periodontal space width, lamina dura continuity, reparative bone new formation, apical resorption and structural impairment degree, in addition to the frequency of instrument fracture. The new technologies for analysis have developed significantly and, now, allow the assessment of endodontic therapy advances in humans.

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Evaluation of silver nanoparticles as irrigating solution

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ABSTRACT

Introduction: Irrigation is an important procedure during root canal treatment once it can help cleaning those areas of the root canal system not directly reached by instruments **Objective:** The aim of this study was to evaluate the biocompatibility and disinfection ability of silver nanoparticles dispersion in comparison to 2.5% sodium hypochlorite. **Methods:** Thirty two rats individually received 4 infected and uninfected dentin tubes irrigated with 47 ppm and 23 ppm silver nanoparticles dispersion, 2.5% sodium hypochlorite, and saline solution. Sixteen rats received one infected and one uninfected dentin tube, as the control group. After 7 and 30 days, all the animals were killed, the tubes and surrounding tissues were removed, and prepared to be analyzed in light microscope. Qualitative and quantitative assessments of the reactions were carried out. **Results:** All solutions in uninfected tubes caused mild reactions after 30 days. All solutions in infected tubes caused severe reactions after 7 days and mild reactions after 30 days. The outcomes were similar to those of the uninfected control group, but better than those of the infected control group. **Conclusions:** It was possible to conclude that silver nanoparticles dispersion was biocompatible and may act as disinfectant in contaminated tubes, especially at 23 ppm.

Keywords: Endodontics. Biocompatibility. Connective tissue biology.

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Introduction

Irrigation is an important procedure during root canal treatment, once it helps with cleaning those areas of the root canal system not directly reached by instruments.[1] Teeth with incomplete root formation present large root canals, with thin and fragile walls. These features hinder instrumentation of the canal. In such cases, in order to allow pulp regeneration, treatment of immature teeth in an attempt to revascularize the pulp has been considered. The treatment consists of irrigation and disinfection carried out with antimicrobial agents achieving successful revascularization.[2] In other studies, the protocol differs from other apexification techniques in which disinfection of the canal is performed with both sodium hypochlorite (NaOCl) and chlorhexidine (CHX), using a combination of antibiotics such as ciprofloxacin, metronidazole and minocycline,[4] achieving successful revascularization.[3,4] Sodium hypochlorite (NaOCl), chlorhexidine gluconate and saline solution are routinely used as irrigants.[5,6,7] Several studies have compared their antimicrobial effects, chemical properties and biocompatibility in order to establish an ideal solution that can be used during root canal treatment.[5,6]

Nanomaterials have been used to create new consumer products as well as applications for life sciences and biotechnology due to their physical and chemical properties.[8] Chemically, the nanoparticles (NPs) are very diverse. Silver nanoparticles (Ag NPs) are widely used in electronics[9,10] optical devices,[10,11] catalysis,[10,12] and antimicrobial agents.[10,13] Monovalent silver compounds, especially silver nitrate, have been extensively used for antimicrobial treatment. These antimicrobial properties are retained in Ag NPs and exploited in nanofiber mats, bandages, wound dressings and ointments. In addition, Ag NPs have been used to prevent bacterial colonization on various surfaces such as catheters, prosthesis and clothing.[14] However, silver should be used with caution, since its toxicity depends on its concentration.[14] On the other hand, it has been recently observed that silver nanoparticles dispersion was biocompatible, especially at a lower concentration.[8]

Considering that there are few studies in the literature assessing the use of Ag NPs in steps of root canal treatment, especially as irrigating solution, the aim of this study was to evaluate the biocompatibility and disinfection ability of Ag NPs dispersion in comparison to 2.5% sodium hypochlorite using a rat subcutaneous tissue as model.

Material and Methods

Forty-eight male 4- to 6-month-old Wistar albino rats, weighing 250–280g, were used. The animals were housed in temperature-controlled rooms and received water and food *ad libitum*. The care of the animals was performed according to the College of Dentistry — Araçatuba (UNESP) Institutional Review Board which approved the project before the experiments began.

One hundred and sixty dentin tubes were prepared using bovine teeth roots. This technique was adapted from the preparation of dentin tubes with human teeth.[15] The root canals were enlarged to K-file #35 and overinstrumented 2 mm beyond the apical foramen. The canals were thoroughly irrigated with 2.5% sodium hypochlorite during instrumentation. Endo-Z bur (Maillefer Dentsply, Tulsa, OK) was used to shape the dentin wall thickness to about 0.5 mm. At the end of the manufacturing process, the length of the tubes was standardized to 7 mm. Smear layer was removed with 17% EDTA and 5.25% NaOCl under ultrasonic vibration and saline solution was used as final irrigant. The dentin tubes were autoclaved for 30 min at 134°C.[15]

Human saliva was used to infect half of the tubes. Human saliva was collected (3 mL) and distributed into 3 vials containing 4 mL of Brain Heart Infusion broth (BHI; Himedia, Mumbai, India) and stored for 48h at 37°C. Under laminar flow, the tubes were aseptically and individually set in a 24-well plate (Corning, NY, USA) using alcohol decontaminated wax and filled with contaminated BHI. The plates were stored for 7 days at 37°C in order to allow dentin tube contamination. Every day, 0.1 mL of contaminated BHI was used to refill the tubes. Two extra tubes were used to check the contamination. The remaining tubes were not contaminated and also aseptically set in a 24-well plate.

Sixty four uninfected tubes and sixty four infected tubes were irrigated with 5 mL of 47 ppm Ag NPs dispersion, 23 ppm Ag Nps dispersion (Khemia Equipamentos Tecnológicos de Efluentes Ltda, São Paulo, São Paulo, Brazil), 2.5% sodium hypochlorite

(Apoticário, Araçatuba, São Paulo, Brazil) and saline solution (16 tubes/treatment). Sixteen extra uninfected tubes and sixteen extra infected tubes were not irrigated with any solution and were used as control.

Four pockets were created in thirty two animals according to methods previously published.[15] Half of the animals received four uninfected tubes and the remaining animals received four infected tubes (one tube for each treatment solution). For the controls, in sixteen remaining animals, only two pockets were created to receive untreated tubes (uninfected/ infected).

After 7 and 30 days, the animals were euthanized by overdose of anesthetic solution, and the tubes with surrounding tissues were removed, fixed, decalcified and processed using glycol methacrylate and hematoxylin-eosin stain.[16,17,18]

Reactions in the tissue in contact with the material on the opening of the tube were scored according to previous studies, with 0 being none or few inflammatory cells and no reaction; 1, less than 25 cells and mild reaction; 2, between 25 and 125 cells and moderate reaction; and 3, 125 or more cells and severe reaction. Fibrous capsules were considered to be thin when thickness was <150 mm and thick at >150 mm.[17-20] An average of the number of cells for each group was obtained from 10 separate areas. Results were statistically analyzed using the Kruskal-Wallis test.

Results

Uninfected dentin tubes

Similar histologic characteristics were found after the implantation of uninfected tubes, regardless of the treatment, including the control. After 7 days, a moderate inflammatory cell infiltration with chronic inflammatory cells consisting of lymphocytes, macrophages, and fibroblasts was present in the thin fibrous capsule. The inflammatory reaction decreased and the tissue was more organized with the predominance of fibroblasts and connective fibers on the 30th day (Fig 1).

Infected dentin tubes

Ag NPs dispersion (23 ppm)

After 7 days, a severe inflammatory cell infiltration consisting of neutrophils, lymphocytes and macrophages was present in the fibrous capsule (Figs 2A and 2B). The intensity of the inflammation was reduced to mild on the 30th day consisting only by chronic cells and the fibrous capsule near the tube was thin (Figs 2C and Fig 2D).

Ag NPs dispersion (47 ppm)

On the 7th day, a severe inflammatory cell infiltration consisting of neutrophils, lymphocytes and macrophages was present in the fibrous capsule similar to that observed with the 23 ppm Ag NPs (Figs 2E and 2F). The intensity of the inflammation was reduced to mild on the 30th day when it consisted only of chronic cells and the fibrous capsule near the tube was thin and well organized (Figs 2G and 2H).

Sodium hypochlorite (2.5%)

On the 7th day, a severe inflammatory cell infiltration consisting of neutrophils, lymphocytes and macrophages was present in the disorganized fibrous capsule (Figs 2I and 2J). The intensity of the inflammation was reduced to mild on the 30th day, consisting only of chronic cells in a thin fibrous capsule (Figs 2K and 2L).

Saline solution

On the 7th day, a severe inflammatory cell infiltration consisting of neutrophils, lymphocytes and macrophages was present in the disorganized fibrous capsule (Figs 2M and 2N). The intensity of the inflammation was reduced to mild on the 30th day, consisting only of chronic cells in a thin but partially disorganized fibrous capsule (Figs 2O and 2P).

Control (empty tubes)

On the 7th day, a severe inflammatory cell infiltration consisting of neutrophils, lymphocytes and macrophages was present in the disorganized fibrous capsule (Figs 2Q and 2R). The intensity of the inflammation was reduced to moderate on the 30th day, consisting of chronic and acute cells in a completely disorganized fibrous capsule (Figs 2S and 2T).

Comparison among groups

The data were compared in each period of time and are shown in Table 1.

Uninfected dentin tubes

There was statistically significant difference ($p < 0.05$) between the results observed on the 7th day (median 2)

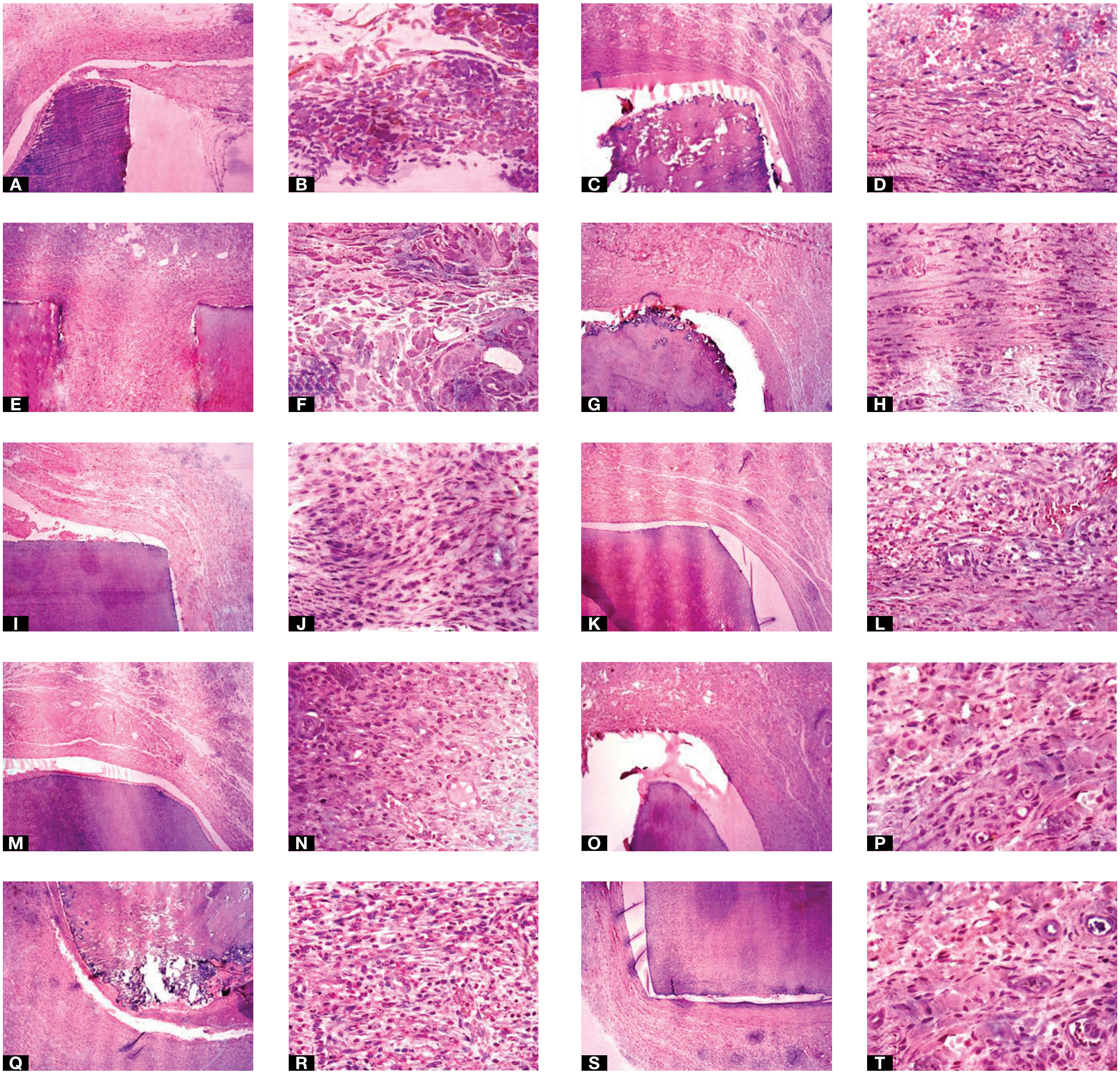

Figure 1. Uninfected dentin tubes. 47ppm Ag NPs: **A, B**) thick fibrous capsule and moderate inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **C, D**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). 23ppm Ag NPs: **E, F**) thick fibrous capsule and moderate inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **G, H**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). 2.5% NaOCl: **I, J**) thick fibrous capsule and moderate inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **K, L**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). Saline solution: **M, N**) thick fibrous capsule and moderate inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **O, P**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). Control: **Q, R**) thick fibrous capsule and moderate inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **S, T**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x).

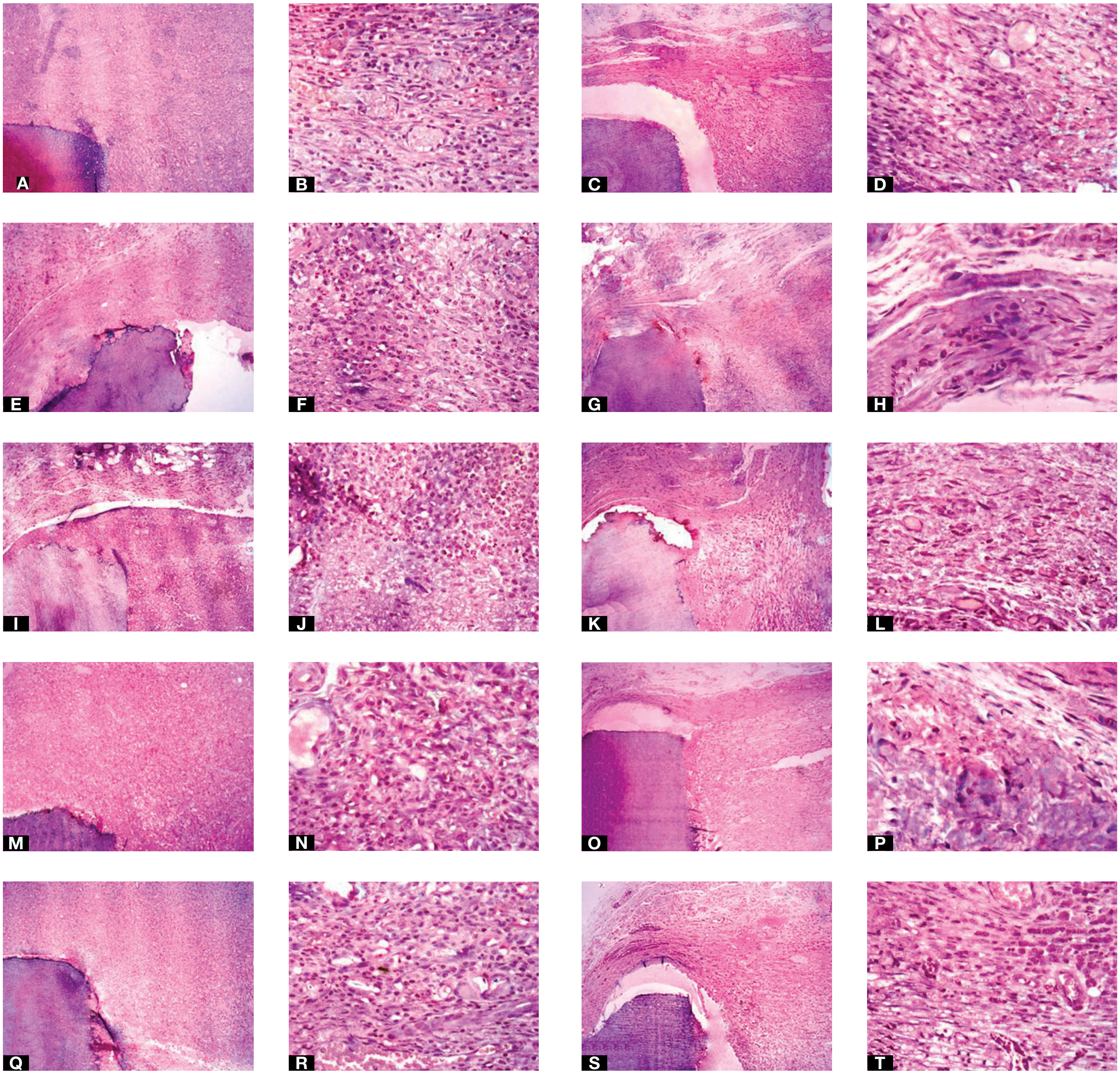

Figure 2. - Infected dentin tubes. 47ppm Ag NPs: **A, B**) thick fibrous capsule and severe inflammatory cell infiltration including the presence of neutrophils (7 days, hematoxylin and eosin, 10x and 40x); **C, D**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). 23ppm Ag NPs: **E, F**) thick fibrous capsule and severe inflammatory cell infiltration, observe the more organized tissue (7 days, hematoxylin and eosin, 10x and 40x); **G, H**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). 2.5% NaOCl: **I, J**) thick fibrous capsule and severe inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **K, L**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). Saline solution: **M, N**) thick fibrous capsule and severe inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); **O, P**) thin fibrous capsule and mild inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x). Control: **Q, R**) thick fibrous capsule and severe inflammatory cell infiltration (7 days, hematoxylin and eosin, 10x and 40x); (**S, T**) thin fibrous capsule and moderate inflammatory cell infiltration (30 days, hematoxylin and eosin, 10x and 40x).

Table 1. Percentage of samples from each group, categorized according to the inflammatory score, presence of necrosis and thickness of the fibrous capsule.

Material	Score				Necrosis	Capsule
	0	1	2	3		
7 days						
47 ppm	0	0	100	0	Absent	Thick
23 ppm	0	0	100	0	Absent	Thick
2.5% NaOCl	0	0	100	0	Absent	Thick
Saline solution	0	0	100	0	Absent	Thick
Control	0	0	100	0	Absent	Thick
Infected 47 ppm	0	0	0	100	Absent	Thick
Infected 23 ppm	0	0	0	100	Absent	Thick
Infected NaOCl	0	0	0	100	Absent	Thick
Infected saline	0	0	0	100	Absent	Thick
Infected control	0	0	0	100	Absent	Thick
30 days						
47 ppm	0	100	0	0	Absent	Thin
23 ppm	0	100	0	0	Absent	Thin
2.5% NaOCl	0	100	0	0	Absent	Thin
Salina solution	0	100	0	0	Absent	Thin
Control	0	100	0	0	Absent	Thin
Infected 47 ppm	0	100	0	0	Absent	Thin
Infected 23 ppm	0	100	0	0	Absent	Thin
Infected NaOCl	0	100	0	0	Absent	Thin
Infected saline	0	100	0	0	Absent	Thin
Infected control	0	0	100	0	Absent	Thin

and 30th day (median 1) for all treatments. No statistically significant difference was observed among the materials on day 7 or 30 ($p>0.05$).

Infected dentin tubes

There was statistically significant difference ($p<0.05$) among the results observed on the 7th day (median 3) and 30th day (median 1 for all treatments except for the control — median 2) for all treatments. No statistically significant difference ($p>0.05$) was observed among the materials on the 7th day. On the 30th day, thee was statistically significant difference among all treatments (median 1) ($p<0.05$), except for control (median 2).

Discussion

The aim of this study was to assess the biocompatibility and disinfection effect of Ag NPs dispersion for possible use as an irrigating solution in comparison to sodium hypochlorite. Infected dentin tubes were used to simulate a root canal infection which was obtained with saliva in order to generate a biofilm similar to that formed naturally with pulp exposure to the oral environment. Irrigation was used without instrumentation to achieve a critical condition aiming to test the irrigation solutions.

Biofilms are a result of a sequence of events: microbial surface attachment, cell proliferation, matrix production, and detachment.[8,21] Endodontic infection is a biofilm-mediated infection, and the success of an endodontic treatment will depend on the effective elimination of bacterial biofilm from the root canal system.[22] Resistance of bacterial biofilm to disinfectants such as sodium hypochlorite and chlorhexidine is due to inherent microbiologic factors and the complex anatomy of the root canal system.[22]

In the present study, the uninfected control tubes exhibited moderate response in the beginning. This response was reduced to mild within 30 days and similar to other studies.[15] The infected control group exhibited a severe reaction in the beginning, which was reduced to moderate, showing persistence of the infection. The infection was reduced with saline solution irrigation, but the tissue was not completely organized evidencing some hazard in the healing process.

Sodium hypochlorite was biocompatible, since it was observed just a mild reaction after 30 days, similar to what was observed in the uninfected control tube. Sodium hypochlorite was also able to disinfect the dentin and it was evidenced by mild reaction after 30 days, corroborating previous reports.[6,8] Sodium hypochlorite is one of the most widely used endodontic irrigants due to its antibacterial activity and capacity of dissolving necrotic tissue remnants.[7,8] The antimicrobial effect of sodium hypochlorite is a result of the formation of hypochlorous acid (HOCl) when in contact with organic debris. HOCl exerts its effect by oxidation of sulfhydryl groups within bacterial enzyme systems, thus, disrupting microbial metabolism.[7,8]

On the other hand, Ag NPs were also biocompatible exhibiting tissue response similar to that observed with 2,5% sodium hypochlorite in uninfected tubes. They were also able to disinfect the infected dentin tubes, similarly to the hypochlorite. Nevertheless, the fibrous capsule seemed to be more organized with 23 ppm Ag NPs than with 2,5% sodium hypochlorite or 47 ppm Ag NPs. Antibacterial experiments have demonstrated that silver is effective against a broad range of bacterial cells and mature biofilms; however, concentration is an important factor which can partially explain the results observed.[8,21] Nanoparticulates exhibit high antibacterial activity as a result of their polycationic/polyanionic nature, with high surface area and charge density, increasing the degree of interaction with the bacterial cell.[22,23]

Silver compounds have been extensively investigated in comparison to other metals because of their antibacterial, antifungal and antiviral actions.[21,24,25] Silver ions have been used in biomedical applications, including, within the dental field, as an antibacterial component in dental resin composites, tissue conditioners, acrylic resins, and mouthrinses.[24,26-29]

This study concluded that Ag NPs dispersion was biocompatible and able to disinfect the infected dentin tubes, similarly to 2.5% sodium hypochlorite. However, other studies are necessary to better analyze the behavior of this material and confirm the observed data.

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Can the sodium hypochlorite tissue dissolution ability during endodontic treatment really be trusted? An in vitro and ex vivo study

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ABSTRACT

Objective: The aim of this study was to (1) evaluate the tissue dissolution effect of sodium hypochlorite (NaOCl) at different concentrations on the apical portion of mesial root of human mandibular molars with isthmuses and (2) evaluate the dissolution time of bovine pulp tissue in direct contact at different concentrations and volumes of NaOCl. **Methods:** Histologic investigation was performed in thirty mesial roots of human mandibular molars that were instrumented using the Mtwo system and irrigated with 2.5% NaOCl or 5.25% NaOCl. Saline solution was used as control. Each sample was submitted to histologic processing and the images were analyzed using the ImageJ software. The percentage of area occupied by tissue was calculated by dividing the area of tissue by the canals area. Data were analyzed by means of the analysis of variance with Tukey test ($P < 0.05$). Dissolution time was analyzed by immersing bovine pulp tissue in different volumes of 2.5% and 5.25% NaOCl solution. **Results:** No significant difference was found between the NaOCl concentrations in the histological investigation. No substance was able to completely clean the isthmuses. Moreover, a higher dissolution rate for the bovine pulp tissue was found in NaOCl with a concentration of 5.25%, in addition to a shorter dissolution time for larger volumes. **Conclusion:** The NaOCl is effective for tissue dissolution when in direct contact, however, NaOCl solution, even in high concentrations, was not competent to dissolve remnants of pulp tissue in root isthmuses during endodontic treatment.

Keywords: Sodium hypochlorite. Dissolution. Anatomy.

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Introduction

One of the goals of endodontic therapy is the removal of all vital or necrotic tissues, microorganisms and microbial by-products from the root canal system.[1,2,3] Complete debridement of the root canal system is complicated due to the presence of a complex system of isthmuses, accessory canals and deltas that can provide ideal locations for bacteria and harboring debris.[1,4,5,6]

An isthmus is defined as a narrow, ribbon-shaped communication canal between two root canals that contains pulp tissue.[7,8] The prevalence of isthmuses in the mesial root of mandibular first molars has been reported in previous studies in which observations were carried out using different methods and at varying distances from the apex.[8,9,10] These areas have proved to be inaccessible to conventional manual and rotary instrumentation.[4,6,11,12,13] To aid in the removal of debris and the disinfection of these areas, the use of various irrigating solutions has been advocated.[14,15] Sodium hypochlorite (NaOCl) is the most widely recommended irrigating solution used during the chemomechanical preparation of the root canal system. This endodontic irrigant has the ability to destroy a broad spectrum of microbes, and its antimicrobial property has been widely reported.[16,17,18] Furthermore, the NaOCl is a non-specific proteolytic agent with excellent tissue dissolution ability.[19]

Tissue dissolution depends on 3 factors: frequency of agitation, amount of organic matter in relation to the amount of irrigant in the system and amount of available tissue surface area.[20] Many studies have examined the tissue dissolution ability of NaOCl, and have presented some conflicting results.[1,2,21,22] Apparent inconsistencies among the results could be explained by the great variety of methods used for assessing tissue solubility in those studies. Several in vitro studies have showed the NaOCl ability to dissolve the pulp tissue by direct contact[16,23]. However, studies in which the real goal was not to show the NaOCl dissolution ability demonstrated that this irrigating solution was not able to dissolve pulp tissue in anatomical complexity areas, especially in isthmus.[1,2,22,24]

Thus, the purpose of this in vitro study was to evaluate (1) the tissue dissolution effect of NaOCl at different concentrations (2.5% and 5.25%) on the apical portion of mesial root of human mandibular molars with isthmuses and (2) the dissolution time of bovine pulp tissue in direct contact at different concentrations and volumes of NaOCl (2.5% and 5.25%).

Material and Methods

Histological evaluation

Thirty mesial canals of vital freshly extracted human mandibular molars were selected for this study. Pulp vitality of the 30 test teeth was initially established with Endo-Ice refrigerant spray (Hygenic Corp., Akron, OH). The teeth were referred to extraction due to nonrestorability or patient's refusal of endodontic treatment. After extraction, the teeth were stored in 0.1% thymol solution and maintained at 4°C before use. Conventional access preparations were made and #10 K-type file was introduced into each canal until it reached the apical foramen. The working length (WL) was established at this distance. Canals were randomly divided into three groups of ten teeth each according to the irrigation protocol.

The root canals were prepared by the crown-down technique using the Mtwo system (VDW, Munich, Germany) with up and down movements, as recommended by the manufacturer. After an initial enlargement with a stainless #10 file, sequential Mtwo instrumentation (10/.04; 15/.05; 20/.06; 25/.06) was performed to the working length. The root canal was irrigated with a 27-gauge needle syringe. A volume of 10 mL of each irrigating solution (2.5% sodium hypochlorite; 5.25% sodium hypochlorite and 0.9% saline solution) was used in each tooth after each file, and then 10 mL of the same solution was used for final irrigation. A total volume of 50 mL of solution was used in each tooth. Recapitulation was performed with a #10 file at the WL. Afterwards, the same procedure was carried out with larger files. The solution was kept in the root canal system for a period of 45 minutes.

Apical 4 mm pieces of each root was sectioned and removed for histological processing. Canals were flooded with 10% neutral buffered formalin and stored in this same solution until histological processing was carried out. Specimens were then washed and decalcified in an aqueous solution containing equal parts of 50% formic acid and 50% sodium citrate for 20 days, and embedded in paraffin wax. Serial cross-sections were cut at 6 μm and alternately stained with hematoxylin and eosin. The images taken were analyzed by means of the ImageJ software (National Institutes of Health, Bethesda, MD, USA). The outline of the canals were traced to determine the surface area of the region. Areas occupied by stained tissue in the region were also determined.

The percentage of area occupied by tissue was calculated by dividing the tissue area by the canal area, for each canal. Data were analyzed by means of analysis of variance with Tukey post hoc tests (significance level, $P < 0.05$).

Bovine pulp tissue dissolution

The pulp tissue was collected from extracted bovine teeth stored in 0.1% thymol solution and maintained at 4°C. Two longitudinal grooves were cut in the proximal surfaces of the teeth with diamond burs. The teeth were split in halves. The bovine pulp tissue samples were weighed and standardized at 0.20 g. Pulp tissues with lower weight were discarded and those, in which the weight was greater, had some parts removed to achieve the proposed weight. Pulp tissues that were fragmented during removal were discarded.

Each bovine pulp tissue sample was placed separately into amber vials with NaOCl solution at different concentrations (2.5% and 5.25%). The pH of the solutions was 11. At first, the samples were immersed in 1 mL of solution and kept under constant agitation, at 37°C, during 30 minutes, until all the pulp tissue was dissolved. Tissue dissolution was timed, and the average of dissolution time was calculated among the three tissue samples in observation. When the pulp tissue was not dissolved within 30 minutes of observation, the sample was collected and weighed. Afterwards, pulp tissue samples were immersed in NaOCl solutions increased by 1 mL, until the volume used did not alter the time of tissue dissolution.

All the experiments were done in triplicate. The mean tissue dissolution times were compared using the One Way ANOVA statistical test for comparison between the different volumes used for each concentration as well as the comparison of the ability to dissolve tissue between the different NaOCl concentrations (2.5% and 5.25%).

Results

The in vitro bovine pulp tissue dissolution results are presented in Table 1. The One-way ANOVA test indicated statistically significant differences between the 5.25% and 2.5% NaOCl solution, in which the former had a higher tissue dissolution rate. Conversely, no statistically significant difference was observed between different volumes of 5.25%, which did not happen for 2.5% NaOCl solution. No pulp dissolution was found with less than 13 mL of 2.5% NaOCl and 4 mL of 5.25% NaOCl. The 5.25% NaOCl showed a stable dissolution time as from 8 mL of solution.

The histological evaluation results of pulp tissue dissolution in isthmuses are presented in Table 2. There were no differences among the different sodium hypochlorite solutions used for irrigation in endodontic treatment for tissue dissolution in root isthmus. Although the three substances used were able to remove parts of the pulpal tissue in the isthmus, none of them was able to completely clean it (Figs 1A to F).

Table 1. Comparison between the mean bovine pulp tissue dissolution times, in minutes, according to the volume in mL, and the NaOCl concentration (Mean ± standard deviation).

Volume (ml)	Dissolution time	
	5.25% NaOCl	2.5% NaOCl
1	*	*
2	*	*
3	*	*
4	29.00 ± 1.01^{A}	*
5	27.15 ± 1.62^{AB}	*
6	23.56 ± 1.02^{BC}	*
7	24.43 ± 0.75^{BC}	*
8	22.50 ± 1.83^{C}	*
9	22.63 ± 0.25^{C}	*
10	22.30 ± 0.81^{C}	*
11	21.30 ± 0.81^{C}	*
12	21.06 ± 1.67^{C}	*
13	21.64 ± 1.92^{Cb}	28.00 ± 0.34^{Aa}
14	21.56 ± 0.92^{Cb}	28.06 ± 0.40^{Aa}
15	21.03 ± 1.92^{Cb}	28.01 ± 0.26^{Aa}

Different lowercase letters used horizontally indicate statistically significant differences between concentrations ($p < 0.05$). Different uppercase letters in column indicate statistically significant differences between the volumes at the same concentration ($p < 0.05$) *Tissue dissolution not observed after 30 minutes.

Table 2. Mean ± standard deviation of percentage of canal cleanliness.

Group	Canal cleanliness
0.9% saline solution	62.5 ± 14.6^{A}
2.5% sodium hypochlorite	68.6 ± 09.7^{A}
5.25% sodium hypochlorite	71.1 ± 10.2^{A}

Different letters show statistically significant differences among the groups ($p < 0.05$).

Discussion

Sodium hypochlorite, at different concentrations, has been used as an irrigant of the root canal for a long period. Its use is supported not only by its good physical and chemical properties, but also by other properties such as antimicrobial and tissue dissolution.[25,26,27] The ability to dissolve tissues can be considered one of the most important properties of the NaOCl solution.[28] However, many studies have shown that variables such as concentration, contact time and volume affect the solution tissue dissolution capacity, questioning the NaOCl ability to dissolve pulp tissue.[1,2,16,20,25,28,29] One of the objectives of the present study was to assess the irrigant solution volume needed to dissolve pulp tissue; varying the volume throughout the experiment and using pulp samples of same weight.

It was noted that the higher the concentration, the greater the ability to dissolve pulp tissue when different concentrations of NaOCl were evaluated. These results are in accordance with previous studies, which stated that stronger concentrations of NaOCl result in greater tissue dissolution.[23,25]

It was also observed that in the first minutes of contact with the solution, the tissue dissolution occurred rapidly and the ability to dissolve decreased with time. This fact indicates that the potential for tissue dissolution will be reduced over time and it may be related to the chemical reactions (saponification) that occur between NaOCl and the pulp tissue. In this reaction, NaOCl in contact with organic material hydrolyzes proteins transforming them into amino acids and lipids that are converted into free fatty acids.[30] As result, the NaOCl is dissociated and

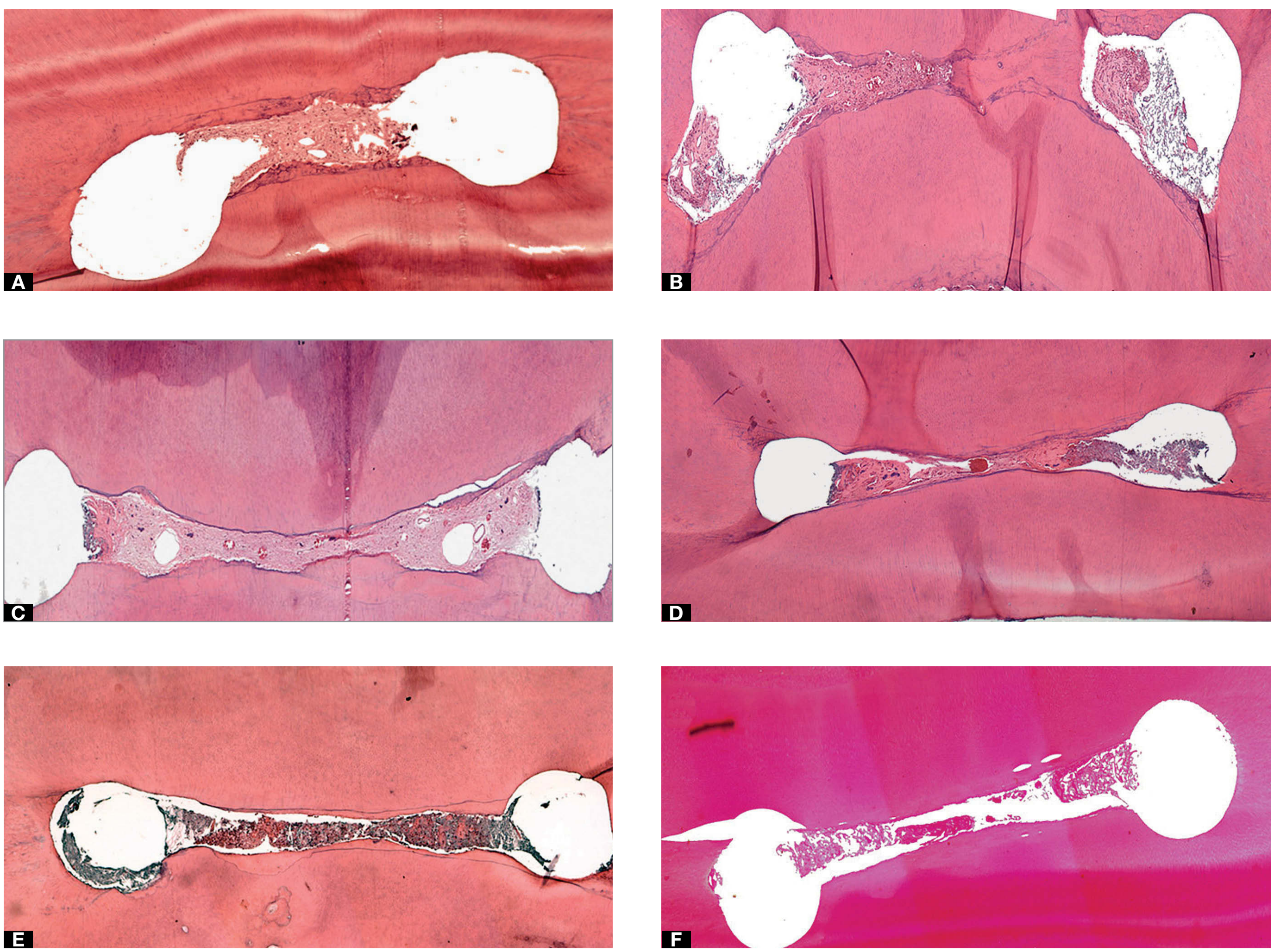

Figure 1. Light microscopy images of hematoxylin and eosin stained cross-sections of root specimens that were irrigated with (**A**, **B**) 0.9% saline solution; (**C**, **D**) 2.5% sodium hypochlorite; and (**E**, **F**) 5.25% sodium hypochlorite (Original magnifications, 40X).

the activity of tissue dissolution is reduced.[31] Due to the consumption of reagents and their influence on the speed of chemical reactions, it is suggested that constantly renewing the irrigating solution during endodontic procedures would increase both speed and potential for tissue dissolution when compared to simple contact between NaOCl and pulp tissue.

Moreover, the volume used directly affects the ability of the solution to dissolve tissues. A minimum volume of 4 mL of 5.25 % NaOCl was requested to completely dissolve 0.2 g of bovine pulp tissue. On the other hand, a minimum volume of 14 mL of 2.5% NaOCl was necessary to reach the total tissue dissolution of a similar sample.

Although tissue dissolution was observed upon direct contact with NaOCl solution, some studies evaluating different instrumentation techniques show that when the canal anatomy is not favorable, the NaOCl becomes less effective in dissolving organic tissues and, in some cases, no tissue dissolution is observed in difficult anatomic areas.[1,2,24,32,33] The results of the present study confirm these findings and show that despite being a tissue solvent ,the NaOCl is not competent to dissolve remnants of pulp tissue in root isthmus during endodontic treatment. Even when it was used at 5.25%, the NaOCl was not able to completely clean any isthmus. The presence of pulp tissue was observed in areas where endodontic files were not able to reach and carry out the physical cleaning.

In an attempt to remove pulp tissue not removed by tissue dissolution, recent studies have indicated the use of different irrigating devices, such as the passive ultrasonic irrigation device, due to the fact that the ultrasound technique shows improvements in pulp tissue removal, including areas with isthmus.[1,2,12,22] However, no study has showed canal and isthmus cleanliness values of 100%.

This fact leads us to believe that the endodontist should use increasingly higher concentrations of NaOCl to achieve total tissue dissolution in areas of difficult access. However, this practice is inadvisable because the increase in tissue toxicity is proportional to the increase in solution concentration. High concentrations can lead to risks of harm to patients and delay regeneration of periodontal tissues.[34,35] Despite considering that, in clinical practice, the NaOCl solution at higher concentrations should be used in areas of difficult access for mechanical instrumentation, such as the isthmus ones, doubts arise when the small volume of solution that reaches those areas is taken into account. Thus, the actual ability to dissolve pulp tissue by direct contact is questionable.

Understanding that the NaOCl is unable to dissolve tissue in irregular areas such as isthmus on root canal, and that it may cause injury during the endodontic treatment, allows endodontists to think about other auxiliary chemical substances which have good antimicrobial properties and offer lower risks to patients during the course of endodontic treatment. Furthermore, if we accept that a large number of endodontic treatments keep tissue inside the root canal without interfering in the success of treatment, we can reconsider the importance of completely cleaning the root canal in order to achieve a successful endodontic treatment. Such success is evaluated by means of assessing the health of the periodontal ligament in the apical region and the periodontal ligament associated with openings in the lateral canals. Even when the root canal is all contaminated, parts of the periodontal ligament surrounding the root of the tooth will only make inflammatory changes when there is a communication canal, such as a lateral canal or an apical foramen. Thus, it seems more likely that the success of the endodontic treatment depends more on blocking the communication between root canal and periodontal ligament than on the complete removal of pulp tissue from root canal systems.

Conclusions

In conclusion, the present study demonstrated that depending on the concentration, a minimum volume of the NaOCl solution is necessary to dissolve pulp tissue in direct contact. However, NaOCl solution at different concentrations was not competent to dissolve remnants of pulp tissue in the root isthmus during endodontic treatment.

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Quantitative assessment of the presence of calcium hydroxide remnants associated with different vehicles after removal of intracanal medication

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ABSTRACT

Objective: The aim of this study was to assess, after removal, the presence of calcium hydroxide (CH) remnants associated with different vehicles in the cervical, medial and apical thirds. **Methods:** Forty-five bovine incisors were transversely sectioned at 18 mm from the apex. The canals were biomechanically prepared and received CH. The samples were divided into groups (n = 10): G1, saline solution; G2, CH(bp); G3, polyethylene glycol; G4, polyethylene glycol + CMPC; Negative control, no CH (n = 5). After 7 days, the medication was removed by means of mechanical action of files associated with saline solution irrigation, until the irrigating solution became transparent. The roots were longitudinally sectioned in half. Afterwards, they were photographed and the images were digitalized, allowing the calcium hydroxide remnants to be macroscopically quantified by the Image Tool® software. **Results:** The statistic results reveal that all roots presented remnants from the medication within the canals. Saline solution presented a lower amount of remnants, however, it showed a higher concentration in the apical third.

Keywords: Endodontics. Calcium hydroxide. Residue removal.

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Introduction

Cleaning and disinfection of the root canal system are among the principles that guide endodontic therapy. These requirements are essential to achieve the desired sanitization and provide conditions for the damaged tissues to return to normality.[1] Most endodontic infections show a predominance of restricted anaerobic bacteria. In these cases, there is a long-term pulp infection that promotes bacterial spread to the entire root canal system, including isthmus, branches, holes and tubules. In these regions, bacteria are protected from the effects of biomechanical preparation. Thus, the use of intracanal medication during preparation of the root canal is necessary to control endodontic infections and for periapical repair in case of *E. faecalis* infection.[2] Intracanal calcium hydroxide (CH) has been the most widely used medication.[3,4] CH is known for its antimicrobial action and ability to stimulate mineralization.[5] For these reasons, this material is commonly used in pulpotomies[6] and as an intracanal medication.[7]

The CH mixed with an appropriate vehicle and left in the root canal for several days or weeks has been widely accepted in endodontic therapy.[8,9] It can be associated with different vehicles, with different characteristics: I) Soluble-aqueous (distilled water, saline solution and chlorhexidine); II) Soluble nonaqueous (propylene glycol and polyethylene glycol) and III) Insoluble in water (camphorated paramonochlorophenol).[10] CH can be combined with other medications, such as camphor paramonochlorophenol (CMPC),[11] in order to supplement or enhance its antibacterial properties. Saline vehicles,[12] polyethylene glycol and olive oil[13] are also used to influence the CH action as well as its ionic dissociation and diffusion. On the other hand, according to Estrela and Holland,[14] associating aqueous vehicles with CH provides the best biological and antimicrobial action, allowing higher rates of dissociation and diffusion.

Nevertheless, the use of CH is questioned when its residues are taken into account. Evaluation of apical infiltration after root canal obturation are focused by other studies. Some authors claim that the residue of $Ca(OH)_2$ hinders the penetration of cement in the tubules[15] and changes the characteristics of zinc oxide-eugenol cements, causing their consistency to become brittler and more granular.[16] These residues may also increase apical leakage after obturation.[17]

Methylene blue stain tests have evaluated the sealing ability of CH. However, with the recent discovery that the CH discolored methylene blue, which results in a misinterpretation of results, it was concluded that this technique could not be used alone.[18]

Researches investigating the effects of two formulations of CH on its sealing ability by means of adding other references such as India ink or radionuclide to it, revealed that CH does not increase its sealing ability in root apex with filling.

Other researches evaluated whether intracanal medication would act to prevent penetration of bacteria inside the canal. They concluded that these medications do not provide adequate protection against bacterial infiltration by interfering in the sealing ability of cements.[16-19]

Thus, the aim of this study was to analyze the calcium hydroxide removal capacity when associated with different vehicles, by means of the filing technique and irrigation.

Material and Methods

Forty five single-rooted lower bovine incisors of adult animals, with anatomic diameter compatible with K-files #35/40 (anatomical diameter) and stored in 10% formalin were used. The crown portion was perpendicularly removed (along the axis of the tooth) with steel disc (KG Sorensen, São Paulo, Brazil) under constant cooling in water, resulting in a backlog of 18 mm from the apical portion of each root.

The step back instrumentation technique was performed, starting with K-files #35/40 (Dentsply Maillefer, Tulsa, Oklahoma, USA) in the real working length (RWL) of 17 mm, with 1 mm being respected in the apical foramen, and finishing with K-files #50/55 (Dentsply Maillefer, Tulsa, Oklahoma, USA) at the same length, which determined the diameter of the canal surgery. 5 ml of 1% sodium hypochlorite (Biodynamic Ibiporã, PR, Brazil) was applied at each change of file. A disposable syringe and a 0.55 x 20 mm needle (BD, Curitiba, PR, Brazil)were used and final irrigation was done with saline solution (ADV, Nova Odessa, SP, Brazil).

After biomechanical preparation, the canals were dried with absorbent paper cones (Tanari, Brazil) of which diameter was compatible with the last instrument, and divided into four groups:

» Group 1 (n = 10): CH + saline solution (ADV, Nova Odessa, SP, Brazil).
» Group 2 (n = 10): CH + BP (Biodinâmica, PR, Brazil).
» Group 3 (n = 10): CH + polyethylene glycol (Calen, SS White, RJ, Brazil).
» Group 4 (n = 10): CH + polyethylene glycol + camphor paramonoclorofenol (Calen + CMPC, SS White, RJ, Brazil).
» Negative control (n = 5) without CH.

In group 1, the medication was conditioned with a Centrix syringe, apically to the cervical direction, assuring that it was placed all over the length of the canal. In group 2, a curettage instrument was used and the material was condensed with paper cones. In groups 3 and 4, the canals were filled with medication by means of a ML endodontic syringe (SS White, RJ, Brazil). The canals were sealed in the cervical portion with intermediate restorative material (IRM) (Dentsply, Catanduva, SP, Brazil) and stored at 37°C in 100% relative humidity for seven days. A spoon excavator was used to remove the IRM from the canal entrance. Calcium hydroxide removal began with saline solution irrigation and movement of the K-file #45 (Dentsply Maillefer) in the CRT, without touching the walls, until CH was absent in the irrigating solution.

Then, longitudinal grooves limited to the dentin were made with double-sided steel disks (KG Sorensen), using a chisel and a hammer to prevent dentine pieces from being thrown into the canal, promoting total cleavage, which was followed by photographic documentation (Fig 1A).

Assessment of medication residues in different types of vehicles was carried out by digitized photographic images. To match the working length, the tooth canal guides were divided into three parts: apical, medial and cervical (Fig 1B). The software Image Tool 3.00 (The University of Texas Health Science Center at San Antonio, USA) was used to quantify the CH present in each third of the canal (Fig 1C).

Results

To verify whether or not statistically significant differences were identified among the proportions (quantification/perimeter) found in the cervical, medial and apical thirds, the Kruskal-Wallis relative values were applied to the four subgroups tested. Differences were statistically significant between the CH + saline solution proportion, when the values obtained in the three groups were compared (Table 1).

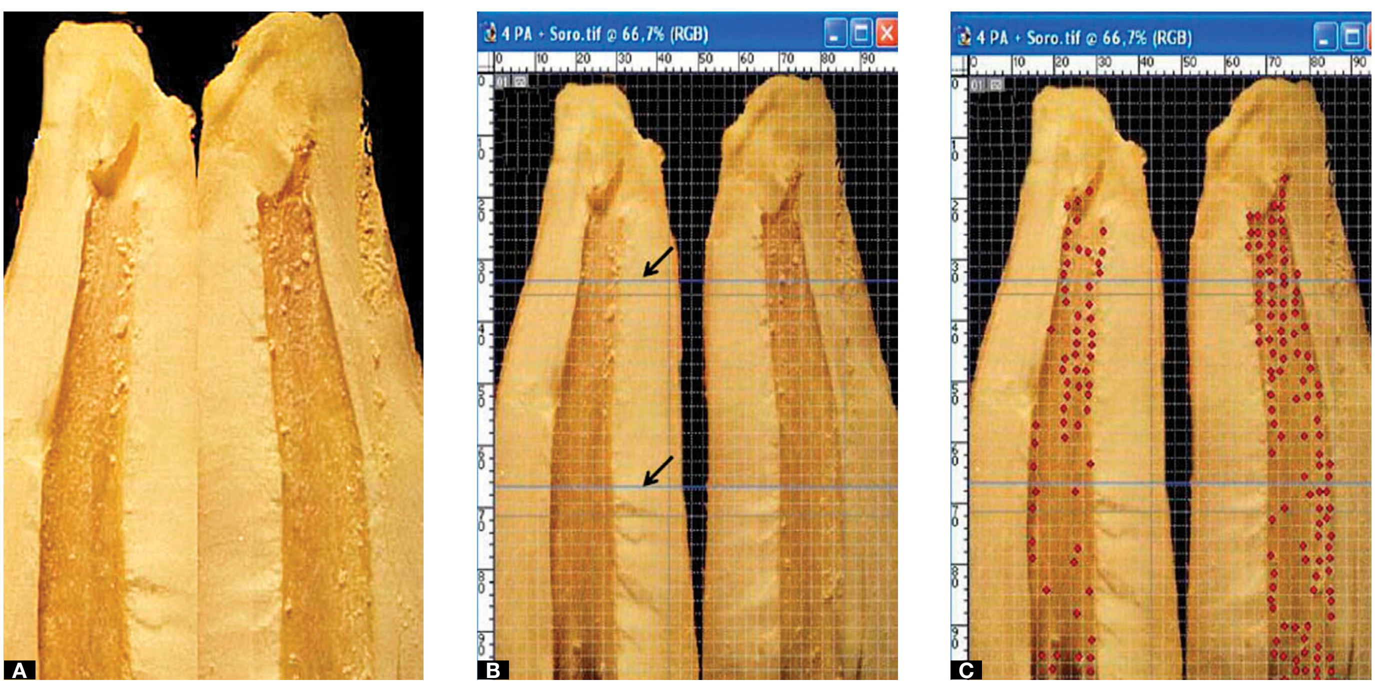

Figure 1. A) Longitudinal root section. **B**) Apical, medial and cervical thirds definition. **C**) Quantification of CH residues.

Afterwards, the Mann-Whitney U test was applied to the series of values of which pairs were compared considering the results obtained with each one of the four subgroups. The results showed that differences were statistically significant among the three comparisons made with CH+saline solution. The highest values were obtained from the apical third while the lowest values were obtained from the cervical third. As for the polyethylene glycol + camphorated paramonochlorophenol, the differences were statistically significant in the comparison between the cervical and the apical third, with the highest values obtained from the apical third (Table 2).

Discussion

Calcium hydroxide can be combined with other vehicles such as canfor paramonochlorophenol,[7] saline solution,[8] polyethylene glycol and olive oil,[9] when it aims at complementing or potentizing its action. However, it is known that the vehicle used can influence the CH ability to act as well as its ionic dissociation and diffusion. In addition, it is known that its association with aqueous vehicles provides better biological and antimicrobial action, allowing higher rates of dissociation and diffusion.[14]

Thus, in this research, undissolved pure calcium hydroxide powder (BP) was used in association with the following vehicles: saline solution (soluble in water), polyethylene glycol (soluble in water) and CMPC (oily, insoluble in water). All canals were adequately instrumented and filled by a single operator who is a specialist in Endodontics with technical expertise. Therefore, the present work does not refer to the efficiency of properties, but it aims at raising questions about which vehicle is the best when associated with calcium hydroxide, presenting the best and most efficient technique for removal of intracanal medication.

Studies assessing the cleaning capability for the removal of the medication reported differences in the techniques of evaluation and quantification. Demineralization techniques (clearing) or scanning electron microscopy (SEM) are common in this type of assessment. Based on a literature review, Maníglia et al.[20] considered the possibility of this type of assessment only on the macroscopic aspect, since it is less expensive and more easily accessible.

Table 1. Probability obtained among the proportions (quantification / perimeter) found in the cervical, medial and apical thirds.

Variables	Results
Calcium hydroxide (Saline solution)	0.001*
Calcium hydroxide (BP)	0.486
Calcium hydroxide (Calen)	0.238
Calcium hydroxide (Calen + CMPC)	0.112

* $p < 0.05$.

Table 2. Probability obtained from comparison between pairs, considering the results obtained from each one of the four subgroups.

Variables	Results
Calcium hydroxide (Saline solution)	
Medial third x cervical third	0.008 *
Cervical third x apical third	0.003 *
Medial third x apical third	0.034 *
Calcium hydroxide (BP)	
Medial third x cervical third	0.151
Cervical third x apical third	0.650
Medial third x apical third	0.821
Calcium hydroxide (Calen)	
Medial x cervical third	0.940
Cervical third x apical third	0.131
Medial third x apical third	0.162
Calcium hydroxide (Calen + CMPC)	
Medial third x cervical third	0.364
Cervical third x apical third	0.045 *
Medial third x apical third	0.199

* $p < 0.05$.

These aspects were assessed and proved to be essential for the development of our work.

In this research, after an attempt to remove the calcium hydroxide associated with different vehicles in different test groups, we found that its effectiveness is not complete, as it still leaves a considerable amount of residue to the fullest extent of the canal after removal was carried out. Irrigation is an important factor for any endodontic procedure. Its participation is essential because cleanness happens only when the CH is associated with an irrigating solution. Thus, irrigation with saline solution was constant and controlled.

When looking at the roots immediately after the section (with the naked eye), the medication was not visible, however, after 5 minutes, the residues could be seen due to dehydration of the canal walls in contact with air. The scanned photographs were used to standardize the quantification of these residues in each area represented by the cervical, middle and apical root.

Therefore, once calcium hydroxide, when used as intracanal medication, remains even after multiple removal techniques, new studies should suggest that other techniques for removal of calcium hydroxide and vehicles that facilitate removal of residues remaining in the canal be developed. It remains questionable whether the relevant literature corroborates the claim that these remnants have consequences for the quality of the canal in the event of leakage.[21-24]

Conclusion

All teeth presented residues of calcium hydroxide in the canal walls after medication was removed. According to statistical analysis, significant differences were found in relation to root thirds when the vehicle used was saline solution and Calen + CMPC. The highest values were obtained from the apical third while the lowest values were obtained from the cervical third. Thus, new removal techniques should be studied to improve the removal of these materials without compromising the biomechanical preparation.

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Evaluation of the preparation of root canals with two different systems using micro-computed tomography

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ABSTRACT

Introduction: Root canals with long oval cross section make it difficult for rotating tools, which can not be adapted to the walls in its entire extension. The Reciproc single-file system (VDW, Munich, Germany) was developed for the root canal preparation by the reciprocal motion technique. The reciprocal motion relieves the instrument stress, reducing the risk of cyclical fatigue, caused by the tension and compression. **Objective:** The objective of this study was to evaluate, *ex vivo*, the long oval root canals preparation of lower molars with Reciproc system, comparing it to the preparation with complete rotating tools, BioRaCe, by means of micro-computed tomography. **Methods:** The distal roots of thirty lower molars were used and randomly divided in two groups: G1, Reciproc R40; and G2, BioRaCe. Teeth were scanned by a SkyScan 1172, before and after the root canals preparation. The images obtained were imported, reconstructed and, then, analyzed for comparison of changing in the volume of root canal. **Results:** The results were subjected to Mann-Whitney non-parametric statistical test, for the volume analysis. The root canal preparation resulted in increased volume, with significant difference between groups ($p < 0.5$). **Conclusion:** The Reciproc system removed more dentin from the walls than the BioRaCe one.

Keywords: Dental instruments. Root canal preparation.

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Introduction

The anatomical complexity of root canals, such as canals with oval cross section, long oval (different from the circular one), still represents a challenge for the adequate preparation of wall surfaces of these canals.[1-4] There is a tendency, in such cases, in keeping the non-prepared and contaminated areas of the root canal. In canals with these anatomical conditions, literature reports several studies showing that both manual instrumentation and the continuous rotary instrumentation have left untouched areas.[3,5-8] Not removing the debris on the walls of root canal may compromise the success of endodontic therapy.[9,10]

In the conventional rotating systems, we face a difficulty in instrumenting canals with cross section different from circular ones, once there is a tendency in centralizing the tool, working less in the poles of these canals.[2,4] Searching for a more adequate action of these instruments, it is recommended the brushing movement of the instrument, which rotates continuously, into the poles so that these areas are also reached. Recently, new systems propose instruments with reciprocal motion.[10-13]

Micro-computed tomography (μCT) has got important significance in Endodontic researches, for being a non-invasive method, allowing the three-dimensional analysis of the root canal system,[14-21] as in the evaluation of the instrument action in the canal wall.

The objective of the present study was to evaluate, *ex vivo*, the preparation of long oval canals of lower molars, performed by two mechanical systems: Reciproc, with reciprocal motion; and BioRaCe, with continuous rotary instrumentation. As quality criteria of the preparation, volume changes were evaluated after using each system, with micro-computed tomography.

Material and Methods

Teeth selection

After approval of the Research Ethics Committee of the School of Dentistry of the São Paulo University (FOUSP), thirty extracted lower molars were selected, donated by the Human Teeth Bank (FOUSP). The distal root of these teeth was used.

The teeth had a single canal in the distal root and the angle of curvature was inferior to 20°.[22] When the buccolingual diameter was, at least, 2.5x bigger than the mesiodistal at 5 mm of the root apex, to canals were classified as long ovals.[23,24] These measures were carried by an digital image processing system, Image Tool (University of Texas Science Center, California, USA).

After the surgical access, the root canal were explored with a manual #10 K-file, and the actual working length (AWL) was determined when the end of the instrument was observed through the apical foramen, with the aid of an operating microscope (Alliance, São Paulo/SP), with 8x magnification, pulling back 1 mm.

Teeth were distributed randomly in two experimental groups: G1, Reciproc R40 (n = 15); and G2, BioRaCe (n = 15).

The samples scanning was carried before and after canal preparation, using the device SkyScan 1172 (Kontich, Belgium), with 100 kV, 100 μA, and isotropic resolution of 11. 88 μm. The objects rotate at 180°, with 0.4° of rotating speed. Total time for image scanning was 49 minutes and for image reconstruction was 13 minutes, totalizing 1 hour and 2 minutes for completion.

Canal preparation

Root canals preparation, in all experimental groups, was carried by a single operator.

G1: Reciproc R40 (Reciprocal motion system)

In this group, distal roots were used, which allowed the introduction of a manual #20 K-file, passively until the AWL, as criteria for selection of the R40 instrument for their preparation. No manual instrument was used to create a free path, following the manufacturer's instructions. The activation of the R40 instrument happened with the electric motor Silver Reciproc VDW (VDW, Munich, Germany), adjusted for reciprocal motion, coupled to the handpiece Siron 6:1 (Sirona Dental Systems GmbH, Bensheim, Germany). This instrument operated in a reciprocal motion of 10 cycles per second, taking 3 cycles to rotate 360°.[12] After the AWL determination, the root canals were prepared as following:[12,13] Slow brushing movement of the activated instrument inside and out of the root canal, small amplitude and light apical pressure; continuation of the canal preparation until reaching around 2/3 of the working length, and advancing the instrument to the AWL established. Always verifying if any obstruction occurred, with a manual #10 K-file. Each time the instrument was removed, new chemical substance was placed, using 3 ml of 1% NaCl, associated to Endo-PTC gel.[25]

Once Reciproc is single-use, fifteen instruments were used, thus, avoiding any influence on the obtained results. Final irrigation was performed with 5 ml of 17% EDTA, followed by more 5 ml of 1% NaCl.[25,26] Then, the canals were aspirated with Capillary tips and dried with sterile paper points. Pulp chambers were sealed with temporary sealing material.

G2: BioRaCe (n = 15)

Root canals selected for this group were, Initially, manually prepared with #8, #10 and #15 files in the working length and, then, with BioRaCe files, with the electric motor Silver Reciproc VDW adjusted to complete rotary motion, 500 rpm. The first rotary file BRO (25/0.08) prepared the 4-6 mm of the cervical third, a BR1 (15/.05), BR2 (25/.04) and BR3 (25/.06) were for the AWL. BR3 reached easily the AWL, so BR4 (35/.04) and BR5 (40/.04) carried the final apical preparation.[10,27]

The instruments were used back-and-forth, brushing against the walls of the root canal.

At each file change, 3 ml of 1% NaCl was used as irrigation substance, associated to Endo-PTC gel.[25] Recap was performed with #10 K-files in the AWL, at every instrument change.

The final irrigation, aspiration and sealing were carried out as described for the Reciproc group.

In order to avoid the instrument fracture, interference on the preparation quality and being in accordance with the studies reported in literature,[27,28] each set of BioRaCe was used three times.

Evaluation of the canal preparation

Images were reconstructed and evaluated from the root apex to the cementoenamel junction, in, around, 400 slices for specimen.[16]

The software CTan v 1.12.0.0 (SkyScan) allowed the 2D/3D volumetric analysis of the images. This analysis was carried according to recent works found in literature,[8,19,20,21,29-32] and the root canal volume change was calculated subtracting the values from the canals before preparation. The increase percentage (%Δ) was calculated using the values from before (A) and after (D) the preparation, according to the formula:[31]

$$\%\Delta=(A*100/D)-10$$

RESULTS

Facing the abnormality of samples distribution, non-parametric tests were chosen. For the analysis between groups, the Mann-Whitney test was applied in the volume increase comparison.

Three-dimensional evaluation of the volume change in the root canal

None of the instruments were broken during the root canal preparation.

In the groups of specimens prepared by Reciproc, the initial volume of total root canal varied from 2.70 to 13.31 mm³.

The distal root canal preparation resulted in the increased volume with significant difference between the groups ($p < 0.5$). The average of this increase in all roots from the Reciproc was of 2.52 mm³, while in BioRaCe it was 2.24 mm³. The percent average of volume increase was of 27.52% and 26.31%, respectively, for the Reciproc and BioRaCe systems, without statistically significant difference.

The morphometric changes of the root canal volume increase, in mm³, are presented in Table 1.

Different capital underlined letters between systems shows statistically significant difference.

Discussion

Endodontics comprises correct diagnosis and treatment of pulp diseases and its consequences in adjacent periapical tissues. The efficient preparation and cleaning of the root canal represent a crucial step to reach the objectives of the root canal treatment.[33]

One of these objectives is the removal of the infected dentin layer, which is especially difficult in the preparation of root canals with cross-section different from the circular one: Oval, long oval or flat. The infected recesses are potential retainers of bacterias,

Table 1. Morphometric absolute (Δ) and percent (%Δ) volume changes (mean ± standard deviation) of the root canal for the systems Reciproc and BioRaCe.

System		Volume
Reciproc	Δ	2.52 ± 1.66[A]
	%Δ	27.52 ± 18.98
BioRaCe	Δ	2.24 ± 1.96[B]
	%Δ	26.31 ± 18.39

which may compromise the success of the endodontic treatment.[9,10] In the attempt of extending the root canal preparation to other directions for the inclusion of such areas, it may lead to complications, such as perforations, on the canal danger zone.[2,4]

Due to this situation, several techniques of preparation and instruments have been studied and reported in literature, on an effort to solve the difficulty in preparing these canals, especially the long-oval ones.[8,10,11,12,34]

The technological advancement allowed the improvement of evaluation tools for root canal preparation, of resolution of images obtained without invasion; and CT came as a method of evaluation for research in Endodontics, allowing the detailed reproduction of internal and external anatomy of the tooth, as well as the evaluation of the instrument action on the root canal, without compromising the sample.[14-18] Once the information is stored, it is available for future evaluations, i.e., the original information of the healthy tooth is not lost. In the present work, the isotropic resolution of the microtomography was of 11.88 μm, which increases the sensibility of the device, reduces the artifact and results in a better contrast and detailing of the image.

The present study evaluated the quality of preparation of long oval root canals performed by two mechanical systems: Reciproc and BioRaCe, using micro-computed tomography. As quality criteria of the preparation, the volume was analyzed.

Trying to investigate the possibility of new instruments and techniques improving the preparation of oval canals, the system BioRaCe was selected to be the control group in the comparison of results obtained with the Reciproc system.

The Reciproc single-file system is fabricated from a special alloy NiTi "M-wire", created by an innovative process of thermal-treatment, providing greater flexibility and resistance to cyclic fatigue, combined to reciprocating movement (150° counterclockwise/30° clockwise) with instrument relief in clockwise movement.[35,36,37] Its "S" shaped cross section, according to the manufacturer, allows progression in apical direction. On the other side, the instruments of BioRaCe system with continuous rotary movement present triangular cross section, electrochemical surface finishing and variable helical angle in order to avoid the screwing effect on the root walls.[28]

The instrument selected by Reciproc was R40, due to the passive insertion of a #20 file until the AWL in the distal canal of teeth included in the study, and it was used back-and-forth, and brushing laterally to allow the preparation of all walls with long oval cross section.[12] In the BioRaCe system, the preparation was performed with a sequence from BR0 to BR5.[10,27] The instruments were also used back-and-forth and laterally against the root canal walls.

It is important to emphasize that the apical preparation of Reciproc (R40) and BioRaCe (BR5) were equivalent for both having #40 diameter (D0), thus allowing the comparison between them.

The same parameters of microtomography were used for obtaining and reconstructing images after the root canal preparation, for the postoperative readings and posterior comparison of results.

The volume of interest of reconstructed images after scanning was from the root apex to the cementoenamel junction, in approximately 400 slices for specimen.[16,37]

The quality of the preparation was evaluated quantitatively by the volume increase parameter accessed by the μCT. The volume analysis was carried according to recent works found in literature and the root canal volume change was calculated subtracting the values from the canals before preparation.

The percentage of volume increase was calculated using the measurements from before and after the root canals preparation, with the Versiani et al[31] formula.

The evaluation considered the entire root canal. The pre- and post-preparation images, in this case, were not superimposed. The parameter is evaluated individually by the exact determination of the volume of interest.[8,20,29]

Regarding the increase, in the analysis between groups there was statistically significant difference, which disagreed of the reports from other studies.[8,19,32] The Reciproc system was able to remove more dentin than BioRaCe.

As for the percentage of volume increase, the value for the Reciproc system was 27.52% and 26.31% for BioRaCe, with no significant difference in this case ($p > 0.5$). It means, in the percent evaluation of what really represents the action of the instrument in the root canal surface, there was no statistically significant difference between systems.

Of course, the high cost of the X-ray micro-CT is an obstacle to the better use of this tool in Brazilian researches, but the high correlation of images obtained with the real object and the values from analysis only possible with this tool with overcome all the obstacles. Due to the obtained results, further studies are suggested, assessing and comparing different techniques and/or endodontic instruments, regarding the quality of the canals preparation, exploring other parameters besides the root canal volume.

Conclusion

Based on these results obtained here, it was concluded that:

1) The evaluated systems behaved differently on the quality of preparation, when compared to the volume increase.

2) The Reciproc system promoted greater increase in the entire extension of the canal, when compared to the BioRaCe system.

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Evaluation of the effectiveness of the use of photodynamic therapy (PDT) after cleaning and shaping the root canal: An in vivo study

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ABSTRACT

Objective: The purpose of this study was to assess the effectiveness of photodynamic therapy (PDT) in teeth with periapical lesion seen radiographically. **Methods:** 24 anterior teeth were selected and divided into two groups with 12 teeth each. Three samples were collected in each specimen. In G1, endodontic treatment was performed with a nickel/titanium rotary system, with the first sample being collected at surgical opening; the second, after endodontic treatment; and the third, seven (07) days after canal preparation. In G2, the samples were collected by means of the same procedures used in G1, except for the second sample which was taken after instrumentation and photodynamic therapy (PDT). The third sample was collected seven days (07) after PDT. Sodium hypochlorite at 5.25% was used as irrigating solution, neutralized with 5% sodium thiosulfate at a given time of the study. Photon Laser III was used for 40 seconds, with 0.005% methylene blue dye as photosensitive substance. All samples from both groups were send to laboratory analysis to have potential contamination of the root canal system checked. **Conclusion:** The results revealed no statistically significant difference between groups, but further randomized studies are necessary to demonstrate the effectiveness of PDT.

Keywords: Laser therapy. Enterococcus faecalis. Root canal therapy.

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Introduction

Endodontic treatment poses limitations that can undermine a successful therapy. One often faces hurdles such as anatomical variability, calcifications and atresia when cleaning and shaping the root canal. These difficulties hinder proper cleaning and shaping while favoring bacterial reinfection.

Schilder[13] reported that in cleaning and shaping the root canal one must meet all the requirements necessary to ensure a favorable prognosis. These requirements include conical preparation without changing the position of the apical foramen, removal of bacteria and tissue debris, smoothing of the walls and increase in dentin permeability with the aid of irrigating chemicals which favor microbial decontamination and facilitate access by the filling material. Decontamination and microbial reduction can be more easily achieved in the root canal lumen, although certain bacterial strains can survive in anaerobic environments in the root canal system concealed in accessory, lateral and secondary canals.

Given that the microorganisms reside inside the root canal, they cannot be eliminated by defense mechanisms alone. It is believed that the most likely cause of endodontic failure is the survival of microorganisms in the apical third of the root canal. These microorganisms can also be found in areas of the root canal normally inaccessible to disinfection procedures such as isthmuses, craters, recesses and ramifications of the root canal system, thereby rendering endodontic therapy a daunting challenge.

The microbial species most commonly isolated in root canals when endodontic treatment fails is *Enterococcus faecalis*, a facultative anaerobic microorganism that can thrive with or without oxygen.

Sundqvist et al[18] correlated treatment failure with unfavorable factors or flaws in performing endodontic therapy to treat devitalized teeth with apical periodontitis. They also reported the peculiarities of microbiota found in root canals that had previously undergone unsuccessful endodontic treatment. The failure was due to a selection process that depends on the specific resistance of microorganisms to antimicrobial procedures and drugs used during endodontic therapy, as well as the survivability of certain microbiota in restricted nutritional mediums, where interrelations between bacteria are minimal.

In endodontics, laser has demonstrated its ability to eliminate layers of debris, its capacity to seal the dentinal tubules, vaporize pulp tissue, change dentin permeability and disinfect the root canal system with its bactericidal action.

A number of authors [1,3,4,12,14,15,17,21] reported that several studies have been conducted in Dentistry with the purpose of complementing conventional therapies. Specifically in Endodontics, photodynamic therapy (PDT) plays a promising role as an adjunct in retreating periapical lesions. Studies have been conducted to show intracanal microbial reduction.

This study aimed at assessing the efficacy of PDT in cleaning and shaping the root canal system.

Material and Methods

Twenty-four anterior teeth with radiographically visible periapical lesions were selected. After all patients had signed an informed consent form (Appendix 01), the teeth were divided into two groups (G1 and G2) of 12 teeth each.

The teeth in group 1 (G1) were opened using a round high rotation bur #1015 (KG Sorensen Ltda, São Paulo, SP, Brazil), rubber dam isolation (Madeitex Indústria e Comércio Ltda Latex supplies, São Paulo, São Paulo State, Brazil), disinfected with iodine 0.1% alcohol (Farmax, Minas Gerais State, Brazil), use of Endo Z bur (Dentsply/Maillefer Corp., Bellagues, Switzerland) for convenience form, use of # 2, # 3 and # 4 Gates Glidden drills (Dentsply/Maillefer Corp., Bellagues, Switzerland) for the pre-enlargement phase in finishing the coronal opening. The canal was shaped with ProTaper system (Dentsply/Maillefer Corp., Bellagues, Switzerland) and sanitized with 5.25% sodium hypochlorite (Marcela Dourada Compounding Pharmacy Ltd., Vitória da Conquista, Bahia State, Brazil).

Tooth length measurement was performed with a foramen locator (Root ZX, J Morita Corporation, Ltda. Japan) seeking apical foramen patency.

Three samples of the material were collected in the following order:

In G1, the first collection was made after surgical opening; the second, after canal preparation and the third seven days after cleaning and shaping the root canal. Canal preparation was performed by means of the crown-down technique using spherical high rotation burs #1015 (KG Sorensen Ltda, São Paulo, São Paulo

State, Brazil). In the pre-enlargement phase, Gates Glidden #2, 3 and 4 burs (Maillefer Corp., Bellagues, Switzerland) and F3, F4 and F5 rotary files Dentsply ProTaper system (Maillefer Corp., Bellagues, Switzerland) were used. Five ml of sodium hypochlorite at 5.25% (Macela Dourada compounding pharmacy Ltda., Vitória da Conquista, Bahia State, Brazil) were used for irrigation every time instruments were replaced. Prior to collection, the sodium hypochlorite was neutralized with sodium thiosulfate at 5% so that the hypochlorite would not interfere with the results of the samples. Throughout the study intracanal medication was not employed between sessions. Balls of sterile cotton were inserted into the specimens, and then closed with a temporary sealer (Coltosol by Vigodent ind. e Com. Ltda, Rio de Janeiro, Brazil). The material was collected from the root canal system with the aid of absorbent paper points #20 or 25 (Dentsply/Dentsply Ind. And Com. Ltda., Petrópolis, Brazil), placed into a transport medium and sent to a clinical analysis laboratory (Hermes Pardini Ltda., Belo Horizonte, MG, Brazil) to ensure the growth of a culture of anaerobes, thereby disclosing whether or not contamination had occurred in the root canal system.

Teeth in G2 underwent the same procedures as G1, but with the addition of Photodynamic Therapy (PDT) after cleaning and shaping the root canal system.

The device used in the research was a Photon Laser III (DMC Equipmentos Ltda, São Carlos, SP, Brazil) with red laser irradiation and optical fibers of 660nm, 100mw, 140j/cm² for 40 seconds. The dye used in the study was methylene blue at 0.005%, which was left for 5 minutes for pre-irrigation inside the canal. The material was then collected with an absorbent paper point #20 or 25 (Dentsply / Dentsply Ind. e Com. Ltda., Petrópolis, Brazil), and taken to the clinical analysis laboratory (Laboratório Hermes Pardini Ltda, Belo Horizonte, MG, Brazil) to check whether or not bacterial growth culture had occurred, thereby demonstrating — or not — the effectiveness of Photodynamic Therapy (PDT) as an adjunctive therapy in reducing contamination of microorganisms in the root canal system.

The results were analyzed with a view to proving or disproving the effectiveness of PDT in reducing contamination of microorganisms in the root canal system.

The data were initially analyzed by contingency tables and correlated Chi-square tests by comparing the response variable distribution according to the levels of the factor "treatment" at each stage. Thereafter, analysis of variance was applied utilizing a model suitable to experiments with two factors and interaction. In this analysis, the existence of repeated measurements was noted, since the same volunteers were evaluated at both stages. The analyses were calculated using SAS (SAS Institute Inc., The SAS System, Release 9.2. SAS Institute Inc., Cary NC. 2008). The contingency tables and Chi-square tests were calculated by FREQ procedure, and the analysis of variance using GLIMMIX procedure.

Results

For the purposes of statistical analysis, it became clear that all samples in the first collection (in both G1 and G2) were contaminated and, therefore, only the second and third samples were analyzed.

For clarification purposes, the term "BEFORE" was used to refer to the first sample, "DURING" to the second, and "AFTER" to the third sample. In the present study the significance level was set at 5%.

The analysis began with the contingency table, which compares the frequencies and ratios in the levels of the treatment factor in the "DURING" phase (Table 1).

Likelihood ratio chi-square test (G2) provides no evidence ($p>0.10$) of an association between treatment and outcome.

Whereas in the treatment with a rotary instrument there were 02 positive cases and 10 negative cases, treatment with PDT yielded very similar quantities, with 03 positive cases and 09 negative cases. Clearly, this difference can be incidental, since it refers to a single event in the PDT group which happened to migrate from negative to positive.

Hence the absence of significant differences, which occurs when there is evidence to assert that such difference is not incidental, which would not be reasonable in this case.

Table 1. Frequency (percentage) of result in treatments during experiment.

Treatment	Results		χ^2 Likelihood ratio Chi-square
	Negative	*Positive*	
Rotary (G1)	10 (83.33)	2 (16.67)	G2: 0.2540 – GL: 1 Valor-p: 0.6143
PDT (G2)	9 (75.00)	3 (25.00)	
Total	19 (79.17)	5 (20.83)	

The next step was to evaluate the result ratios in the "AFTER" phase (third sample) displayed in Table 2.

Likelihood ratio chi-square test (G2) provides scarce evidence ($p>0.10$) of an association between treatment and outcome.

In the "AFTER" phase, a different behavior is observed in the positive treatments, in which most of the results were positive (58.33%) and treatment with PDT remained at precisely the same ratio as in the "DURING" phase, in which most of the results were negative.

Treatment with a rotary instrument showed a change, whereas PDT treatment results remained stable in this case. It can be concluded that there were no statistical differences between the two types of treatment used in this study.

Discussion

According to Nair et al,[7] Peciuliene et al,[8] and Sundqvist et al,[18] the presence of microorganisms in the root canal system favors the appearance of periapical lesions as a result of microbial aggression. Thus, the key objective of endodontic treatment is to eliminate infection, given that allowing a viable microbiota to survive within the dentinal tubules may — depending on their virulence factor — enable the pathogenic process to reestablish itself and consequently undermine therapy. Therefore, disinfection of the root canal system is a decisive factor for therapeutic success.

According to Wilson,[22] the use of low power lasers causes denaturation of microorganisms due to structural damage (bacterial wall) or metabolites produced by oxygen when the photosensitizer is activated by laser light, which causes cell death.

Table 2. Frequencies in treatment results in the "AFTER" phase (third study sample).

Treatment	Results		χ^2 Likelihood ratio Chi-square
	Negative	*Positive*	
Rotary (G1)	5 (41.67)	7 (58.33)	G2: 2,8046 – GL: 1 Valor-p: 0.0940
PDT (G2)	9 (75.00)	3 (25.00)	
Total	14 (58.33)	10 (41.67)	

According to Love[6] and Sirien et al,[16] the microbiota found in the canal system are dynamic and diverse.

According to Walsh,[20] temperature variation is less critical due to low power being used during the procedure, but professionals should be aware of this fact. A previous study showed an increase of 3.9° C in the mean temperature, which indicates biocompatibility.

Ferrari,[2] Peciuliene[8] and Pinheiro et al[9] argue that *Enterococcus faecalis* is the bacterium predominantly found in cases of refractory apical periodontitis.

According to Radaelli,[11] in cases of necrotic pulp, the bacterial flora is rich in substrate, and metabolic changes tend to occur in the specimens.

Garcez et al[4] and Walsh et al[19] demonstrated that methylene blue is the best photosensitizer given that it is easy to handle and widely available on the market. Additionally, it features an absorption coefficient compatible with the wavelength of low laser power (PDT).

Zanin[23] found that the older the biofilm, the less sensitive it appeared to be to photodynamic therapy. He also noted that photosensitizing occurred in the outer layers of the biofilm. Bacteria were, therefore, allowed to exist in the innermost regions of the biofilm due to poor penetration of the dye or difficulties penetrating the biofilm.

Garcez et al[4] showed that in conventional endodontic treatment of infected root canals a reduction in bacteria count is accomplished by a combination of mechanical instrumentation, various irrigation and medication solutions or antimicrobial dressings placed within the canal. Photodynamic therapy is a treatment which can be considered an adjunct to conventional endodontic therapy for producing a significant bacterial reduction.

Pinheiro et al[9] demonstrated the use of low-power lasers in various dental specialties such as Pediatric Dentistry, Periodontics, Endodontics and Implantology in Pediatrics.

The present study used 24 teeth with periapical lesions radiographically evidenced and divided into two groups of 12 teeth each. In G1, canal preparation was performed using rotary instrumentation and the ProTaper system. In G2, in addition to the rotary instrumentation, photodynamic therapy (PDT) was employed shortly after endodontic instrumentation.

In order to standardize the methodology used in this study, three samples of each specimen were collected from both groups and sent to a clinical analysis laboratory to determine whether or not PDT was effective.

Furthermore, a single device (Photon Laser III, DMC Equipamentos Ltda, São Carlos, Brazil) was used, as well as methylene blue dye as photosensitizer.

All patients were treated by a single operator working in the same environment to ensure research standardization. Recent studies have proved PDT to be highly effective in reducing the presence of microbes in the root canal system. Several studies have reported the use of photodynamic therapy as an adjunct in endodontic treatment.

Conclusions

Based on the results of this study it is reasonable to conclude that:

» No statistically significant differences were found among the results of the samples.

» Additional studies are warranted to further investigate this topic.

» Photodynamic therapy can be used as an adjunct treatment in addressing root canal system issues.

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Stem cells: A breakthrough in Dentistry

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ABSTRACT

Introduction: Scientific advances made to understand the molecular regulation of tooth morphogenesis, biology of stem cells and biotechnology provide opportunities that will enable tooth regeneration in the near future. Stem cells are capable of stimulating tissue regeneration and, as a consequence, present many therapeutic perspectives, which make them feasible to be applied in Dentistry. Their applicability in the regeneration of oral structures becomes nearer and nearer every day; however, additional studies are warranted to further comprehend the best method for storing stem cells and the adequate laboratorial procedures that shall be applied when those cells are used. Furthermore, it is necessary to know all cell subdivisions, according to their place of origin. **Methods:** The method employed for conducting the present study was the search for scientific articles in journals, books as well as in the following databases: BIREME, LILACS, PubMed and SciELO. **Conclusion:** This literature review aimed at exemplifying the main groups of cells, their functions and difficulties in order to provide basic knowledge that may be used by dental surgeons.

Keywords: Stem cells. Tissue engineering. Rehabilitation.

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Introduction

Embryonic stem cells derive from embryos developed from ovules that are fertilized in vitro. Those embryos are usually four or five days old, and are seen as a hollow ball of cells named blastocyst. These cells can differentiate themselves into any type of cell and are named totipotents.[1]

Conversely, the term pluripotent is used to describe stem cells that derive from three embryonic germ layers: mesoderm, ectoderm and endoderm. The different types of specialized cells that comprise the body originate from these three layers. Pluripotent cells are able to originate any type of cell.[1]

Adult stem cells are considered as multipotent, in other words, they are undifferentiated cells that are found among the differentiated cells of a given tissue or organ and may renew and differentiate themselves so as to produce specialized types of cells.

Recent researches have been conducted on the use of stem cells therapy, and have presented satisfactory results with regard to cure and treatment without precedents of certain diseases. The search for methods that allow tissue repair and even the formation of new tissue aims at drastically opening up the therapeutic possibilities in different areas of the health field.

In recent years, the greatest findings show that stem cells have been used to treat several diseases such as cancer, neurodegeneration and Alzeimer, in the recovery of tetraplegic and paraplegic patients, as well as in Dentistry.[2]

Studies conducted with stem cells highly interest the scientific field due to their ability in stimulating tissue regeneration and, as a consequence, presenting many therapeutic perspectives. Such facts enable stem cells to be used in different dental procedures of which aim is to recover the quality of patients' oral health.

There are many factors that contribute to tooth loss, namely: deleterious habits, genetic defects, congenital anomalies or early losses caused by trauma, periodontal disease and dental caries. Scientific evidence has recently shown that to recover lost dental structures it is necessary to employ non-biological techniques, such as prosthesis and implants. Other techniques employed to re-establish and recover oral health without any complications could be successfully used, for instance, the biological techniques that are highly desirable to replace lost teeth, minimizing the costs related to oral health recovery.

The method employed for conducting the present study was the search for scientific articles in journals, books as well as in the following databases: BIREME, LILACS, PubMed and SciELO. This research aimed at conducting a literature review on the different types of stem cells in order to demonstrate their importance in Dentistry, describe and classify the different groups of cells, discuss them in light of the literature and scientific evidence, search for the most recent researches that focus not only on the difficulty of isolating them, but also on the potential of using such cells.

Literature review

It all began with Thomson et al,[30] with their publication on the first procedure for isolation of stem cells in human embryos. Mice's embryonic stem cells were isolated[31,32] in 1981, and many researches demonstrated that they could be unlimitedly multiplied in culture, maintaining their ability in producing all types of cells found in mice.

Ferrari et al[33] published the first of a series of reports about the plasticity of adult stem cells, challenging the elder belief that adult stem cells are of restricted lineage. Most studies into plasticity, genetically marked from adult mice's organ cells, apparently originated types of cells that are characteristic of other organs after transplant, thus suggesting that those cells were more plastic in their potential of development.

The use of adult stem cells has avoided some ethical issues, presenting the following advantages: The cells may be isolated from patients in need of treatment, thus, avoiding immunological rejection and reducing the risk of tumor formation which frequently occurs when heterogeneous embryonic stem cells are used.[21]

Stem cells are undifferentiated cells with high capacity of self-renovation and production of, at least, one type of cell highly specialized. There are two categories: pluripotent embryonic and unipotent or multipotent, adult or somatic, which can be found in differentiated tissues.

The use of stem cells with therapeutic purposes has interested many areas in the health field, including Dentistry.

These researches and findings have broadened the horizons of genetic engineering on the use of those tissues, and studies conducted within the dental field revealed the stem cell's ability in generating teeth and other oral tissues as well as bone tissue cells.[3]

Mesenchymal stem cells are found in the periodontal region. They can differentiate themselves into fibroblasts, osteoblasts and cementoblasts, and are responsible for periodontal ligament repair. The identification of a population of adult stem cells in the dental pulp is considered a significant advance, since these cells are able to differentiate themselves into fibroblasts, which compose the connective tissue, and into odontoblasts, which are involved in the formation of dentin.[4]

Seo et al[9] conducted a study in which stem cells were isolated in normal human third molars collected from adults aged between 19 and 29 years of age. The results provided preliminary evidence that suggest that transplanted dental pulp stem cells (DPSCs) not only compromise themselves with the odontoblastic lineage, but can also exit in the pulp, similarly to connective tissue, fibroblasts and other cells. It has been recently reported that the genes that encode proteins of the extracellular matrix and the dentin (Dentin Sialophosphoprotein – DSPP) can also be expressed in bone, although at low levels, showing that the potential of these cells is greater than expected. Other researchers[6-9] grew the same type of cells in a similar mineralization inducing environment and obtained the formation of hydroxyapatite with a small amount of carbonates which are characteristic of biological apatite.

Advances in sciences have brought innumerous improvements for human kind by introducing new vaccines and technologies, leading to an increase in life expectancy and an improvement of the health condition of many people around the world.

Researches have been conducted on the use of stem cells therapy, and have presented satisfactory results with regard to cure and treatment without precedents of certain diseases.

The importance given to the use of embryonic stem cells concerns their ability in proliferating and differentiating themselves into many types of cells. However, they also have some disadvantages, such as genetic instability, the fact that they must be transplanted to immunocompromised hosts, the risk of teratocarcinoma formation, and contamination due to being grown in mice's fibroblasts,[10] in addition to ethical issues.[11] The possibility of using somatic cells to rebuild and regenerate tissues has instigated new researches and has aroused great interest to the scientific community.[12]

In contrast, somatic cells have the advantage of autogenicity, do not incur moral limitations and respond to growth factors that are inherent to the host. However, they also present some disadvantages, for instance, the fact that they are not pluripotent, the difficulty one has in obtaining them, *in vitro* purification and growth as well as the small amount in which they are found in the tissues.[12] The main source of adult stem cells is the bone marrow. Taking into account the plasticity level of these cells, how many paths they can follow and to which portion of a functional organism they can contribute, these somatic cells are classified into multipotent and unipotent.[3]

Pluripotent stem cells can originate not only a totally functional organism, but also any type of cell in the body, including the central and peripheral nervous system.[13] However, totipotent cells are ephemeral, the reason why they must be used right after they have been obtained, and disappear a few days after fertilization.[34] Despite being found in smaller amounts and being difficult to be isolated, pluripotent stem cells are also present in adults. Arising from the bone marrow, they can originate blood cells as well as bone, cartilage, muscle and skin cells, in addition to connective tissue.[13]

Conversely, multipotent stem cells are more differentiated. They can be found in adults and are able to originate a limited number of tissues. They are designated according to the organ from which they derive and can originate cells of that organ, only; thus enabling tissue regeneration.[13] Onipotent cells, on the other hand, can be easily isolated and are found in larger amounts; however, they can originate only one tissue cell type.[13]

Nevertheless, with the advances in research, the categories into which stem cells have been divided are being increasingly questioned, given that multipotent cells, such as neural stem cells, have proved to be pluripotent.[15]

Storage of stem cells is possible in Brazil, however, only those cells that derive from umbilical cord and placenta blood (UCPB). Such procedure is regulated by the Brazilian Health Surveillance Agency (ANVISA), of which operating rules have been defined by the Resolution of the Board of Directors (RDC153/04) in which all steps involved in the rendering of services are included.[16]

The public bank aims at collecting UCPB from licensed maternity hospitals so that it can be used by the general population, provided that it is compatible. Positive maternal serology for any disease that can be transmitted by blood, including positive IgM for cytomegalovirus (CMV), is also an exclusion criterion for public banks. Conversely, private UCPB banks have different criteria, given that the material that is stored is exclusively for autologous use. UCPB for private storage can be collected in any maternity hospital that holds a health license. There are no restrictions on maternal age or the baby's size and weight, and positive serology can be stored if the parents would like to do so.[16]

Umbilical cord and placenta blood is known as a rich source of hematopoietic stem cells (SC) that can be used to substitute the bone marrow in cases of transplant. The cells can be separated, quantified, processed and stored at −196°C in order to keep their original characteristics, which allows them to be used in the future.[17]

It should also be highlighted that postnatal stem cells have been used in tissue engineering due to being easily isolated and characterized. It is important to remember that those cells seem to have a "memory" of the tissues from which they were obtained.[18] Thus, cells of mesenchymal origin (from the dental pulp, for instance) are more able to differentiate themselves into mesenchymal tissues (pulp, dentin and alveolar bone).[4]

Five different cell populations have been found to exist in the dental tissues: dental pulp stem cells (DPSC);[7] stem cells from human exfoliated deciduous teeth (SHED);[8] periodontal ligament stem cells (PDLSC);[9] dental follicle progenitor cells (DFPC)[19] and stem cells from the apical papila (SCAP).[20]

The DPSC are obtained through a protocol of enzymatic digestion. They were the first stem cells of dental origin to be isolated and the ones on which the greatest number of studies concerning differentiation and tissue regeneration potential have been conducted. They are able to differentiate themselves into osteoblasts, chondrocytes, neurons, endotheliocytes and dental pulp cells.[4,21]

The SHED are obtained from deciduous teeth and are an interesting therapeutic alternative, since all individual would have their own source of reserve cells for dental tissue regeneration. SHED have greater potential for proliferation in comparison to DPSC. Moreover, it has been proved that the former are able to differentiate themselves into odontoblasts capable of generating not only tubular dentin and vascular endothelial cells, but also neurons and tissues that are similar to the dental pulp.[22,23]

The PDLSC are obtained from the periodontal ligament and are highly able to differentiate themselves into supporting periodontal tissue, demonstrating a great potential for differentiating themselves into chondrocytes, adipocytes, and osteoblasts.[24]

The DFPC derive from the tissue that involves the developing tooth germ. Tooth follicle progenitor cells also have a great therapeutic potential for differentiation due to the tissue from which they are collected.[19] They are able to differentiate themselves into osteocytes, adipocytes, chondrocytes and periodontal ligament. Recent studies have shown that these cells are able to promote bone and periodontal tissue regeneration.[25]

As for the SCAP, they are obtained from the dental papilla. This tissue can also be found in healthy teeth with incomplete root formation. Due to being an undifferentiated tissue, it is believed that the SCAP have a potential for differentiation as well as regeneration that is greater than DPSC and SHED. This information can be confirmed by data available in the literature, which show the ability in complete root formation (pulp, cementum and periodontal ligament) in cases of apicification.[26]

A long path must yet be followed with regard to the use of stem cells, despite the great variety of sources from which stem cells can be collected as well as their regenerative potential.

When employed, stem cells must be as appropriate as possible for each tissue that will be originated. In case of regeneration of dental supporting tissues, the literature recommends the use of PDLSC or SCAP.[20] As for regeneration of functional dental pulp, especially in cases of which purpose is to close the apex of endodontically treated young teeth, cells such as SHED and/or DPSC have proved to have a great potential.

These cells have odontoblastic marker genes and are able to form tissues that are very similar to the dental pulp.[22] For that to occur, those cells need an appropriate micro environment, specifically aimed at inducing differentiation. For dental purposes, cell differentiation in different tissues depends on certain structures such as hydroxyapatite or dentin.[23] It should also be highlighted that in order to use stem cells for therapeutic purposes in humans, appropriate matrixes will have to be developed.[4] Dentistry has undoubtedly walked towards regenerative therapies conducted with biological inducers of tissue recovery. Therefore, clinicians and researchers will need basic qualifications in molecular and cellular biology in order to be able to apply the most developed treatment technologies and strategies. By means of such a technique, we will be able to treat diseases in the oral cavity and the craniofacial complex that are untreatable nowadays.

Conclusion

Slack[1], Harada[3], Risbud[12], Gronthos[5], Miura[8] and Huang[26] agree that, regardless of where the cells are obtained, they present a great potential for oral structures formation, including the tooth germ. However, they claim that additional clinical studies are warranted to further investigate this topic.

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Photodynamic therapy in Endodontics: Use of a supporting strategy to deal with endodontic infection

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ABSTRACT

Endodontic treatment is of paramount importance to abolish infection in teeth with pulp necrosis. The success of this type of treatment depends on efficient elimination of infection in the root canal system (RCS) and correct sealing carried out with root canal filling materials. Due to the anatomical complexity of the RCS, certain areas may be inaccessible to biomechanical preparation (BMP), therefore, the use of intracanal medication enhances the reduction in microorganisms (MO) and their toxic products inside the RCS. MO can still survive even with the scientific and technical advancement of endodontic therapy, being primarily responsible for maintaining endodontic infection. Thus, new treatments should be investigated. Alternative treatments have emerged in the health field with the advent of laser and LED devices, such as photodynamic therapy (PDT), which is a set of physical, chemical and biological procedures that occur after the administration of a photosensitizing agent (PS) activated by visible light of a specific wavelength (laser or LED) to destroy the target cell or assist infection combat. In Endodontics, based on *in vitro* and *in vivo* studies, the use of PDT has proved to act as an adjunct, enhancing the disinfection of the RCS, besides being easy to be applied and not promoting microbial resistance. The aim of this review is to present the current status of photodynamic therapy in Endodontics.

Keywords: Endodontics. Endodontic infection. Photodynamic therapy.

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Introduction

Endodontic treatment is of paramount importance to abolish infection present in the root canal system (RCS).[1] Biomechanical preparation (BMP) with irrigating solutions aims at cleaning and shaping the RCS reducing the number of microorganisms (MO).[2]

Due to the complex anatomical variation of the RCS, certain areas may be inaccessible to BMP,[3] therefore, using calcium hydroxide as intracanal medication increases the opportunity of reducing the MO and their toxic products in the RCS.[4,5]

In recent years, important advances in technology and science occurred with regard to the development of new materials and techniques for endodontic therapy.[2,6] However, even with this progress, there are MO that survive endodontic treatment. These MO are responsible for the persistence of resistant endodontic infections, which contributes to failures[6,7]. Therefore, new therapeutic strategies used during endodontic infection treatment must be constantly investigated.

New alternative treatments in the health field emerged with the advent of laser and LED devices.[8,9] Photodynamic therapy (PDT) is among such therapeutic alternatives. It uses a photosensitizing agent (PS) that is activated by laser or LED and which aims at destroying the target cell or assist infection combat.[8,9,10]

In Endodontics, PDT emerges as an adjunct and innovative therapeutic modality that enhances disinfection of the RCS with a view to suppressing the MO resistant to endodontic treatment.[11,12] PDT is easy to apply, does not promote microbial resistance and can be used after the BMP and before the canal filling, with or without intracanal medication.[11-14]

The aim of this literature review is to present and discuss the use of photodynamic therapy in Endodontics.

Endodontic treatment

The aim of endodontic treatment in teeth with pulp necrosis consists in combating endodontic infection by eliminating bacteria as well as inactivating their toxic products, such as lipopolysaccharide (LPS)[5-16] and the apical biofilm.[6,7,17] When well executed, infection combat associated with adequate root canal filling can provide conditions for tissue repair.[4-7,15,16,17]

However, the complexity of the internal dental anatomy hinders the disinfection of the RCS, requiring the use of intracanal dressing, such as calcium hydroxide, to help combating endodontic infection.[1,4,5,18]

In primary endodontic infections, different bacterial species can propagate in the entire RCS, leading to a polymicrobial infection with a predominance of Gram-negative anaerobic bacteria.[1,6,19] However, in endodontic failures or resistant infections, there are less microbial species and characteristics that differ from those of primary infections. In these cases, endodontic infections have predominance of Gram-positive bacteria.[19,20,21]

The RCS have to be cleaned to eliminate microorganisms and the smear layer in order to allow adequate obturation and post-treatment tissue repair.[4,6,7] The use of sodium hypochlorite and EDTA effectively removes any organic and inorganic components allied to the use of calcium hydroxide as intracanal dressing, thus, promoting disinfection.[5,15] In recent years, advances in endodontic treatment such as nickel-titanium and self-adjusting files (SAF),[2,17] surgical microscope and ultrasonics have transformed the techniques of RCS treatment. However, the anatomical variation of SCR[3] and resistant endodontic infections sustain failures.[21]

Thus, new strategies of endodontic treatment are constantly investigated in order to broaden the spectrum of activity against MO present in endodontic infection.

Using light as a therapeutic agent

In the past, sunlight was widely used in countries such as Egypt, India and China for the treatment of skin diseases (psoriasis, vitiligo), however, empirically.[10] After the technical-scientific advancement of optical techniques, it is now possible to use the light as a therapeutic agent in the health field.[8,9,10]

In the 60s, with the advent of laser and LED devices, new treatment options emerged due to the beneficial therapeutic properties of these devices.[8,9,10,22,23] Laser presents peculiar characteristics such as: monochromaticity, little divergence, intense energy and ultra-short pulses.[24] LED is an acronym for Light Emitting Diode, a low thermal component with a spontaneous radiation mechanism that requires little energy to generate light.[25] Photodynamic therapy is among the applications of laser and LED for therapeutic purposes.[8-12]

Low intensity red lasers are extensively used in PDT because they absorb phenothiazine-based PS and are absorbed by biological tissues.[13,14] LED has been used in optical techniques as an alternative to the use of laser because it provides spontaneous radiation and uses little energy to generate light, with results as good as those of laser.[26]

Photodynamic therapy

Photodynamic therapy was discovered in 1900 by Oscar Raab, who employed a small concentration of acridine dye on protozoa. He observed that after light exposure, a lethal reaction occurred to protozoa, whereas in darkness nothing happened.[10]

PDT is characterized by physical, chemical and biological processes that occur when the light source absorbs PS and destroys or leads to lysis of the target cell (damaged tissues or MO present) by oxidation. PDT has been currently established as a treatment modality for cancer and non-oncological diseases, in addition to acting as an adjunct to other therapies already recognized.[8-10,27]

Studies carried out in the 90s showed that PDT can also be used to combat infections due to its good antimicrobial action. Additionally, PDT has proved to be more advantageous than antibiotics as it does not promote bacterial resistance. This type of treatment is also known as antimicrobial photodynamic therapy (aPDT).[28,29,30]

Photodynamic therapy mechanism of action

When PDT is performed, at the moment of its application and at a molecular level, an energy exchange occurs among the molecules of the photosensitizing agent employed. Such molecules are activated by visible light source (laser or LED) with specific wavelength for the respective PS, which induces destructive reaction towards the target cell in the presence of oxygen.[10]

In PDT, the molecular reactions can be classified into type I and type II. Type I increases the hydroxyl radicals which react with biomolecules resulting in the formation of hydrogen peroxide. The cytotoxic effects cause hydrogen loss in unsaturated molecules, such as phospholipids from cytoplasm membrane, thus, changing membrane permeability and integrity. As for type II reaction, an energy transfer between photosensitizing agent and oxygen occurs, producing a highly reactive singlet oxygen, which temporarily reacts with cellular components (cell wall, nucleic acid, peptides and molecules involved with cell wall structure maintenance). Singlet oxygen oxidizes in a quick, safe and efficient way, promoting local specific necrosis, eliminating the target cells, only.[10,31,32]

PDT mechanism is also effective for inactivation of fungi, as it changes the integrity of cell wall and membrane, allowing photosensitization that determine the changes on cellular organelles and subsequent cell death.[33,34]

Photosensitizing agent (PS)

In order to generate the desired effect of the PDT, the PS must have selectivity and biological stability, good photochemical action and low toxicity to healthy tissues.[31,32] The PS must have a resonant absorption band with spectrum of action of light on a particular wavelength of maximum absorption. The effect of PDT in the tissue depends on the level of PS.[10,31,32] The closer the wavelength of light used in the PS, the more efficient the PDT, provided that this PS has low toxicity and absorption bands that do not cause any injury to adjacent tissues and biological target.[10] The action of PS on bacteria is directly related to the load. PS with positive or neutral charge interacts in a dynamic way, inactivating the layer of peptidoglycan and lipoteichoic acid in the outer membrane of Gram-positive and allows PS diffusion.[10,28,31] In Gram-negative bacteria, PS interacts with their outer membrane, acting as a functional and physical barrier among the cells and the biological environment.[35,36]

The PS most commonly reported in the literature are: methylene blue, toluidine blue, rose bengal, malachite green, erythrosine, rhodamine, porphyrins, and phthalocyanines.[31,32]

In Endodontics, it is possible to employ the PDT with PS of the phenothiazine class: methylene blue (MB) and toluidine blue (TB),[14,37] both activated by red laser or LED. However, in addition to TB and MB, new PS have been investigated in order to assist and improve microbial reduction of the root canal system.[38]

MB is a cationic photosensitizing agent used as a dye to indicate the presence of bacteria. It is soluble in water and alcohol, offering electrocatalytic features in several enzymatic reactions.[39] MB has also good light absorption, reaching 660 nm bands (red light) and demonstrating the ability in generating reactive oxygen species.[10,32]

Fimple et al[13] showed that improving AM concentration and density of light energy (J/cm²) increases bacterial destruction because the major targets of such PS seem to be the components of DNA and the cell membrane of which permeability is intensified.

Pre-irradiation period

The pre-irradiation period comprises the time between the application of PS and the beginning of light use (LED or laser). This pre-irradiation time is of paramount importance for absorption by PS, even before irradiation starts.[10,31,32] In Endodontics, the pre-irradiation period may range from two to five minutes, and it is the time when the PS reaches and crosses the bacteria cell membrane.[12,14] It is noteworthy that the PS should be applied locally or near the target cell to prevent the formation of toxic species in undesired regions.[13,14]

Photodynamic therapy in Dentistry

PDT appears as an adjunct and alternative treatment used along with antimicrobial agents since it does not promote microbial resistance[40]. This fact highlights PDT as an attractive treatment strategy in Dentistry, which aims at eliminating or reducing the microorganisms and oral biofilms responsible for oral diseases[40,41]. The efficacy of PDT in oral bacteria was demonstrated *in vitro* for the first time in 1992, by Wilson et al,[28] who found reduction in *Porphyromonas gingivalis, Fusobacterium nucleatum* and *Aggregatibacter actinomycetemcomitans* by using the He-Ne laser with TB and MB as photosensitizing agents. In the same year, the same researchers[29] successfully proved PDT action against *in vitro* biofilms formed by *Streptococcus sanguis, Porphyromonas gingivalis, Fusobacterium nucleatum* and *Aggregatibacter actinomycetemcomitans* which were irradiated with He-Ne laser with TB and MB as photosensitizing agents.

Several areas of Dentistry have successfully employed PDT. In Periodontology, for instance, PDT is performed after scaling and root planning in periodontal pockets.[42] In Cosmetic Dentistry, PDT is used for decontamination of carious dentine;[43] in Prosthodontics, PDT is performed for decontamination of stomatitis caused by full or partial prosthesis;[44] in Implantology, for the treatment of peri-implantitis;[45] in Pathology, PDT is used in various oral lesions such as herpes labialis;[46] and in Endodontics, it is used to assist decontamination of the RCS after biomechanical preparation.[47]

Photodynamic therapy in Endodontics

In Endodontics, PDT is indicated for treatment of teeth with necrotic pulp as well as for re-treatments, with a view to assisting and enhancing disinfection of the RCS after BMP, as an attempt to act in endodontic infections combating Gram-negative and Gram-positive bacteria in addition to biofilms.[11-14,47,48] The remaining biofilm can hinder the action of intracanal dressings, in addition to enabling microbial resistance, therefore, its inactivation is extremely important.[11,48]

Different PDT susceptibility of microorganisms have been reported, with a reduction of 97% in *Enterococcus faecalis*.[37,49] However, statistically different results were found by Souza et al[50] who did not obtain significant microbial reduction in *Enterococcus faecalis*. Fungi such as *Candida albicans*, can also be found in endodontic infections, and PDT may be indicated as adjunct treatment in these cases.[49]

The use of light (laser or LED) alone may not be effective against microorganisms in endodontic infection. However, if it were used with the photosensitizing agent, it would allow the release of singlet oxygen, thus, achieving the aimed results. With regard to the advantages of PDT, it can be mentioned that this therapeutic modality generates no thermal effects, and there is no harm or death of cells of healthy tissues adjacent to the RCS.[49]

The most commonly used photosensitizing agents in endodontic photodynamic therapy are synthetic and phenothiazines-based, such as MB and TB[37,51] that, at low concentrations, cause the microorganisms to die without being cytotoxic to the surrounding tissues.[52]

Nevertheless, when used in the root dentin, the photosensitizing agents may stain the dental structures. However, such hypothesis may be discarded provided that low concentrations be used, although antimicrobial activity may decrease in view of PS low concentrations.[53] In spite of that, studies have been conducted to test new photosensitizing agents that could be used at higher concentrations without the risk of staining tooth structures, but also providing favorable results with regard to bacteria control.[54]

Researches have currently been carried out in order to obtain better results regarding irradiation time, power unit, core diameter of optic fiber for intracanal use, different types of photosensitizing agents, as well as different concentrations of these agents. Bouillaguet et al[55] have demonstrated that light (laser or LED) was effective in activating photosensitizing agents and that the blue light was as effective as the red one in the production of singlet oxygen. Moreover, they recommended the use of PDT as an auxiliary technique in Endodontics.

Pagonis et al[38] used *in vitro* nanoparticles of poly (L-lactic-co-glycolic acid) containing MB to potentiate the action of the photosensitizing agent in the production of a more reactive oxygen, allowing the killing of various species of microorganisms. They concluded that the synergism between MB and the nanoparticles promoted a significant reduction in colony-forming units and demonstrated the effectiveness of this technique as adjunct to endodontic treatment.

In an *in vitro* study, Nunes et al[56] showed that there is no significant difference in PDT whether or not optic fiber is used in the root canal space for the reduction of *Enterococcus faecalis* species. However, the authors recommend its use due to its ability in uniformly distributing light and reaching all areas of the main root canal, as well as across all the root canal system.

Rios et al[57] concluded that PDT with toluidine blue as photosensitizer agent can be used as adjunct antimicrobial procedure in conventional endodontic therapy. Similar results were found by Ng et al[14] who found a favorable result of PDT as adjunct in Endodontics. Both authors recommend further research to obtain better scientific basis prior to using the technique.

Silva et al[58] conducted a study using dogs' teeth with periapical lesions. They achieved tissue repair in groups that used PDT after biomechanical preparation and concluded that PDT may be a promising adjunct therapy in endodontic procedures.

Cheng et al[59] conducted *in vitro* studies and showed that the PDT or just the use of one of the laser systems (Nd: YAG, Er: YAG; ERCR: YSGG), when associated with endodontic treatment, reduced the number of *Enterococcus faecalis* bacterial colonies. The authors recommend the technique for clinical application.

Komine and Tsujimoto[60] showed that a small amount of MB was able to generate singlet oxygen and produce bactericidal effects against *Enterococcus faecalis in vitro*.

Researches reporting the possible influence of PDT on the types of irrigating solutions, on the presence or absence of intracanal medication or on the smear layer, have not been found in the literature.

The photodynamic therapy technique in Endodontics

The literature remains controversial with regard to application parameters, but it is noteworthy that, according to the scientific results found to date, PDT in Endodontics is gaining prominence.

In general, PDT is indicated in Endodontics for teeth with pulp necrosis with or without periapical lesion, treated in a single session or in multiple sessions. It can also be used in re-treatments.

After biomechanical preparation, the root canal must be effectively dried with cannulas and absorbent paper points.[11] Afterwards, the PDT is carried out, generally with MB or TB as photosensitizer agents, which can be commercially found. This photosensitizer agent is a liquid that must be inserted into the root canal and that should react between 2 and 5 minutes (pre-irradiation period).[1-14,37,38,47,52,53]

Once the pre-irradiation period is concluded, the light (LED or laser) is applied at a specific wavelength, according to the photosensitizing agent used. In the case of MB or TB, red light in a band ranging from 660nm to 685nm should be applied for approximately 3 to 4 minutes. The use of intracanal flexible optic fiber with diameter core compatible with the root canal size is also recommended. After that, the photosensitizing agent must be removed with irrigating or saline solution and the root canal must be aspirated with a cannula and dried with absorbent paper points.[11-14,37,38,47,52,53]

At this point, the clinician can opt for using an intracanal dressing and fill the root canals in another session, or go straight to root canal filling in one session. It should be noted that PDT does not substitute the intracanal medication.

Biosafety

As any other light-emitting device (laser or LED), the use of protective eyewear with specific wavelength is mandatory for both the clinician and the patient. This protection items are generally part of a kit that is obtained when the light sources are purchased. The optic fiber used in PDT must be sterilized or disinfected according to the manufacturer's instructions.[31,32]

Final considerations

PDT in Endodontics can be an important adjunct that helps reducing and controlling microorganisms and their toxic products that are present in endodontic infection, provided that an efficient photosensitizer agent is selected and appropriate parameters for the application of the laser or LED are attended. However, further studies are needed to improve the clinical application protocols.

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Diagnosis of vertical root fractures in endodontically prepared teeth, with or without the presence of intracanal cast metallic posts using Cone Beam Computed Tomography

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ABSTRACT

Objective: To assess the diagnosis of vertical root fracture in teeth endodontically treated, with or without cast metal post (CMP), by means of CBCT, using Prexion Scanner. **Methods:** The sample consisted of 48 human premolars extracted, single-rooted, which were divided in 3 groups: Group 1, control, 16 teeth without gutta-percha and CMP, from which 8 were artificially fractured; Group 2, 16 teeth presenting gutta-percha, from which 8 were artificially fractured; Group 3, 16 teeth presenting CMP, from which 8 were artificially fractured. The teeth were fractured according to the method set out in literature. A specialist in dental radiology, with 10 years of experience in tomography, evaluated the scans. Sensibility, specificity and accuracy were calculated by means of a dichotomous evaluation (presence or absence of fracture). **Results:** By means of Fisher's test, it was not detected statistical difference between groups regarding accuracy, sensibility and specificity for the fracture diagnosis, yet there was a high percentage of false positive for the Group 3. **Conclusion:** CBCT is an excellent tool for the vertical fracture diagnosis; however, the CMP presence generates images with many artifacts, resulting in a high percentage of false positive, being of paramount importance to join the tomographic findings to the signs and clinical symptoms for the most possible accurate diagnosis of fracture.

Keywords: Image diagnosis. Endodontics. Spiral cone beam computed tomography.

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Introduction

The vertical root fractures (VRFs) are a challenge for the dentist as for its early detection and conduct to be taken. VRF may be defined as a complete or incomplete longitudinal line fracture, which has its origin in the internal portion of the root canal and extends to the periradicular tissues, until reaching the external surface of the teeth.[1] The fracture may be located in the cervical, middle or apical third of the root canal and, generally, affects endodontically treated teeth. When it occurs, being complete or incomplete, it extends to the periodontal ligament. In touch with the oral cavity by means of gingival sulcus, foreign material, food debris and bacteria have access to the fracture area. Thus, an inflammatory process is induced,[2] resulting in the rupture of the periodontal ligament, alveolar bone loss and granulation tissue formation.[3]

The main causes of VRF are physical trauma, occlusal prematurities,[4] repetitive parafunctional habits of masticatory stress,[5] pathological resorption inducing root fractures and iatrogenic dental treatment.[6] Among the iatrogenic causes, endodontic therapy is an important etiological factor for the VRF, due to the excessive force application during lateral and/or vertical condensation, due to the weakening of internal dental structure with the wedge effect caused by inadequate CMP, to dilatation of metals used in the posts for the difference of linear thermal expansion coefficient of dentin and intraradicular retention, to induction of stress during installation of prefabricated threaded posts or during cementation of rigid posts.[7,8] Once there is not always signs, symptoms and/or exact radiographic characteristics, the VRF may be taken as an endodontic treatment failure and even as a periodontal disease. However, when these fractures happen, the signs and symptoms more frequent in endodontically treated teeth are pain, edema, fistula and isolated, deep and thin periodontal pocket. Now, the radiographic characteristics are represented by the thickening of the periodontal ligament, vertical, local or deep bone losses, and periradicular local bone loss.[9]

CBCT is often used in Implantodontics, Orthodontics, Periodontics, Surgery and Endodontics. In Endodontics, CBCT proves to be very useful in diagnosis of alveolar and radicular fractures, in assessing morphology of root canal and localization, in root resorption evaluations, on endodontic-surgical planning, and in many other areas, including in endodontic researches.[10] Considering the difficulties on diagnosing VRF, the objective of the present research was to assess the accuracy of CBCT for endodontically treated teeth, with or without CMP.

Material and Methods

The work started after its approval by the Research Ethics Committee of the University of Pernambuco (UPE), (protocol CAAE n° 0251.0.097.000-11).

Forty eight single-rooted teeth with a single root canal were used. After being carefully analyzed by a radiographic and visual exam with the aid of a magnifying glass (4x), the teeth selected were those presenting no incomplete root formation, calcification, root resorption, previous endodontic treatment, root fracture or intraradicular instruments/retention. After removing the debris from the root surface with pumice and water, teeth were kept in distilled water in order to avoid dehydration. All teeth were prepared by a single operator.

The 48 teeth were then divided into 3 groups:

» Group 1 (control) (n = 16): Teeth presenting gutta-percha and without cast metal post (CMP), from which 8 were artificially fractured and 8 did not present any fracture.

» Group 2 (n = 16): Teeth with endodontic treatment and presenting gutta-percha, but with no CMP, from which 8 were artificially fractured and 8 did not present any fracture.

» Group 3 (n = 16): Teeth with endodontic treatment, and presenting gutta-percha and CMP, from which 8 were artificially fractured and 8 did not present any fracture.

Root canals were instrumented with NiTi files Protaper Universal (Dentsply-Maillefer), motor driven. The apical prepare of the teeth was carried with F3 file. The rotating instruments were used with X-Smart (Dentsply-Maillefer). The chemomechanical preparation was carried with 2.5% NaOCl, non manipulated, as irrigating substance.

Eight teeth, from each group, were artificially fractured. Dies[11] were made to adapt the teeth; then, the teeth were fractured. Roots were isolated with Vaseline and involved with lead sheets with Vaseline, obtained from the envelopes of radiographic films. Then, were included in self-polymerizing acrylic resin (Jet), and vertically adapted. After this, the roots were removed, thus opening a space similar to an alveolus. The lead sheet was then removed from each root, and inside of the artificial alveolus was inserted a molding material silicon-based to simulate the periodontal ligament. The roots were immediately placed back to the alveolus and, after condensation silicon polymerization

After the repair of all the specimens, vertical root fractures were induced.[11-16]

The specimens were adapted in a special metallic device, Kratos testing machine, positioned in the inferior part of the machine. Another metallic device was positioned in the superior part of the testing machine, and a digital spacer D (Dentsply Maillefer) was adapted to this device to pressure it and promote the fractures on the teeth. The force application point was directly on the access opening of the root canal for all teeth. Teeth underwent a progressive compression effort, at 1.0mm/mim speed. After starting the machine, the superior part moved downward, so that the spacer were introduced in the root canal. The load was increasing gradually, until the fracture occur. In this moment, occurred a sudden drop of the force and the machine was turned off to finish the test. In almost every specimen it was heard a crack in the fracture moment. The mean force used in the fracture moment was 14.3 kgf.

The root canals of Groups 2 and 3 were filled by the single-cone technique, using the gutta-percha F3 cone and Sealer #26 cement (Dentsply-Maillefer).

For the CMP, the teeth of Group 3 were used. A #4 Gates-Glidden drill was used to removing the remaining filling material, preserving only the 5 mm of gutta-percha filling the root apex, in order to let the root canal prepared to receive the CMP. For the Duracast CMP, the direct technique was used, where the acrylic resin (Duralay) produced a copy of the root canal, being then forward to the prosthetic lab to be molded. The posts were positioned in each teeth and cemented with zinc phosphate cement.

For the tomographic images, the teeth were placed in the empty alveolus of a dry human mandible. For each tomographic carried out, four teeth were randomly placed in the mandible. In order to simulate the soft tissue, the teeth were placed in the alveolus with utility wax and the mandible was immersed in a recipient with water.

The sample was scanned with a Prexion 3D (90kV, 4mA, 5 cm of FOV, 37 seconds of acquisition). The software used for image analysis was PrexViewer. The data was exported in DICOM format, 0.1 mm voxel size. The data was reconstructed with sections on sagittal, coronal and axial planes, and the obtained images were analyzed by a radiologist with 10 years of experience in CBCT. All the images were analyzed in a computer with a LED, 27" monitor, in a dark room. The observer was questioned on presence or absence of fractures in a dichotomous scale (fractured/not fractured teeth).

RESULTS

Results were evaluated by absolute and percentage distribution for obtaining percentage measures of: Sensibility, false negatives, specificity, false positives, positive predictive value, negative predictive value and accuracy. To evaluate the difference between groups regarding accuracy, sensibility and specificity, Fisher's exact test was used. The margin of error was set in 0.5% of the statistical test.

Table 1 presents the results of sensibility, false negatives, specificity, false positives, positive predictive value (PPV), negative predictive value (NPV) and accuracy. Table one emphasized the sensibility variance of 62.5 to 87.5%, in corresponding groups from 5 to 7 cases of fractured teeth, according to the answer of the evaluator. The lowest specificity occurred in teeth with CMP (37.5%), and it varied from 75.0% to 87.5% on the other two groups. Accuracy was of 56.3% in the group of teeth with CMP, and varied from 75.0 to 81.2% in the gutta-percha and control groups, respectively. It is important to emphasize the high percentage of false positives for the Group 3 (62.5%).

Table 2 is presenting the results of comparative tests between groups, regarding sensibility, specificity and accuracy, for the margin of error at 0.5%. No significant difference was observed between the 3 groups, regarding any of the analyzed measures ($p > 0.05$).

Discussion

Periapical radiographs are not reliable methods to carry out diagnosis of VRF, and CBCT allow the detection, localization and extension of fractures accurately.

Table 1. Values for sensibility, false negatives, specificity, false positives, positive predictive value, negative predictive value and accuracy. Answer of the evaluator regarding the fracture occurrence, for each group.

Group	Evaluated parameter	n	%	Basis for calculating
Control (without gutta-percha and without CMP)	Sensibility	7	87.5	8
	False negatives	1	12.5	8
	Specificity	6	75.0	8
	False positives	2	25.0	8
	PPV	7	77.8	9
	NPV	6	85.7	7
	Accuracy	13	81.2	16
Teeth with gutta-percha	Sensibility	5	62.5	8
	False negatives	3	37.5	8
	Specificity	7	87.5	8
	False positives	1	12.5	8
	PPV	5	83.3	6
	NPV	7	70.0	10
	Accuracy	12	75.0	16
Teeth with CMP	Sensibility	6	75.0	8
	False negatives	2	25.0	8
	Specificity	3	37.5	8
	False positives	5	62.5	8
	PPV	6	54.5	11
	NPV	3	60.0	5
	Accuracy	9	56.3	16

Table 2. Comparative tests results between groups, regarding Sensibility, Specificity and Accuracy.

Group	Sensibility		Specificity		Accuracy	
	n	%	n	%	n	%
Control	7	87.5	6	75.0	13	81.2
With gutta-percha	5	62.5	7	87.5	12	75.0
With CMP	6	75.0	3	37.5	9	56.3
Basis for percent by group	8		8		16	
P value	p (1) = 0.837		p (1) = 0.162		p (1) = 0.375	

Obtained results of the present study shows that CBCT is a tool with accuracy to diagnosis the VRF, corroborating with several authors.[14-20]

Through the high values obtained for sensibility, specificity and accuracy, mainly regarding the control group, this research proves the efficacy of CBCT technology in diagnosing these fractures. Despite the values for sensibility, specificity and accuracy being lower than in group 2 and 3, there was no significant difference between the values found in the 3 groups. However, the presence of radiopaque material inside the root canal, such as gutta-percha and the CMP, hindered the interpretation of the CT scans.

These results are similar to the ones observed in other studies,[14] but disagree with others, 18 in which was presented good efficacy of CBCT for detection of VRF only in Control group teeth, being verified only 75% of accurate results in the CMP teeth group. A recent work[15] have shown sensibility and specificity values regarding control and gutta-percha groups similar to the values found in this present research.

This same work showed a significant difference in sensibility and accuracy of CT scans between teeth of both groups, corroborating its results with the present ones. However, there was a significant reduction on specificity (p = 0.016) of images regarding the teeth filled with gutta-percha, diverging from the present results, in which the values for it was not reduced.

In clinical researches,[17,19] it was concluded that the presence of gutta-percha on root canals did not influenced significantly the sensibility, specificity and, consequently, accuracy on VRF diagnosis, thus, showing that even with this filling material, CBCT is able to precise VRF diagnosis. These *in vivo* research results corroborate with the ones found in the present *ex vivo* study.

Conclusion

1) Accuracy in diagnosing VRF by CBCT with Prexion 3D was higher in teeth without the presence of gutta-percha cones and CMP.

2) Teeth with CMP presented higher percentage of false positives.

3) There was no statistical significant difference between the 3 groups as for the accuracy, sensibility and specificity on diagnosis of VRF.

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Accidents and complications in Endodontics caused by sodium hypochlorite: literature review

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ABSTRACT

This review shows the accidents and complications that can be caused by inappropriate use of sodium hypochlorite (NaOCl) during the endodontic treatment. This solution has been used since 1920 in concentrations of 0.5% to 5.25% as an antimicrobial irrigant to assist the mechanical preparation of root canals, it is clinically proven to be a lubricant, antiseptic and solvent of body tissue. However, serious accidents, such as skin and intraoral mucosa burns, laryngeal edema, upper airway obstruction, paresthesia, bleeding and others, may occur when used inadvertently. Thus, careful technique, storage and handling must be taken, in order to prevent these undesirable complications. Furthermore, the professional must be able to identify and solve problems when it occurs.

Keywords: Sodium hypochlorite. Accident. Irrigant. Endodontics.

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Introduction

One of the aims of endodontic therapy is the maintenance of the dental element in the oral cavity. Bacteria in the root canals often result in infection and apical periodontitis.

The use of chemicals in order to reduce or eliminate bacteria has always been present in Endodontics. The chemical methods (auxiliary chemical substances) along with mechanical methods (action of instruments) and physical (irrigation and aspiration) form a single, simultaneous, continuous and inseparable process, which is the chemical-mechanical preparation of the root canal[1].

A lot of substances such as hydrogen peroxide, saline solution, water, sodium hypochlorite (NaOCl), chlorhexidine gluconate and water electrochemically activated have been used during and immediately after the biomechanical preparation of the root canal to remove the debris and necrotic pulp, in addition to aid in the elimination or reduction of microorganisms that can not be only achieved by mechanical instrumentation.[2]

It is essential that chemicals substances selected as endodontic irrigants have properties such as antimicrobial activity and ability to dissolve organic tissues, in addition to help in the debridement of the root canal system and not be toxic to the tissues[3].

Thus the NaOCl has been elected as an irrigating solution in various concentrations ranging from 0.5% to 5.25% for endodontic use by most professionals. A solution of NaOCl at 0.5% (Dakin's solution) was used for the first time in 1920 by Crane in order to promote sterilization and debridement of the root canal. Since then, it has become the most commonly irrigant used in Endodontics[2]. This is due to the mechanism of action of this solution which can promote cellular biosynthetic alterations, cellular metabolism, phospholipid destruction, as well as for its excellent properties: ability to dissolve organic tissues, be antimicrobial, has an alkaline pH, promote whitening, be deodorant and have low surface tension[4]. Besides being cheap, available and easy to store.[2]

However, it is toxic to the vital tissues causing hemolysis, ulcers, inhibition of neutrophil migration, damage to endothelial cells and fibroblasts, facial nerve damage and necrosis when the irrigant is extruded from the periapical area during irrigation of the root canal[5-9]. The NaOCl also has an unpleasant odor and causes staining when it is in contact with the tissues.[10]

Wong[11] describes the endodontic treatment as a routine procedure performed in the dental clinic with few complications reported. However, NaOCl accidents have been reported because of accidental injection of NaOCl stored in empty anesthetic cartridges and also by the leakage of NaOCl to periapical tissues during the root canal irrigation.[12-15]

The hypersensitivity or allergic reactions,[16] contact with the eyes,[17] facial hematoma,[18] severe palatal tissue necrosis,[19] heavy bleeding, emphysema,[5,12,20-23] impairment of airways,[24] hemolysis, skin ulceration, localized swelling,[25,26] gingival necrosis,[27] immediate pain, paresthesia, facial weakness,[9] diffuse pain and lip burning,[7] sinus, erythema,[28] secondary infection and ulcer.[6] All these situations have been reported in the literature as complications caused by the inadvertent handling of NaOCl.

Regardless of the reason or cause, an accident with sodium hypochlorite is a scary event and precautions must be taken to prevent it.[29] Some of these may include: use of plastic bib to protect the patient's clothing, use of eye protection for both patient and operator, use of a rubber dam to isolate the tooth being treated, use of needles for root canal irrigation with side exit, use of irrigation needle calibrated 2 mm short of the working length and avoid excessive pressure during irrigation.[24]

Within this context, this study aims at conducting a literature review in order to present accidents and complications caused by NaOCl during endodontic treatment and how to prevent and solve them.

Literature review

Spangberg, Engström and Langeland[30] claimed that one of the concerns of the endodontists is to promote disinfection of the root canal system, since microorganisms can remain in branches and in irregularities, as well as inside the dentinal tubules. Therefore, cleaning the root canal depends not only on the mechanical action of the instruments, but also on the action of irrigating solutions that lubricate the root canal during the cutting action of endodontic instruments, assisting in the removal of smear layer, decontaminating through its germicide potential and acting as a solvent in exudate and pre-dentin.

Knowing that the components of such formulations may cause more or less irritation to the periapical tissues, it is worth noting the need for care and attention of the dentist when handling different concentrations of NaOCl. Due to the fact that it is highly irritating when extravasated to the vital tissues, we highlight in this literature review four main points regarding accidents and complications of using NaOCl. We believe that this division facilitates understanding of the study. Taking into account the high number of researches, we decided that only those publications with the best reported and solved clinical cases should comprise this review. As a result, the researches selected are all in vivo studies. This review comprises researches published between 1973 and 2012. MEDLINE, PubMed, BBO, Lilacs, SciELO, Library of the College of Dentistry of Piracicaba (FOP-UNICAMP) and the Library of the Ingá College (UNINGÁ) were used as source of research.

Inadvertent injection of sodium hypochlorite in the soft tissue

NaOCl accidents have been commonly reported as a result of accidental injection of this solution stored by dentists in empty anesthetic cartridges.[5,12,14,19,21,27,31,32,33] Usually, this type of accident can cause: severe pain, necrosis of palatine mucosa,[19,31.32] gingival necrosis,[27,31] diffuse pain, swelling, lip burning, hematoma[7,14,21] and bleeding[21].

Treatment options for this type of accident included surgical debridement, free gingival graft,[5,19] saline solution irrigation, antibiotics and antiflamatory.[7,14,21,27,34]

Gursoy, Bostanci and Kosger[19] reported a case of an adult male patient sent to the university hospital 15 days after an inadvertent injection of NaOCl in the palatal mucosa. In the anamnesis, the patient reported that immediately after the solution injection, he felt an intense pain that persisted for 2 days. During the intraoral test, it was found a whitish-yellow necrotic tissue area in the palatal mucosa, with a purple, swollen area surrounding it. An intraoral radiography showed no sign of bone resorption. Possible treatment options include surgical debridement and free gingival graft. However, as the mucosa began to heal after 15 days and the patient had no further complications, no surgical intervention proved to be necessary. After 30 days, there was tissue repair without scarring.

Accidental extrusion of NaOCl beyond the apical foramen

During root canal irrigation, NaOCl may accidentally leak beyond the apex reaching the apical tissues.[12,24,35] This accident can happen in cases of teeth with incomplete root formation, wide apical foramen, apical root resorption, exaggerated foraminal extensions, when the apical contrition was destroyed during the biomechanical preparation of the root canal, when an extreme pressure is performed during irrigation[6] or when the irrigation gauge is incompatible with the diameter of the root canal and it is inadvertently trapped, which blocks the reflux of the solution.[12]

These accidents may be associated with an extreme reaction of acute pain, swelling, tissue damage, hematoma, [8,12,24,36] hemorrhagic ecchymosis[6], chemical burn, extensive tissue necrosis and paresthesia. It can affect adjacent innervation causing, for example, weakness of the facial nerve and infraorbital trigeminal, loss of lip and cheek function, trismus, necrosis and ulceration of alveolus around the teeth.[9,24]

According to Becker, Cohen, Borer;[12] Mitchell, Baumgartner, Sedgley;[36] Desai and Himel[37], the accident can be avoided by careful observation of the root diameter in order to use irrigation needles compatible with the canal diameter, observe the initial diameter of the apical foramen in order not to extend it disproportionately, or use an irrigation system that provides control of the solution flow in the root canal.

Treatment options for this type of accident include placing the patient in an upright position in order to relieve some of the head pressure, applying cold compress to relieve the pain and burning sensation, followed by hot compress to stimulate local systemic circulation, leave the root canal open in order to allow drainage of any exudate, analgesic and antibiotic administration.[4,6,9,12] In more severe cases, there may be a need for urgent hospitalization, intravenous steroids, surgical drainage and debridament.[9,24]

Witton et al[9] described a case of endodontic treatment in which NaOCl was being used as a root canal irrigating solution and during the procedure, there was extrusion of it through the foramen into the surrounding tissues. The patient, who immediately complained of pain and swelling in the face, was taken to the hospital where physical examinations were performed. The examinations revealed loss of sensation in the infraorbital nerve as well as weakness of the buccal facial nerve, resulting in slope right corner of the mouth, without evidence of intraoral soft tissue damage and trismus. The patient was treated with antibiotics and analgesics, followed by evaluation at regular intervals in the clinic every week. In one month, it was observed that the weakness of the facial nerve was significantly improved and about 3 months after the accident, both the paresthesia and facial weakness were completely resolved.

Complications caused by NaOCl swallowing or inhalation

The use of NaOCl for root canal irrigation without complete isolation of the teeth can lead to leakage of the solution into the oral cavity, causing the patient to ingest or inhale it. It may result in irritation of the throat, dysphonia and drooling. In more severe cases, the upper airway can be compromised due to glottic edema.[24,35]

This accident can be avoided if the rubber dam is used to isolate the tooth, and minor adaptation defects should be corrected with a caulking agent for optimal sealing. The treatment proposed for more severe cases is the immediate hospitalization with tracheal intubation.[24]

Ziegler[38] presented a case of a 15-month girl who arrived at an emergency department with acute laryngotracheal bronchitis and excessive salivation as a result of ingestion of a high concentration of NaOCl. A similar clinical picture can occur if NaOCl is ingested during endodontic treatment, depending on the concentration and the volume ingested. Nasal optical fiber and tracheal intubation followed by decompression surgery are performed in order to manage the airway swelling appearing within three hours after NaOCl exposure during root canal treatment.

Complications caused by NaOCl overflow

Accidental NaOCl overflow is probably the most common accident that occurs during root canal irrigation. Even when spilled in low amounts in the patient's clothing it will rapidly and irreversibly bleach the affected area. Patients should wear a plastic protector and the dentist should be careful when handling the NaOCl near the patient.[6,24]

Another accident commonly caused by NaOCl overflow during endodontic treatment is when the solution is sprinkled in the patient's eyes, causing injuries, burns, or even loss of epithelial cells in the outer layer of the cornea, followed by instant severe pain, profuse burning and erythema.[6,24] Treatment includes flushing the eye with large quantities of water or sterile saline solution and immediately taking the patient to an ophthalmologist. The prophylactic measure suggested is the use of eye protection during endodontic treatment for operators and patients.[24]

Damaged skin caused by NaOCl overflow can be avoided by immediately washing the affected area with water at low pressure in order to prevent the NaOCl to spread. Allergic reactions are also reported when there is NaOCl spill during endodontic treatment. It is important for professionals to recognize the symptoms of allergy, such as hives, swelling, shortness of breath, bronchospasm and hypotension. In these situations, the patient should be urgently referred to a hospital.

Discussion

A successful endodontic therapy, related to effective cleaning and disinfection of the root canal, faces a complex anatomy which hinders its execution. Thus, in order to contribute to a better cleaning of the root canal system auxiliary chemicals substances are used for irrigation.

The NaOCl is an effective endodontic irrigating solution used at different concentrations ranging from 0.5 to 5.25%.[6,39] According to Grossman,[40] it is the most widely used irrigant due to its ability to dissolve organic tissues as well as its antimicrobial properties , in addition to its non-specific ability to oxidize, hydrolyze and act osmotically in the tissue fluids. However, NaOCl can cause hypersensitivity as well as serious complications if it is inadvertently used,[16] since it is toxic to the vital tissue, causing hemolysis, ulcers, inhibition of neutrophil migration, damage to the endothelial cells and fibroblast.[5-9]

Treatments for NaOCl complications during endodontic treatment have been described in the literature.[6,20] However, according to Becking[31], only some of these complications have been recorded. The most commonly reported complication is the accidental NaOCl leakage into the periapical tissues, in teeth with open foramen or when the apical constriction was broken during root canal preparation, or due to root resorption, or even because the root of the tooth may be within the maxillary sinus.[8,14,15]

In the majority of cases reviewed, the postoperative patient who suffered this accident had severe and immediate pain, followed by gradual formation of edema and profuse bleeding and bruising. However, the majority of patients had complete resolution within a few weeks and only some of them suffered long paresthesia or scar tissue.

Another accident commonly reported in the endodontic literature is the NaOCl injection in the buccal or palatal mucosa caused by improper storage of this solution into anesthetic cartridge. According to Gursoy, Bostanci and Kosger,[19] 0.1 to 0.2 mL of injected NaOCl is sufficient to cause necrosis tissue. All authors who reported[5,7,12,13,14,19,21,27,31,32,33] this type of accident are against this form of NaOCl storage and claim that should the dentist insist on this form of storage, the cartridges must be properly identified and stored far from the cartridges containing anesthetic.

When adverse reactions occur, right conduct includes changing the irrigating solution, preventing additional reactions, calming the patient and establishing adequate analgesia. Prophylactic antibiotic therapy, corticosteroids and antihistamines should be considered to prevent infections resulting from the damage in specific cases. For immediate relief of pain, a local anesthetic should be considered. Cold compresses should be used to minimize swelling in the affected area.[29]

Additionally, our literature review shows that the first procedure to be performed when an accident with NaOCl occurs is reassuring the patient by telling him that cure will occur within a few days or weeks, and that symptoms are completely relieved in most cases. Afterwards, the NaOCl toxic effect must be neutralized in water or saline solution, application of ice packs in the first and second day to minimize the edema, followed by application of warm compresses to promote the liquefaction of the hematoma. According to Mehra, Clancy and Wu,[18] pain should be controlled with analgesics and antibiotic therapy for two reasons: the possibility of root canal infection to diffuse into the periapical tissues with NaOCl irrigation and the presence of a significant amount of necrotic tissue and empty space that can promote a secondary infection. The most severe cases must be identified by the dentist and sent to the hospital for surgical intervention.

Conclusion

Sodium hypochlorite is an efficient irrigation solution commonly used in endodontic therapy. However, it can be highly toxic, causing serious consequences if improperly handled. It has advantages and disadvantages which should be considered according to its applicability in clinical cases. Some necessary cares should be taken to achieve treatment success when using the NaOCl and, in case of incident, the patient must be warned about the consequences and told that the recovery will occur within a short period of time. Thus, we should closely follow the problem until all signs and symptoms are resolved, making the patient feel calm and comfortable.

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Odontogenic cutaneous sinus tract: Case report

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ABSTRACT

Introduction: Odontogenic sinus tracts are canals originated from dental inflammation and which drain into the orofacial and neck region. One of the most common causes of odontogenic sinus tract formation is the presence of cavities or dental trauma, with bacterial invasion in the pulp tissue and subsequent pulp necrosis. **Objective:** To report the clinical history of a patient who attended the UESB College of Dentistry presenting an odontogenic cutaneous sinus tract. **Case report:** A 47-year-old woman presented herself to the service of endodontics of UESB College of Dentistry complaining of an extraoral sinus tract on the left side of her face. After appointments with otolaryngologists, ophthalmologists and other physicians, the patient sought dental care. Periapical radiographs revealed carious lesions in the left lateral incisor, with the presence of periapical pathology. Endodontic treatment was proposed and performed in a single session. **Results:** Three days later, the sinus tract had regressed and there was only a scar on the site, due to tissue retraction for closing the opening hole of the lesion. Two months later, a radiographic examination showed bone formation in the apical region of the tooth and no pathology. **Conclusion:** Knowing this condition proves to be of paramount importance for dentists and physicians to correctly conduct the diagnosis and treatment of the disease.

Keywords: Cutaneous sinus tract. Diagnostic services. Endodontics.

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» The patient displayed in this article previously approved the use of her facial and intraoral photographs.

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Introduction

The odontogenic sinus tract is a canal originated from dental inflammation and which drains into the orofacial and neck region. They are usually misdiagnosed and in many cases treatment is not appropriate, in which case it is extremely important to know about its etiology.[1,2,3]

One of the most common causes of odontogenic sinus tracts is the presence of caries or dental trauma, with bacterial invasion of the pulp tissue and subsequent pulp necrosis.[4,5] This microbially induced inflammation can penetrate the alveolar bone and spread itself throughout the path of least resistance, causing apical periodontitis.[4] The inflammatory process can reach the surrounding soft tissues and form a path for drainage, thus forming the sinus tract.

The site of extraoral drainage depends on the affected tooth, as well as on specific factors such as the virulence of the microorganism, resistance of the patient's body and the relationship between anatomy and muscle facial attachments.[3,6,7,8] The dental elements mostly associated with cutaneous sinus tract are the third molars, followed by maxillary third molars and maxillary canines.[1,7,9] The areas most commonly affected are the chin and the submental region, other areas include the cheeks, nasolabial folds and the inner corner of the eyes.[4,6,7,10]

The aim of this study is to present the report of an odontogenic sinus tract case, showing the etiology of the disease, the difficulties in establishing an exact diagnosis and the correct procedures, all of which should be followed by health care professionals for the remission of the problem.

Case report

A 47-year-old female patient presented herself to the College of Dentistry UESB complaining of discomfort. The patient presented an extra-oral sinus tract in the left region of her face, with an approximate size of 5 mm x 5 mm, near the bridge of the nose and positioned over the nasofacial groove (Fig 1A). During the interview, the patient reported that the sinus tract had appeared 4 years before and several treatment attempts had been made. The medical history did not include two facial traumas in the same region of the face, one of them had occurred 30 years before and the other 10 years before, with no apparent dental complications.

The patient reported that she sought care for the first time in 2007, with symptoms of headache and itchiness in the tooth. At that time, the doctor suggested that it was sinusitis. Not satisfied with the diagnosis, she sought a second medical opinion with an otolaryngologist who suggested that the lachrymal duct had broken out because of the sinusitis, thus forming the sinus tract. The doctor did not consider the possibility of it being a dermatological problem and confirmed the need for surgery of the lachrymal duct.

One month after the appointment, the patient gave up the surgery and decided to seek other treatments. To control the drainage of pus, she made use of corticosteroid and antibiotics. At that time, there was swelling on the left side of her face and lips, with a purplish color, but the sinus tract always presented the same size. She felt no pain, unless when pressing the site.

Nearly four years after her last appointment, the patient sought dental treatment, reporting itchiness in the tooth. The dentist asked for a panoramic radiograph and diagnosed a sinus tract associated with a tooth. However, the professional extracted a tooth that was not part of the context of the sinus tract. After that, the patient sought treatment at the UESB, looking for a solution for her problem. A radiographic examination revealed periapical lesion associated with #22 tooth (Fig 1B), while a periodontal examination revealed the absence of periodontal pockets, with no possibility of verifying the mobility of the element. Endodontic treatment for the #22 tooth was proposed to the patient, and it was conducted during a single session (Fig 1C). Three days after endodontic treatment, it was possible to see the healing of the sinus tract and the absence of pus (Fig 2A).

At the follow-up appointment, 60 days after endodontic treatment, she no longer complained of discomfort. Only a small tissue contraction was noticed in her face, particularly due to the closing of the sinus tract (Fig 2B). The follow-up radiograph demonstrated an area of tissue repair (Fig 2C). New return visits will be conducted every six months for a period of two years.

Discussion

A dermal sinus tract can be quickly established within a few weeks or as late as 30 years. They are usually caused by apical periodontitis associated with dental cavity.[6] The apical periodontitis, described as

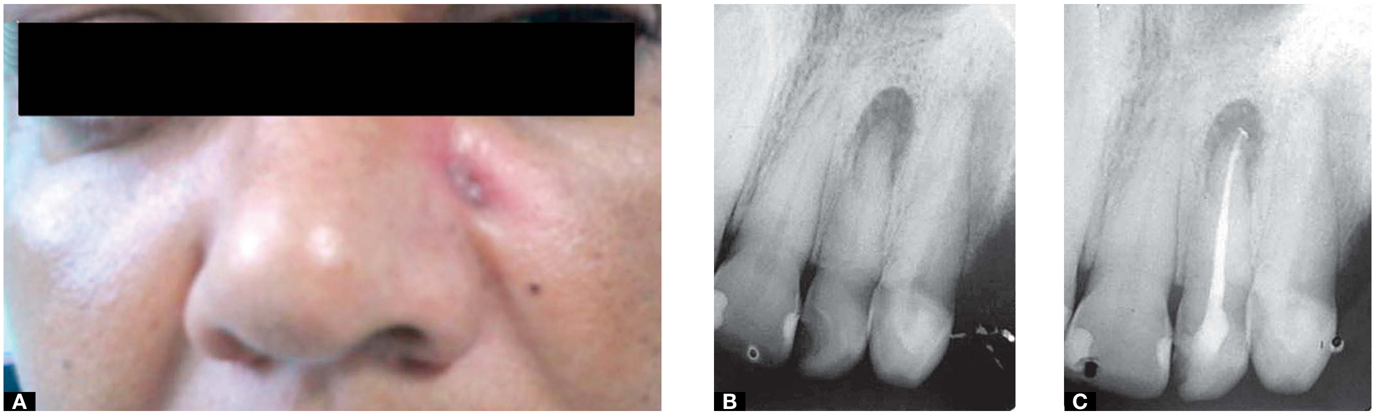

Figure 1. Patient during first appointment. **A**) Location and aspect of the cutaneous sinus tract. **B**) Initial radiograph showing periapical lesion associated with tooth #22. **C**) Final radiograph after root canal obturation.

Figure 2. Patient after endodontic intervention. **A**) Clinical aspect of the sinus tract three days after endodontic treatment. **B**) Clinical aspect of the region 60 days after endodontic treatment. **C**) Follow-up radiograph.

chronic periapical abscess, is characterized by slow and gradual drainage through a sinus tract, intraoral and extra-oral, and without painful symptoms.[11]

An extraoral sinus tract of dental origin can be confused with a variety of diseases, and some authors[1,3,7,8,10,12] include local skin infections, fungal and bacterial infections, ingrown hair, occlusion of the sweat gland duct, traumas, osteomyelitis, neoplasms, carcinoma, tuberculosis, actinomycosis, tertiary syphilis, infected cyst, presence of foreign bodies, pyogenic granuloma. Delays in establishing a correct diagnosis, due to the variety of the situations presented, may lead patients to undergo unnecessary surgeries and treatments. Intraoral and dental examinations are indispensable for the diagnosis. The examiner should assess the presence of cavity, oral hygiene, restorations or identify the presence of periodontal disease, keeping in mind that the affected tooth can look apparently normal.[1,10,13] An effective method to determine if the sinus tract is of dental origin is through the use of a clean gutta-percha cone which, when inserted into the opening of the lesion, goes through the sinus tract path until it reaches its origin (generally, unhealthy teeth)[4,10,12] discovering the cause of the infection and helping in the final diagnosis.[7] In this report, a pulp vitality test was conducted, and the answer was negative for the cold. This method will also help the professional to complement his information for diagnostic decision. However, one must take into consideration the false positives and the several false negatives of these tests, and associating this test with other diagnostic tests.[3]

Panoramic radiographs can be useful for initial triage of cases with suspected dental pathology. Intraoral periapical radiographs, however, are more useful for specific diagnosis, because they provide more details of the teeth and associated structures.[8,12]

Surgical extraction is one of the treatments of choice, provided that the affected tooth has no possibilities of receiving endodontic treatment. Studies indicate that after eliminating the source of infection, either with root canal treatment or extraction, the time of spontaneous closure of the sinus tract should be from 7 to 14 days.[3,7,10,12,13] Endodontics is the first option of treatment which, after root canal obturation, requires a clinic and radiographic follow-up of more than two years in order to assess the process of complete healing.[11] Some studies[15,16] demonstrate the clinical advantages of performing endodontic treatment during one single session.

In the reported case, this therapy was chosen due to patient's favorable health state, the technology used (apex locators and rotary instruments) and the chlorhexidine medication used as an antiseptic agent to facilitate decontamination of root canals during preparation, and of which effectiveness in this process has already been proved in some studies.[17,18] Such studies[19,20] report that, regardless of the pulpal or periapical pathological stage, final obturation could be performed provided that the canals were conically shaped, the patient was asymptomatic and there was time available. It is worth noting that the patient had been affected by the disease for a long period of time, therefore, it would not be satisfactory to slow down the completion of treatment by exchanging intracanal curatives and medication and keeping the tooth with temporary filling, thus, limiting its function in the oral cavity. In this study, regression in the sinus tract could be observed 3 days after endodontic treatment. Some studies have reported the formation of scar tissue after healing and suggest the need for skin cosmetic treatment for esthetic reasons, especially when the healing area of the sinus tract results in skin retraction or dimpling.[6,14]

On a return visit, 30 days after finishing the root canal treatment, the patient presented only a small scar, as a result of tissue retraction for sinus tract closure.

A multidisciplinary interaction is very important to prevent the patient from being subjected to unnecessary treatments, antibiotics or surgical procedures before performing endodontic treatment or definitive surgical extraction.[1] Even when dental symptoms are absent, health professionals should always consult dentists in order to rule out the dental origin of the sinus tract, expanding the possibility of achieving a successful treatment.

Conclusion

According to the present case report we can conclude that:

- Performing a correct diagnosis as soon as possible prevents the patient from being subjected to inadequate and ineffective surgery and antibiotic treatment.
- Sinus tract of dental origin should be considered for face and neck.
- Root canal therapy is the treatment of choice for these cases.
- Monitoring the patients is necessary until complete healing of the disease.

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The importance of the use of computed tomography in diagnosis and in endodontic planning: a case report

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ABSTRACT

Objective: The aim of this study was to report a case of an endodontic re-treatment in a patient submitted to orthognathic surgery, using computed tomography to aid the diagnosis and treatment plan. **Methods:** The patient was referred for endodontic evaluation of anterior teeth with a history of orthognathic surgery on the maxilla and rigid internal fixation with miniplates for osteosynthesis in the region close to the dental apexes. **Results:** A three-dimensional evaluation of the region demonstrated periapical lesion of the left central incisor. The endodontic re-treatment resulted in remission of symptoms and regression of periapical bone rarefaction. **Conclusion:** The use of computed tomography was essential to the resolution of this case, what was proved with bone neoformation.

Keywords: Cone-beam computed tomography. Periapical periodontitis. Endodontics.

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Introduction

The necessity of evaluating structures in three dimensions in endodontic practice is noted especially in complex cases. Conventional radiographs are originally limited to a two-dimensional visualization, but, even with parallelism techniques, distortions and overlapping structures, are inevitable. The information of the anatomy is obscured and does not accurately reveal some aspects considered important to obtain a correct diagnosis and planning.[1]

The difficulty of visualization of periapical lesions in two-dimensional radiography has been reported.[2-5] Cone-beam computed tomography (CBCT) scans have identified more cases of periapical lesions than conventional radiography.[6]

The use of miniplates for osteosynthesis in orthognathic surgery promotes overlay images in conventional radiographs, which can hinder the diagnosis in Endodontics. There are reports of endodontic complications caused by the installation of miniplates.[7,8]

Computed tomography provides a method for accurate diagnosis with high-resolution images, which can reduce the incidence of false-negatives,[5] minimize interference of the observer and increase the reliability of interventions.

The aim of this study was to report a case of endodontic re-treatment in a patient submitted to orthognathic surgery, using computed tomography for the diagnosis and treatment plan.

Case report

A 32-year-old female patient complaining of pain in the anterior maxilla was referred to the service of Endodontics for endodontic evaluation of anterior teeth. Her previous dental history revealed that the patient had been submitted to orthognathic surgery two years before.

During the intraoral evaluation no edema or mobility of anterior teeth were observed. Palpation did not contribute to the diagnosis due to the presence of miniplates in the area next to the dental apexes. The vertical percussion was positive for tooth #21. Electric pulp testing showed pulp sensitivity consistent with normal teeth for #11 and #22 elements. Radiographic examination showed the presence of endodontic treatment for teeth #21 and #12, with unsatisfactory aspect for tooth #21. However, radiographic interpretation of the periapical region of the teeth was compromised by overlapping images caused by the miniplates (Fig 1). Therefore, a CBCT was requested for a three-dimensional visualization of the anterior maxilla. By means of the CBCT, an extensive area of bone rarefaction in the periapical region of tooth #21 was observed (Fig 2).

With the diagnosis of chronic apical periodontitis for tooth #21, the endodontic re-treatment began. After all preoperative care inherent to the treatment, such as dental prophylaxis, local anesthesia and use of rubber dam, the access to the root canal was performed by means of a round diamond bur and Endo Z bur (Microdont, São Paulo, Brazil). Gates Glidden drills (Microdont, São Paulo, Brazil) were used to remove two-thirds of the root canal material. Hedstrom files (Dentsply-Maillefer, Ballaigues, Switzerland) were then used in a reaming motion to reach the working length and copious irrigation with sodium hypochlorite at 5.25%.

The apparent length of the tooth was obtained by the measuring tool present in the software for reading the CBCT and the working length was determined by means of an electronic apex locator, Endex (Osada, Tokyo, Japan), since the root apex could not be visualized through radiographic examination of the tooth length (Fig 3). The canal was instrumented by K-files (Dentsply-Maillefer, Ballaigues, Switzerland) with a working length of 19 mm to a #60 final file size. The final irrigation was performed with 17% EDTA (Fórmula & Ação, São Paulo, Brazil) and the intracanal dressing for 30 days, with calcium hydroxide Callen (SS White, Rio de Janeiro, Brazil). After that period, there was remission of symptoms and obturation was performed by means of the cold lateral condensation technique with gutta-percha cones and Pulp Canal Sealer EWT (SybronEndo, Orange, USA) (Fig 4).

Two years after endodontic therapy was concluded, a new CBCT was carried out and it revealed regression of periapical bone rarefaction (Fig 5).

Discussion

Periapical radiographs are complementary tests widely used in Endodontics due to their technical simplicity and for allowing the resolution of a large number of cases. However, their limitation of two-dimensional visualization can hinder the diagnosis and the planning of specific cases.[1]

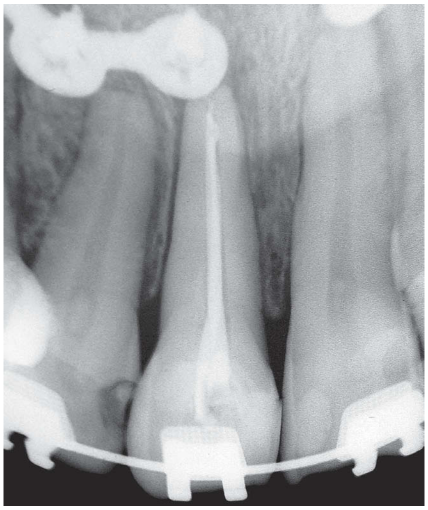

Figure 1. Preoperative periapical radiograph of tooth #21.

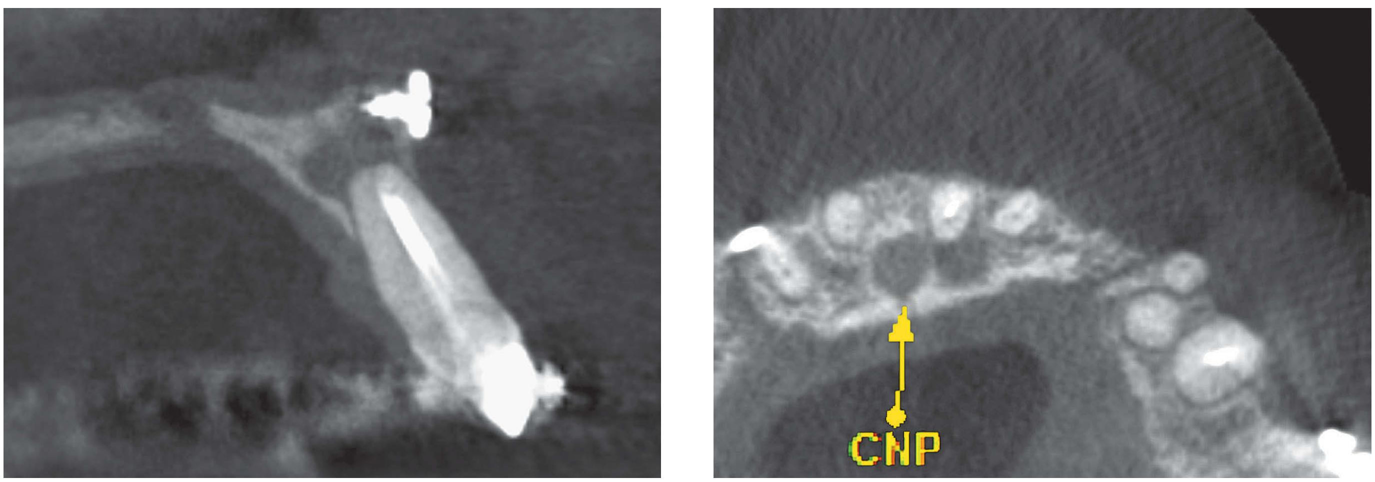

Figure 2. Sagittal and axial CBCT tomographic sections demonstrating periapical lesion.

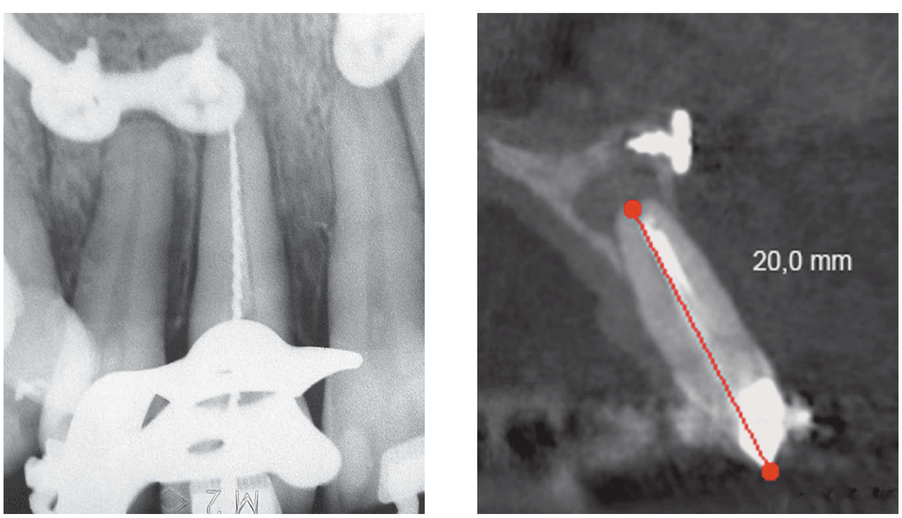

Figure 3. Periapical radiograph and CBCT for odontometry determination.

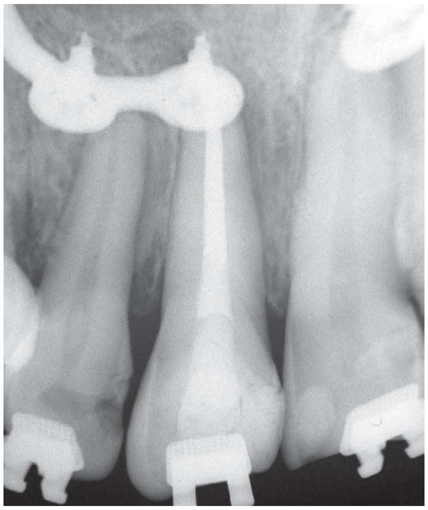

Figure 4. Postoperative periapical radiograph of tooth #21.

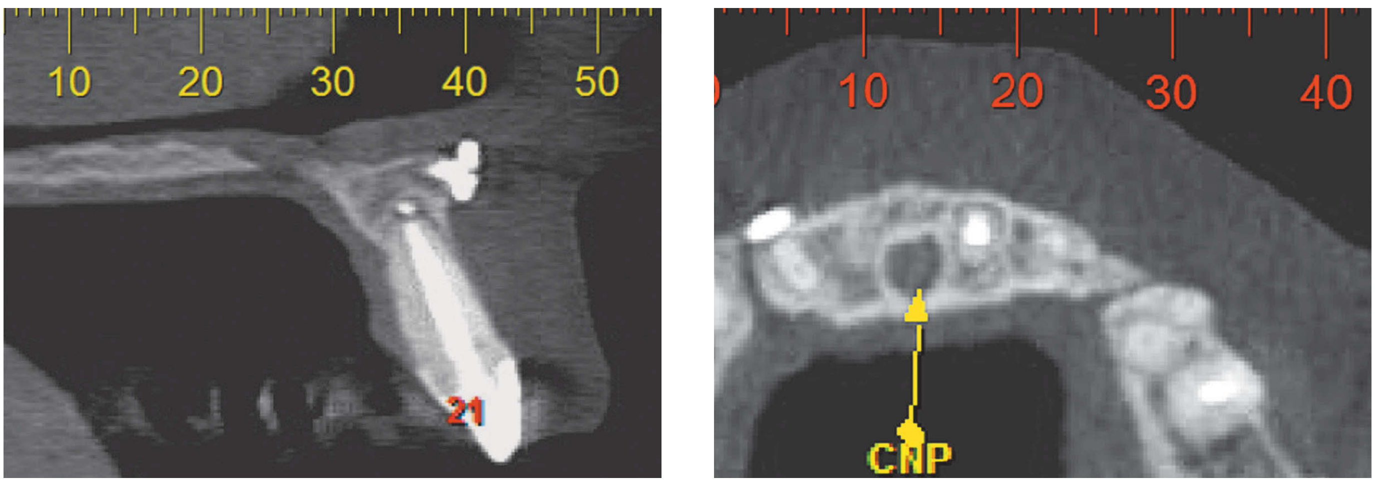

Figure 5. Sagittal and axial tomographic sections taken 2 years after treatment demonstrating regression of periapical lesion.

The importance of computed tomography in Endodontics is unquestionable as it presents many applications such as detection of root fractures, location of root canals, evaluation of complications such as resorption, calcification and perforation, and interpreting three-dimensional anatomical structures.[2,9,10,11] Despite being an excellent diagnostic tool, the request for a CBCT in Endodontics is necessary only for selected cases, since it is able to reproduce images of areas do not reached by conventional radiographies.[9]

In this case report, the symptoms could be interpreted as a complication arising from orthognathic surgery. Complications associated with the use of miniplates include metal sensitivity, infection, neurologic injury, dental trauma, stress shielding, and malocclusion.[7] Arikan et al[8] reported a case of root perforations originated during screws plate installation of miniplates. The injuries caused pulp necrosis in two teeth.

Radiographs showed miniplates overlapping the root apex, which made radiographic interpretation difficult. Tomography eliminated structures overlapping and allowed visualization of the extensive periapical lesion. The diagnosis and planning of this report would not be complete without this tool.

Computed tomography is currently associated with increased rates of identification of periapical lesions when compared to conventional radiograph.[3,4,6,12,13] Estrela et al[6] demonstrated that cone-beam computed tomography (CBCT) identified more cases of periapical lesions than routine radiographic examination, and that these lesions were only identified by conventional methods when a severe condition was present.

Conclusion

Based on these results, it was concluded that the use of computed tomography was indispensable for the diagnosis, treatment plan and for the solution of this case, which was proved by bone neoformation.

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Maxillary sinus disease of odontogenic origin

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ABSTRACT

Introduction: Due to the intimate relationship between the root apices of maxillary posterior teeth and the maxillary sinus, in some cases, maxillary sinusitis may be of odontogenic origin, such as tooth extractions, periodontal and periapical lesions (abscesses, granulomas and root cysts). Computerized tomography is the exam of choice to help with the diagnosis of sinusopathies. **Objective:** The aim of this study was to assess the aspects that characterize an odontogenic sinusitis by means of a case report.

Keywords: Maxillary sinus. Dental infection. Oral diagnosis. Maxillary sinusitis.

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Introduction

Inflammatory sinusopathy has been considered the most prevalent chronic disease in all age groups and the fifth major cause of the use of antibiotics. The occurrence of acute, recurrent inflammatory sinusopathies and chronic inflammatory sinusopathies in children in the age-range between one and seven years may be considered frequent. Sinusitis may develop as a result of sinus membrane inflammation, as a consequence of infectious systemic diseases or general diseases of the body, such as colds, influenzas, measles, pneumonia, among others. Sinus inflammation may also occur through the spread of an infectious focus of odontogenic origin.

Another factor that may contribute to the development of sinusopathies, mainly those of chronic nature, is the consequence of periapical lesions established in a non-vital tooth, with an infectious process, which may promote the occurrence of oroantral fistulas.[1] Another odontogenic infection that may disseminate itself and lead to a sinusopathy arise from endoperiodontal lesions characterized by the association of periodontal and pulp disease in one and the same tooth, thus, once again, the proximity of the teeth to the sinus will cause the infection to be disseminated.[1-5]

Odontogenic sinusitis comprises from 10 to 12% of maxillary sinus. The odontogenic origin of sinusitis must be considered in patients with a history of odontogenic, dentosurgical-alveolar or periodontal infection. Approximately one tenth of all sinusitis cases corresponds to maxillary sinusitis, not only due to the proximity between the maxillary sinus and the maxillary teeth, but also for being more susceptible to invasion by pathogenic microorganisms.

It is important to make an in-depth analysis to determine whether the sinus disease is of odontogenic origin or not. Diagnosing sinus disease of odontogenic origin demands complete clinical and radiographic evaluation, with special attention paid to the patient's history and symptomatologies, which include headache, maxillary sensitivity and nasal congestion.

Computerized tomography is the exam of choice of help with the diagnosis of sinusopathies, as it allows visualization of the main sinus cavity, sinus floor, all of its walls as well as the roof or superior border. Additionally, it not only allows a comparison of both sides and of hard and soft tissues images, but also the identification of the exact location of the lesion and eventual defects in the sinus wall Thus, information is more precise.[1-3,7]

The aim of this study was to report a clinical case of a sinusopathy of odontogenic origin, showing clinical and tomographic information, classifying this pathological condition and forms of treatment.

Case report

A 56-year-old female patient sought an otorhinolaryngologist with the chief complaint of internal pressure, sensation of a heavy head on her right side, and difficulty breathing through the right nostril, with a history of recurrent sinusitis. After antibiotic therapy, there was no remission of symptoms. The professional suspected sinusitis of odontogenic origin. When questioned, the patient reported an episode of a bitter taste in the mouth.

Computerized tomography was performed in a volumetric tomograph, and coronal axial and sagittal reconstructions with thickness and interval of 5 mm were obtained. In addition, panoramic and transverse reconstructions were performed in the region of the maxillary posterior teeth on the right side, with thickness and interval of 1 mm.

In the CT exam, material of density of soft parts (opacification/concealment) were observed, occupying practically the entire right maxillary sinus, extending to the main drainage infundibulum of the sinus which was obliterated. Some anterior ethmoidal cells on the right side presented mucosal and/or partially concealed thickening, with normal intercellular septum. The frontal sinus on this side was also concealed. The frontonasal and sphenoethmoidal recesses on the right side were obliterated. The other paranasal sinuses, as well as their outlines and drainage tracts, were normal. Furthermore, hyperplastic increase in the inferior nasal horn on the right side was observed, diminishing the nasal airway on this side, in addition to nasal septum deviation with convexity facing the left side.

In the panoramic, transverse (Fig 1) and coronal reconstructions, bone rarefaction was observed in the periapical and furca region of tooth 16, with endodontic treatment, compatible with osteolytic lesion of inflammatory/infectious origin. This process promoted discontinuity of the vestibular cortical of the alveolar process and maxillary sinus floor, resulting in dissemination of this condition to the paranasal sinuses on the right side. Thus, it could be concluded that this chronic, recurrent sinusitis was of odontogenic origin.

The treatment proposed was extraction of #16 with remission of the chronic sinusopathy condition. New CT was requested for control.

Discussion

Odontogenic sinusitis is a pathological condition frequently underestimated, and in which tooth infections are responsible for 5% to 10% of maxillary sinusitis cases. In chronic odontogenic sinusitis, asymptomatic development or the presentation of few symptoms is frequently observed, including headaches that increase when moving the head and drainage of secretions through the nasal cavity. Resolution of cases with these characteristics depends on the combination of treatments carried out by doctors and dentists.[1]

An in-depth analysis is important to determine whether the sinus disease is of odontogenic origin or not. Diagnosing sinus disease of odontogenic origin demands complete clinical and radiographic evaluation, with special attention paid to the patient's history and symptomatologies, which include headache, maxillary sensitivity and nasal congestion.[2]

Computerized tomography is one of the main complementary exams that help professionals with the diagnosis of a sinusitis of odontogenic origin. This will be requested by the otorhinolaryngologist when the cause of a sinus disease is unknown, or when there is no remission of the symptoms.[2,8] It is extremely important to have interdisciplinary relationships between the dentist, the otorhinolaryngologist and the radiologist doctors, so that procedures can be correctly performed, thus, leading to adequate diagnosis and treatment of the case.

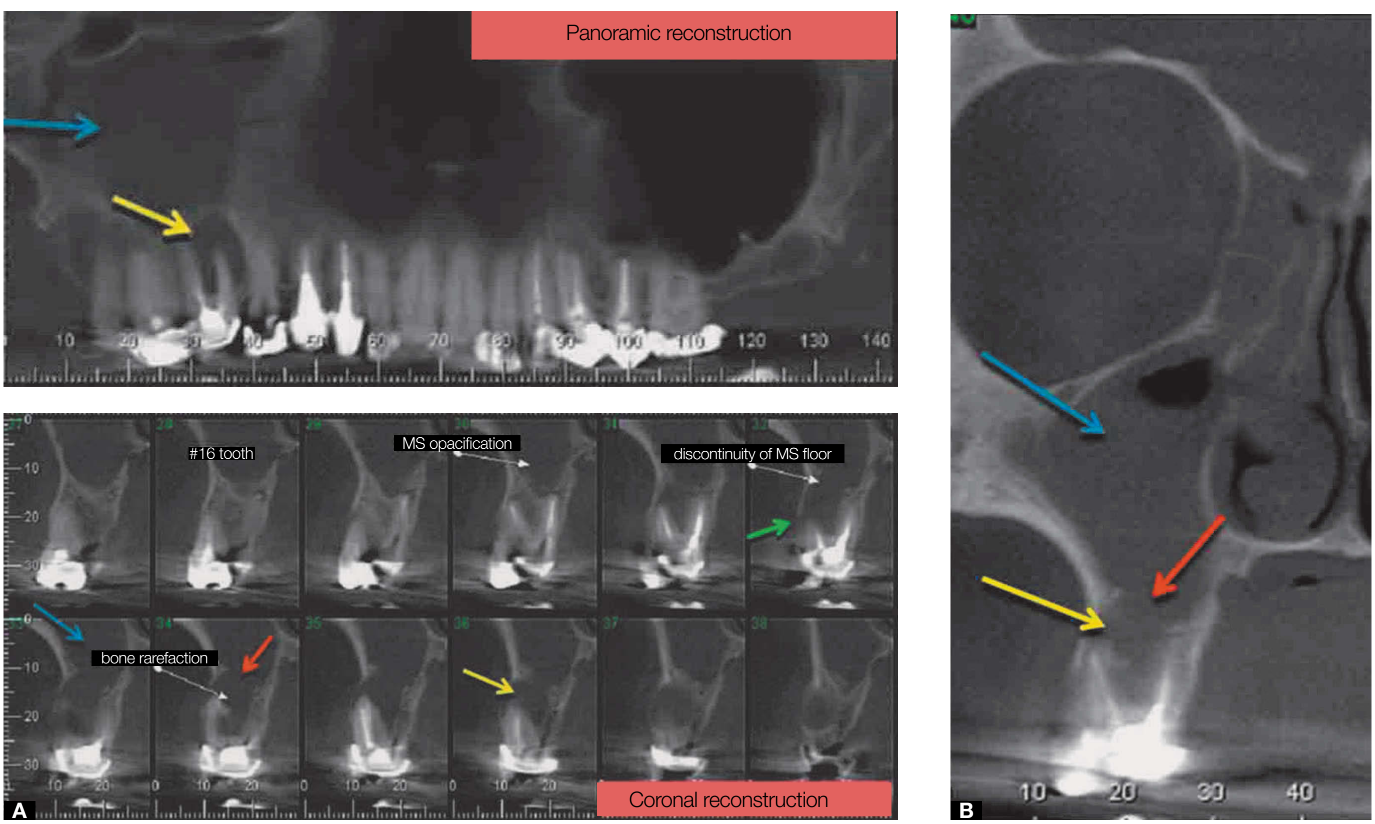

Figure 1. A) Panoramic reconstruction and cross section: Note bone rarefaction in the periapical and furca region of #16 tooth, compatible with osteolytic lesion of inflammatory/infectious origin. **B)** Coronal reconstruction: discontinuity of the vestibular cortical of the alveolar process and maxillary sinus (MS) floor.

The treatment proposed to the patient was removal of the cause, which was tooth 16, and a new CT for control. The resolution of cases with these characteristics depends on the combination of medical and dental treatments, bearing in mind that the patient sought the dentist after having been evaluated by an otorhinolaryngologist and referred by the latter to another professional for evaluation. In this case, the dentist participated in the diagnosis, detecting the tooth that was causing the sinusopathy, and, using his professional skills, took care to have it treated or removed, directly acting on the origin of the problem.

Conclusion

It is important to point out that the CT is one of the main complementary exams that help professionals in the diagnosis of a sinusitis of odontogenic origin, and is requested by the otorhinolaryngologist when the cause of a sinus disease is unknown, or when there is no remission of the symptoms after antibiotic therapy. Nevertheless, it is extremely important to have an interdisciplinary relationship between the dentist and the otorhinolaryngologist, so that procedures are correctly performed, which leads to adequate diagnosis and treatment of the case.

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Apexification without periodic changes of intracanal medicament and MTA apical plug: 5-year follow-up

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ABSTRACT

Objective: The objective of this report was to present a case of apexification in traumatized teeth treated with two different therapies for immature teeth. **Methods:** An 11-year-old male patient was referred to the Dental Trauma Service of the College of Dentistry — Piracicaba (UNICAMP), with enamel dentin fracture in the maxillary central incisors associated with subluxation caused by a bicycle fall 3 years before. The radiographic examination revealed immature teeth. After necrotic pulp had been diagnosed, the treatment plan comprised apexification with intracanal medicament at the right central incisor and MTA apical plug in the left central incisor. The intracanal medicament protocol was performed with an obturation paste composed of calcium hydroxide, 2% chlorhexidine gel and zinc oxide without periodic changes. The MTA plug sealed the apical third of the root canal while the middle and cervical thirds were sealed with coltosol. **Results:** After an 8-month follow-up, apical closure of both teeth could be observed, without dissolution of intracanal dressing. After a 5-year follow-up, the teeth did not present symptomatology and the periapical lesions were repaired. **Conclusion:** Based on the results of this study it is reasonable to conclude that both apexification therapies may be concluded within a few sessions and may provide clinical success and comfort to the patient.

Keywords: Endodontics. Necrotic dental pulp. Tooth root.

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Introduction

Dental trauma may be considered a world health issue, since it promotes great impact on the quality of life of young people, and generally requires multidisciplinary planning[1]. Its incidence is high mainly among children and adolescents aged between 7 and 10 years old[2]. Considering the occurrence of dental trauma episodes with young people who present developing tooth, the conduct adopted should take into account a treatment that stimulates natural root formation.

When immature teeth require endodontic treatment, the therapy must create conditions for obturation and definitive rehabilitation of the tooth. The most traditional treatment is apexification.[3] This technique includes decontamination of the root canal with chemical-mechanical preparation associated with intracanal dressing, with a view to inducing apical closure of these teeth. The calcified barrier formed at the blunt open apex has been described as cementum-like tissue or osteodentine.[4,5] The intracanal medicament will act as an adjunct to disinfection, stimulating apical closure and preventing or stopping inflammatory resorption.[6] Pastes composed of calcium hydroxide and Mineral Trioxide Aggregate (MTA) are the most widely used to induce the formation of a calcified apical barrier and are highly successful.[7,8,9] Whereas calcium hydroxide must be replaced in the interior of the canal, causing treatment to last longer, apexification may be performed in one or two sessions when an apical plug of MTA is used. The MTA plug creates an apical barrier allowing definitive obturation in little time[10].

Recently, an alternative to apexification has emerged as a result of a variety of studies and case reports that show promising results of pulp revascularization in necrotic immature teeth.[11,12] Meantime, there are situations in which revascularization may not be the first choice of treatment due to the need of rehabilitation with intraradicular retainers and the presence of root resorption. Despite the fact that there are some unsolved issues concerning pulp revascularization, apexification is still considered a well-known and successful procedure with follow-up studies being carried out for a long time.[9,13]

Thus, the aim of this work was to report a case of dental trauma in immature teeth treated with two apexification protocols: calcium hydroxide — not periodically replaced — and MTA apical plug.

Case report

An 11-year-old male patient was referred to the Dental Trauma Service of the College of Dentistry — Piracicaba (UNICAMP) due to a bicycle fall happening 3 years before. Dental trauma history and clinical exam revealed enamel dentin fracture in the maxillary central incisors associated with subluxation. The fractured incisors presented adhesive restorations and were subjected to orthodontic treatment. Radiographic examinations revealed immature root canals, absence of root fracture and presence of periapical lesions in both incisors (Fig 1). During the first visit, cold and electric pulp tests showed negative responses for both incisors and the patient reported no pain upon percussion nor palpation.

Based on the negative responses of pulp vitality tests and the presence of radiolucent lesion, treatment planning comprised two apexification protocols: a paste of calcium hydroxide was applied to #11 tooth and it was not periodically replaced during treatment, whereas for #21 tooth, a MTA apical plug was used. The orthodontist was advised not to apply excessive force to the referred teeth before endodontic treatment was finished.

The right central incisor was anesthetized, isolated with rubber dam and accessed by means of diamond burs (KG Sorensen™, Barueri, Brazil) with copious sterile saline solution. The root canal was disinfected with 2% chlorhexidine gel (Endogel, Itapetininga, Brazil), irrigated with sterile saline solution and instrumented by the crown-down technique and manual K-files (Dentsply/ Maillefer, Petrópolis, Rio de Janeiro, Brazil). Thereafter, root canals were dried with absorbent paper cones (Dentsply, Petrópolis, Rio de Janeiro, Brazil) and dressed with intracanal medicament composed of an obturation paste manipulated with calcium hydroxide, 2% chlorhexidine gel and zinc oxide in the proportion of 2:1:2 (Fig 2). This paste remained unchanged, acting as a temporary root canal filling material.

The left central incisor was subjected to the same procedures of access, isolation, decontamination and instrumentation of the right incisor. In order to make the apical plug, the MTA (Angelus™, Londrina, Brazil) was prepared with distilled water, inserted into the apical third of the root canal with condensers (Konne™, Belo Horizonte, Brazil) and radiographically checked (Fig 3).

Figure 1. Initial periapical radiograph revealing immature teeth and periapical lesions associated to right and left central incisors.

As for obturation of the middle and cervical thirds, coltosol (Coltene/Whaledent™, New Jersey, USA) increments were inserted, followed by fixed coronary restoration with composite resin (Filtek 3M Espe™, Sumaré, Brazil) (Fig 3). After a seven-month follow-up, radiographic examination revealed deposition of mineralized tissue in the apical region of the incisors, confirming the occurrence of apexification. In addition, reduction in periapical radiolucency and absence of root resorption (Fig. 4). After eight months, the obturation paste of the right central incisor was removed, and the tooth was filled with gutta-percha and Endomethasone cement (Septodont™, Paris, France). The left incisor remained with the MTA apical plug and obturation. After five years, the teeth presented neither symptomatology, nor root resorption, proving apexification therapy to be successful when performed with different techniques at the same patient, suggesting that both treatments may be equally efficient.

Discussion

The prevalence of pulp necrosis in immature teeth affected by dental luxations is not high (13.6%) when compared to the prevalence of necrosis in teeth with completely formed apexis (63.7%)[2].

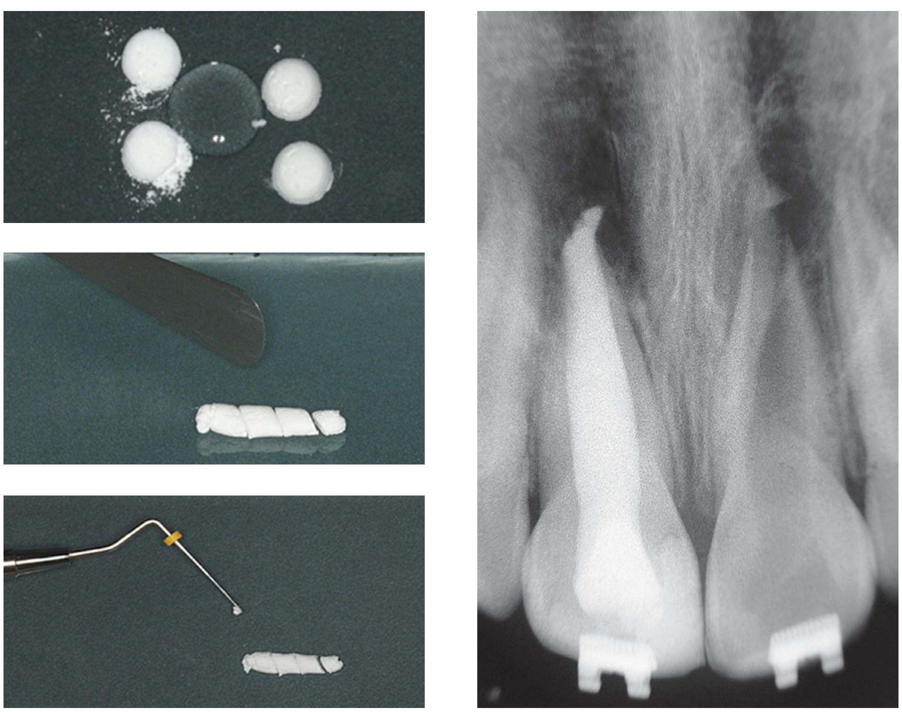

Figure 2. Obturation paste manipulated with calcium hydroxide, 2% chlorhexidine gel and zinc oxide in the proportion of 2:1:2. Radiographic exam after insertion of obturation paste.

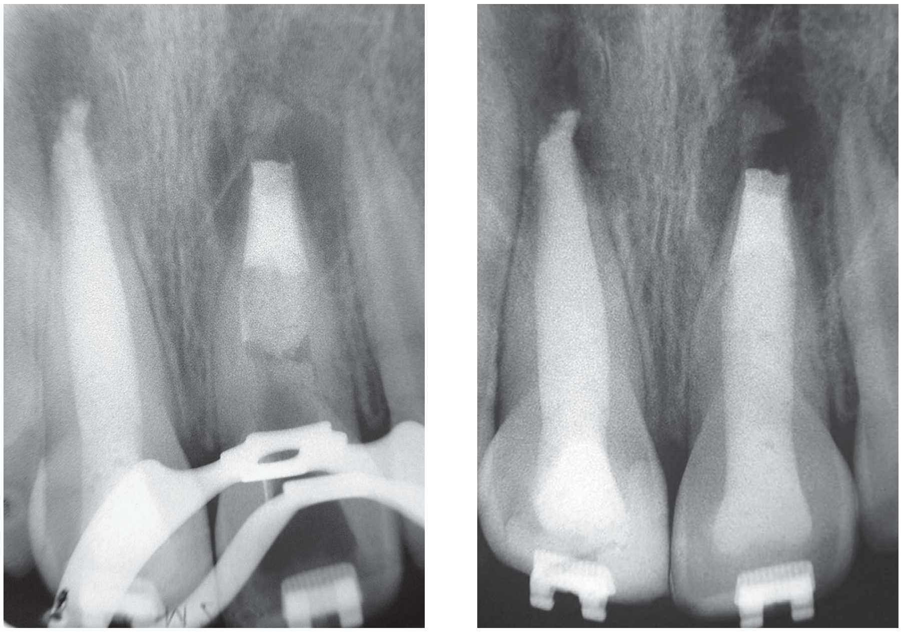

Figure 3. MTA apical plug production.

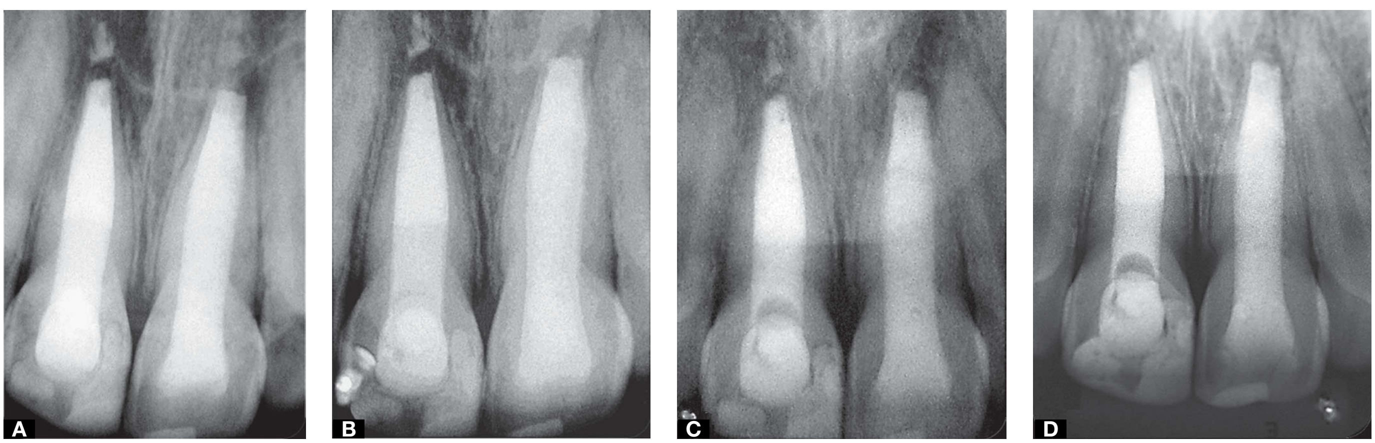

Figure 4. A) 6-month follow-up. **B**) 12-month follow-up. **C**) 4-year follow-up. **D**) 5-year follow-up.

Immature teeth with pulp necrosis require treatments which minimize anatomical difficulties presented by these teeth. Some of these treatments include apexification with periodic changes of intracanal medicament, apexification with MTA apical plug and, recently, pulp revascularization.[14,15] Two of these options were employed in the present case, which proved to be efficient to repair the periapical region and stimulate apical closure.

In the present report, the patient did not seek dental treatment soon after trauma occurred, and such condition increases the probability of sequels such as root resorption and pulp necrosis.[2,16] The evaluated teeth presented no root resorption, which may be explained not only by the effective action of the obturation paste associated with an appropriated coronal sealing that prevented bacteria leakage through dentinal tubules, but also by the fact that the type of trauma was not considered severe.

Many therapeutic protocols have been proposed for the treatment of immature traumatized teeth with the aim of achieving long-term clinical and radiographic success. Previous studies that employed the same obturation paste also demonstrated apical closure and remission of clinical signals and symptoms, besides absence of external inflammatory root resorption.[17,18,19]

In addition, filling the root canal with this paste promoted satisfactory apical sealing, preventing bacterial infiltration and percolation to the periapical region, ensuring good conditions for appropriated repair with deposition of mineralized tissue. In vitro studies carried out with this paste have also demonstrated that this association presents antimicrobial activity and capacity of maintaining root canal pH alkaline.[20,21]

Apexification therapy performed with periodic changes of intracanal medicament may have some disadvantages such as the need for multiple sessions for changes of the intracanal medicament and higher costs. Moreover, some researchers have reported an increase in the susceptibility to root fracture in these teeth.[22,23] In an attempt to improve the limitations of traditional apexification, a therapy including the production of an apical MTA barrier in the open apex tooth has emerged with the advantage of being possible to conclude the treatment in single or double visits, and presenting the same probability of success of conventional apexification.[9] This result was also observed in the present case. Studies have compared the action of calcium hydroxide and MTA, and some of them suggest that MTA may release less calcium ions and hydroxyl, which would reduce the inductive action of apical development.[24,25] In addition, other authors believe that MTA may calcify root canal, which would hinder future intracanal procedures. Furthermore, the high costs and the possibility of promoting crown discoloration are some other disadvantages of MTA treatment[26]. In both teeth reported, no differences were observed in either one of both therapies, which proved to be clinically and radiographically successful, without crown discoloration. Many studies suggest that definitive obturation with gutta-percha and cement should be performed after apical closure induced by calcium hydroxide.[14] However, it has been proposed that this obturation paste composed of calcium hydroxide, 2% chlorhexidine gel and zinc oxide may be capable of promoting appropriate sealing at the root canal, eliminating the need for obturation with gutta-percha.[17,18,19] The cases presented are in accordance with this assertion, since they showed favorable prognosis at clinical and radiographic follow-up. In addition, no paste dissolution was observed even after months. Nevertheless, further studies are necessary to demonstrate clinical and radiographic results with longer follow-ups.

Conclusions

Using the obturation paste composed of 2% chlorhexidine gel, calcium hydroxide and zinc oxide without periodic changes, promoted satisfactory clinical and radiographic results for the traumatized teeth. The apexification procedure carried out with this paste demonstrated similar results to the MTA apical plug procedure, showing advantages such as lower costs and decrease in chairtime. Thus, this obturation paste represents a promising alternative to the treatment of traumatized teeth, especially in immature teeth.

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CBCT-guided endodontic management of maxillary central incisor fused to mesiodens: a case report

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ABSTRACT

Objective: The aim of this case report is to present a predictable and successful solution toward the endodontic and esthetic management of a maxillary central incisor fused to a mesiodens, adopting a conservative and multidisciplinary approach. **Results:** In the present case, cone-beam computed tomography (CBCT) was helpful for endodontic diagnosis and a better understanding of the complex root canal morphology of the fused teeth.

Keywords: Cone-beam computed tomography. Image diagnosis. Fusion. Supernumerary teeth. Endodontics

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Introduction

Rigorous clinical and radiographic examinations are essential for treatment planning. Intraoral periapical radiographs are an important diagnostic tool in Endodontics for assessing the root canal anatomy. However, conventional dental radiographs may not be sufficient to understand the morphology of the root canal system. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy. In addition, they are subjected to geometric distortion of the anatomical structures being imaged[1]. Cone beam computed tomography (CBCT) may overcome these problems. CBCT was specifically designed to produce undistorted three-dimensional images of the maxillofacial skeleton, including the teeth and their surrounding tissues, with an effective radiation dose significantly lower in comparison to conventional computed tomography.[2,3] Potential endodontic applications of CBCT include periapical diagnosis, assessment of root canal morphology and dental trauma.[4-10]

Traumatized teeth may present a clinical challenge with regard to diagnosis, treatment plan and prognosis. Intrusion is a severe injury that affects the development of the tooth germ in children aged 0–2 years[11], which corresponds to the time of calcification of the incisal and middle thirds of the enamel matrix. The effects of trauma on primary teeth vary and include pathological and morphoanatomical changes such as fusion[12]. Fusion is defined as the union between the dentin and/or enamel of two or more separate developing teeth, an uncommon anomaly of the hard dental tissues that might cause clinical problems related to appearance, spacing and periodontal conditions. The incidence of fusion is <1% in the Caucasian population.[13] Pressure or physical force resulting in close contact between two developing tooth buds has been reported as one possible cause.[14] Genetic predisposition and racial predilection have also been reported as contributing factors in the literature.

The degree of fusion depends on the stage of tooth development at the time of fusion, with the union of dentin being the main criterion. Fused teeth might contain separate pulp canals or share a common pulp canal. Fusion might occur between two normal teeth or between a normal tooth and a supernumerary one. Supernumerary teeth in the dentition most probably result from continued proliferation of the permanent or primary dental lamina to form a third tooth germ. The most common supernumerary tooth is the mesiodens, a tooth located between the maxillary central incisors that usually has the form of a cone-shaped crown with a short root. Its incidence in the Caucasian population ranges from 0.15% to 1%, with a 2:1 predilection in males.[13]

This case report describes a multidisciplinary approach for the functional and esthetic rehabilitation of a maxillary central incisor fused to the mesiodens, guided by CBCT for better understanding of the complex root canal morphology and successful management of this rare case.

Case report

A 13-year-old female patient was referred to the College of Dentistry in Piracicaba with an esthetic complaint related to teeth # 7 and # 8 (Figs 1A and B). During the anamnesis, the patient reported being victim of intrusive tooth dislocation when she was 2 years old. The patient had an unsatisfactory composite resin restoration on the buccal aspect of the fused tooth of which original anatomy was modified. Due to the clinical and radiographic anatomical complexity of tooth # 8 (Figs 1C and D) and a non-conclusive pulp thermal test, cone-beam computed tomography (CBCT – iCat / Kavo) was requested.

The tomography suggested fusion of the upper central incisor and a mesiodens, associated with a hyperdensity in the periradicular area (sagittal section – Figs 2B and C). The analysis of sagittal sections showed a sharp palatine depression that was clinically observed after a gingivectomy. The axial sections detected the presence of two separate root canals and confirmed hyperdensity in the periradicular area (Fig 2A). The coronal view showed two separate root canals (Fig 2D). Tridimensional reconstruction provided the necessary clues for atypical access surgery in the buccal-cervical region of the dental crown (Figs 2E and F).

Buccal access and the use of a clinical microscope facilitated the localization of the two root canals with minimal dental structural removal (Fig 3A). Patency was carried out with Hi5 # 15 files (Miltex – USA), and after electronic odontometry the tooth was prepared using Flex-R manual files (Miltex – USA) and Easy

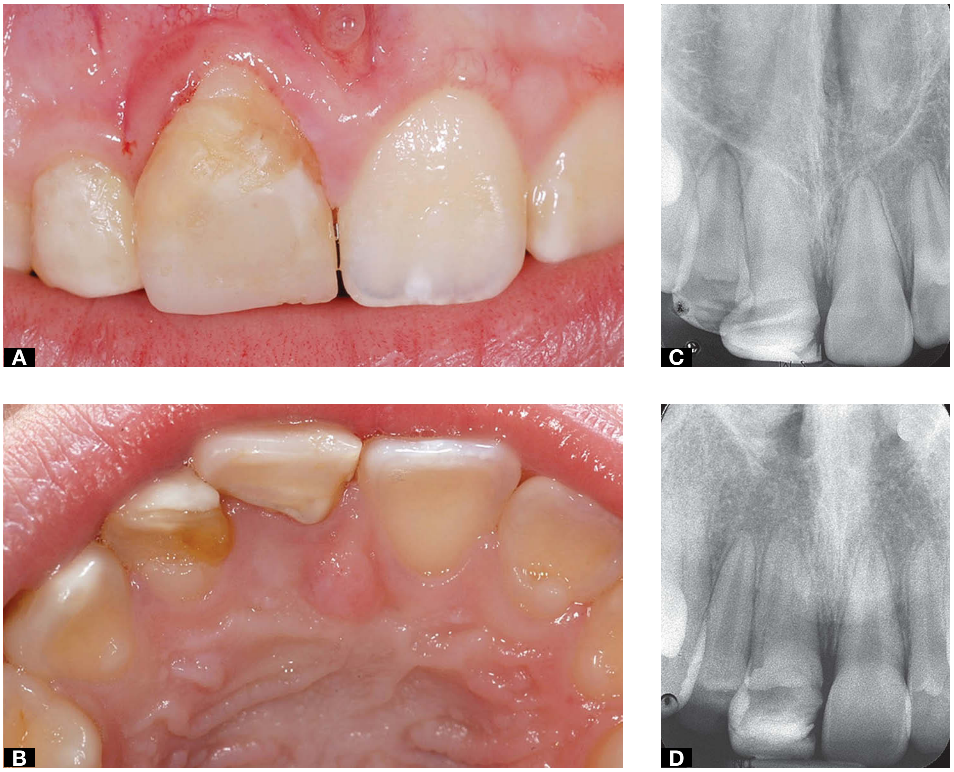

Figure 1. Preoperative photographs: **A**) labial view. **B**) occlusal view. **C**) Preoperative radiograph revealing irregular morphology of tooth 11. **D**) Off-angle angulations.

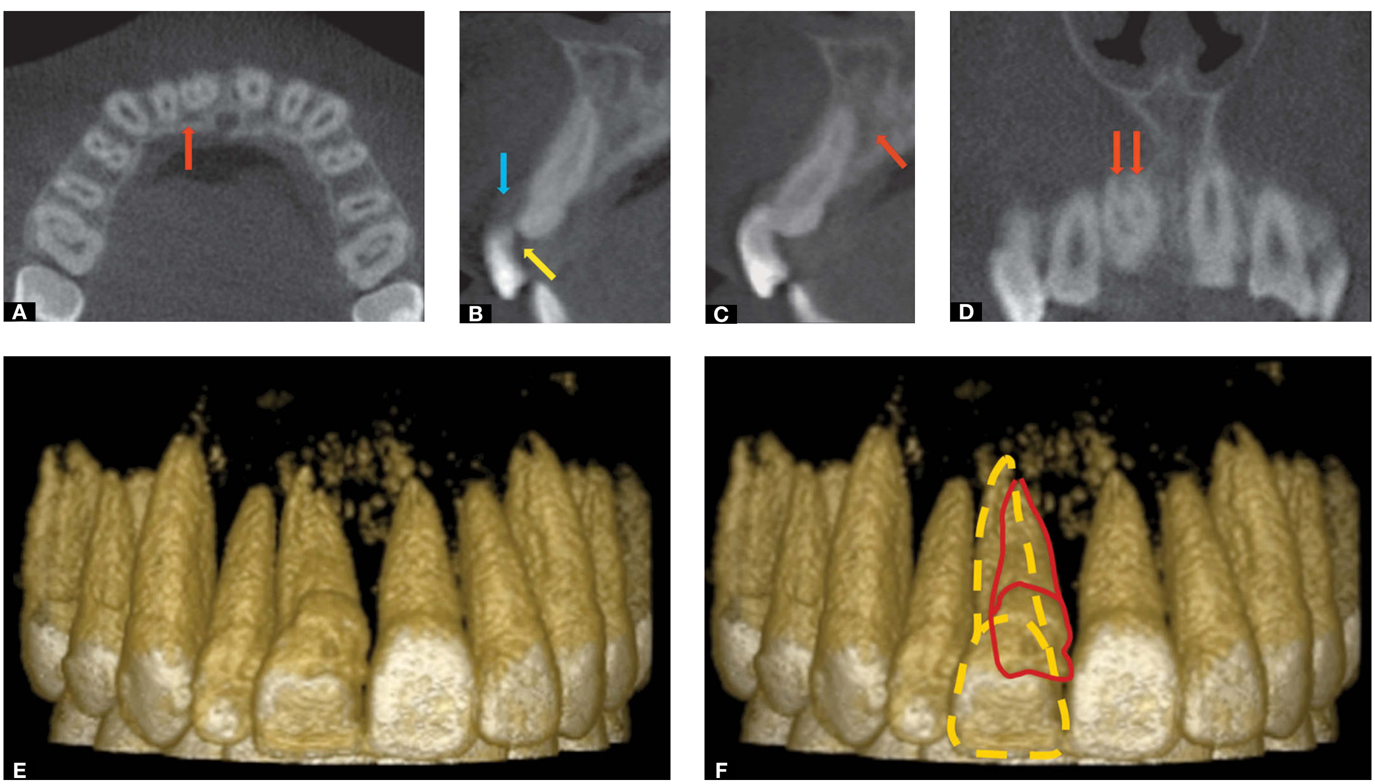

Figure 2. CBCT images of the maxilla. **A**) Axial view reveals the presence of two distinct root canals and periradicular lesion (red arrow). **B, C**) A sagittal view shows a sharp palatine depression (yellow arrow), composite resin restoration (blue arrow) and a periradicular lesion (red arrow). **D**) Coronal section shows two root canals (red arrows). **E, F**) Maxillary 3-D reconstruction shows the maxillary central incisor fused to the mesiodens.

ProDesign rotary instruments (Master Inc. – Brazil). Chlorhexidine gel (Essential Farma-Brazil) was used as an auxiliary chemical substance while saline solution was used as the irrigant (0.9% sodium chloride – Fresenius Kabi/Brazil). 17% EDTA (Dinâmica – Brazil) was used to remove the smear layer. Treatment was carried out during two appointments (Fig 3B), and obturation was performed with thermoplasticized gutta-percha and Endomethasone N sealer (Septodont – France) via the continuous wave technique (Obtura III Max Spartan Endodontics – USA).

Once the endodontic treatment had been completed, the tooth was provisionally restored with direct composite resin (Fig 3D) and the patient underwent root coverage procedures (Fig 3C).

Discussion

Intrusive injuries are the most common type of trauma during primary dentition[15] and require the dentist to carefully examine not only the damaged tooth, but also possible sequelae to the permanent tooth germ. Traumatic tooth injuries have been reported to occur mainly during early infancy between 2 and 3 years old.[13]

Fused teeth represent a striking clinical manifestation of the differentiation and morphogenetic processes of tooth development. Clinically, it might be difficult to differentiate between fusion and gemination when a supernumerary tooth is fused with a permanent tooth. However, with regard to treatment, the differentiation between fusion and gemination may not be critically important. Mader[16] has discussed the difficulty in differentiating fusion and gemination in adult dentition. He suggested that all succedaneous teeth that are joined or fused by dentin be referred to as fused teeth. Fusion of permanent and supernumerary teeth occurs less frequently than fusion between permanent teeth. Supernumerary teeth develop from a third bud arising from the dental lamina near the permanent tooth bud, or possibly from splitting of

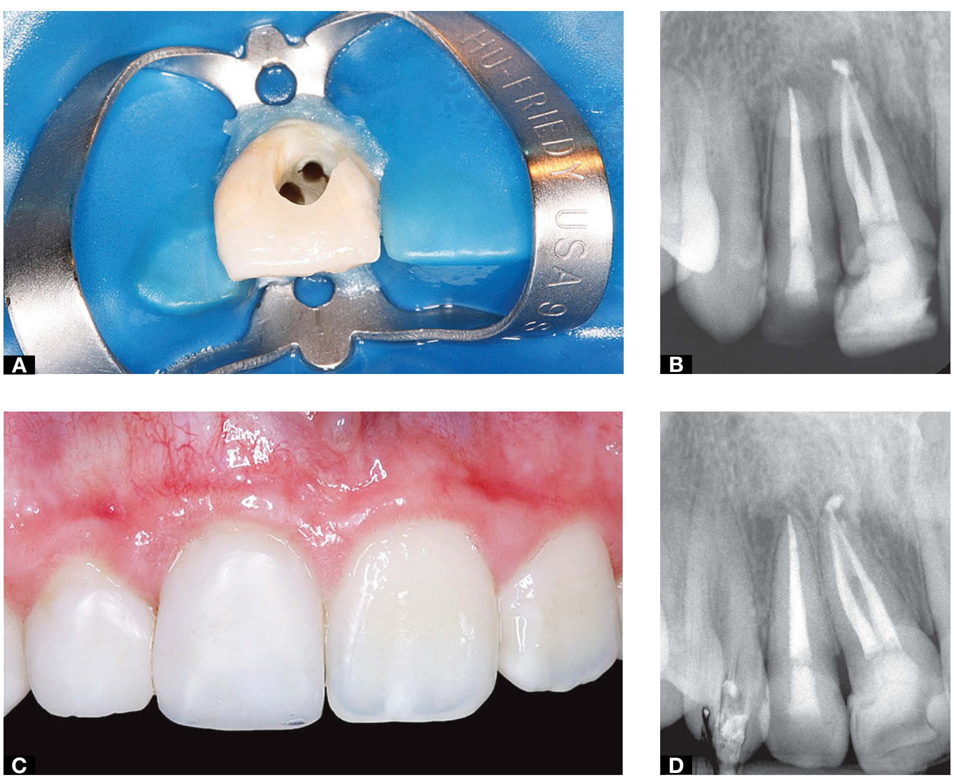

Figure 3. A) Endodontic buccal access. **B**) Periapical radiograph after canal obturation. **C**) Periodontal root coverage procedures and provisional esthetic rehabilitation of tooth 11. **D**) Periapical radiograph after provisional restoration with direct composite resin.

the permanent bud itself.[14] Fusion between supernumerary and permanent teeth occurs less frequently than fusion between other types of teeth. As far as the etiology of fusion is concerned, many theories have been proposed, including genetic factors, local metabolic interference during tooth bud differentiation as well as traumatic and inflammatory causes.[17,18]

Fusion can cause esthetic and functional problems, such as carious lesions in the grooves, particularly in the fusion zone; periodontal problems associated with the grooves that extend subgingivally; asymmetries when fusion occurs in the anterior segment; malocclusions, especially when supernumeraries are involved[18], and endodontic complications, which are frequent because of the reduced thickness of the enamel and dentin[19]. The morphology of fused teeth varies, and complex forms with separated or fused coronal pulp chambers may occur. Even separated chambers can meet in the radicular area or can remain separated.

Radiographic examinations are essential for diagnosis and treatment planning in endodontic practice. Conventional or digital periapical radiographs are often used by dentists. However, these techniques have limited value for diagnosis because the 2D images have several limitations, despite the remarkable improvements in digital radiography.[1,20] Although the use of different horizontal and/or vertical angulations[21] may provide additional information about the area of interest, sometimes this procedure may not be good enough.[22,23] Individual factors such as bone density, morphological variations, difficulty in parallel acquisitions (distortions), poor contrast, and superimposition of anatomical structures might lead to inadequate image assessment.[2,24]

In recent years, there has been a significant increase in interest in this kind of resource by clinicians, especially in more complex clinical cases, such as those involving morphoanatomic changes, in which diagnosis can be very challenging. Therefore, there is a growing need for more sophisticated radiographic tools that may provide accurate 3D information in both pre- and post-treatment assessment.[25,26]

It is important to know and communicate the dose and risks associated with CBCT in children. It is critical for healthcare providers to weigh the potential benefits of diagnostic information against the expense and risk of the imaging procedure. Some reports have suggested that CBCT examination doses are equivalent to a few panoramic exposures.[27]

In this specific case, CBCT was helpful during the diagnosis and decision-making processes for therapy. The CBCT images confirmed hyperdensity in the periradicular area and the complex morphology of the root canal system of the maxillary central incisor fused to the mesiodens. This technique showed the potential to visualize the topography of root canals and this information was invaluable in diagnosis and treatment planning. Palatal endodontic access is the most commonly used access in all situations, but due to the presence of a sharp palatine depression and composite restoration, endodontic access was achieved via the buccal surface, thus facilitating access to the root canals and minimizing the loss of healthy dental structure.

After the endodontic treatment was completed, the tooth was provisionally restored with direct composite resin and the patient was subjected to permanent esthetic rehabilitation.

Conclusion

Complex situations may be really challenging with regard to diagnosis and decision-making, thus, requiring additional resources. In this specific case, CBCT played an important role in the management of endodontic therapy leading to a predictable result.

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The use of MTA in the treatment of cervical root perforation: case report

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ABSTRACT

Objective: The aim of this study was to report the treatment of a tooth with cervical root perforation caused during endodontic treatment. **Methods:** The patient attended the endodontist's office with painful symptoms resulting from a cervical root perforation exposed to the oral cavity. The endodontic treatment was performed in multiple sessions using the dressing with calcium hydroxide and propylene glycol, in order to aid the decontamination of the root canal and the perforation. The root perforation was sealed with MTA because this material is capable of forming mineralized tissue due to its sealing ability, biocompatibility and alkalinity. In addition, the humidity present in the periodontal tissues can provide the necessary means to adapt the MTA on the walls of the perforation and its setting expansion, justifying its use in this case as it is a case of cervical perforation, a difficult site to control humidity. **Conclusion:** The authors concluded that MTA is an excellent material for sealing cervical root perforation.

Keywords: Root perforation. MTA. Calcium hydroxide.

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Introduction

Root perforation is an accident in which an artificial opening is made, communicating the pulp chamber, the root canals and the periapical tissues. These accidents usually occur due to iatrogenic causes including lack of knowledge of dental anatomy, calcification of the coronary and cervical thirds, failure in radiographic analysis, accentuated and misdirected abrasion as well as lack of pre bending of files in case of curved canals. Pathologies such as cavities, internal and external resorption are factors that can also lead to such accidents.

Among the factors that affect root perforation prognosis are the location (cervical, middle and apical thirds), the extent, presence or absence of periodontal pockets, the time between perforation and treatment, biological compatibility and sealing ability of the filling material.[1]

The faster the perforation is sealed, the more favorable is the prognosis, especially when it involves the cervical third and the pulp chamber. In this site, because it is closer to the oral cavity, bacterial contamination becomes easier and may establish an infection at the site, resulting in tooth loss if the repair is not quickly performed. However, for the middle and apical third of the root, immediate sealing is not necessary if the area is adequately protected from bacterial infiltration.[2]

Perforation can be diagnosed not only by sudden onset of bleeding in the root canal or its persistence after the pulp tissue was removed, but also by clinical exploration, radiographic features showing the file in the periodontium, examination of lateral lesion and pin placed outside the long axis of the root.[1]

For proper treatment, the perforation must be sealed with a biocompatible material, capable of producing a good seal with good physical properties, radiopaque, non-resorbable, easy to use and capable of promoting osteogenesis and cementogenesis.[3]

Given the quality and limitations of the materials routinely used for the sealing of dental perforations, other materials with characteristics that are similar to the ideal sealing have been sought. With the purpose of filling these gaps and based on the technological evolution of new materials, emerged in the 90s at the University of Loma Linda, California - USA, headed by Professor Torabinejad, a group that developed a new cement called Mineral Trioxide Aggregate (MTA).

Since then, several studies have been conducted with this material, analyzing its biocompatibility,[4,5,6,7] its physical, chemical and antimicrobial[7] properties, cytotoxicity,[8] mutagenicity,[9] pulp capping,[10,11] analysis of its sealing ability in retrograde fillings,[12,13] marginal adaptation in Scanning Electron Microscopy (SEM), and their use in root perforations.[14-17]

Still on the applications of MTA, it is also indicated in cases of dental pulp conservative treatment,[10,15,18] apixigenesis and apexification treatments[19] as sealing material to repair perforations resulting from communicating internal and external resorptions,[20] as filling material for root canals of deciduous teeth[21] and permanent teeth,[4,15,22] as repair material for vertical and horizontal root fractures[20], and as apical plug.

The ability of MTA to form mineralized tissue can be attributed to its sealing ability, biocompatibility, alkalinity or even other properties associated with it.[20]

The aim of the present study is to report the treatment of a tooth with cervical radicular perforation caused during endodontic treatment and sealed with MTA. In addition, it aims at highlighting the advantages and disadvantages of employing and including this material in the sealing of the perforation and also in the maintenance of the dental element in the oral cavity, performing its esthetic and masticatory functions.

Case report

A 19-year-old patient was referred for endodontic treatment of #43, in June, 2010. During the anamnesis, we found that there was no history of systemic disease, but the patient reported being allergic to Paracetamol. With regard to her dental history, the patient reported being under orthodontic treatment, and that, due to a leakage in the restoration of #43, the patient was referred to a Dental Surgeon (DS) in order to have the restoration exchanged. When the dentist started the restorative procedure, he informed the patient that, due to the depth of the restoration, there had been pulp exposure and, as a result, endodontic treatment would be necessary. After treatment had started, a perforation in the lateral root occurred in an attempt to find the root canal. From this time on, the patient was referred to an endodontist who would seal the perforation and perform root canal treatment.

During the intraoral clinical examination, it was observed that #43 tooth presented open access cavity without temporary restoration or endodontic dressing, and with remaining carious tissue. In addition, it showed sensitivity to vertical and horizontal percussion and absence of edema, sinus and tooth mobility. As for the thermic tests performed to check pulpal sensitivity, the responses were also negative.

The periapical intraoral radiographic revealed excessive abrasion in the opening and in the cervical portion. Mesially, it was possible to see the path of the perforation. The image also had a radiopaque, non-root, suggestive point indicating some type of restorative material (Fig 1A). After all tests and clinical examinations had been performed, the patient was diagnosed with pulp necrosis.

The patient was informed about the different treatment options, for both perforation and root canal. She chose to undergo endodontic treatment with closure of perforation being performed via the canal, preferably without surgery and application of intracanal medication. It was requested that the orthodontist discontinued the application of orthodontic force in this dental element until the end of the endodontic treatment.

From this moment on, the endodontic treatment began, with local anesthesia and installation of rubber dam. Improvements in the access cavity and removal of carious tissue were carried out with a low-speed bur. Biomechanical preparation of the root canal was performed with manual endodontic files and irrigated with sodium hypochlorite at 2.5%. During the biomechanical preparation of the root canal, odontometry confirmation of the length of work and the apical patency were carried out (Fig 1B). After biomechanical preparation of the root canal, it was dried with sterile paper points and then flooded with trisodium EDTA at 17% for 3 minutes, with manual shaking for better cleaning of the canal. After this period, the EDTA was removed and new irrigation was performed with sodium hypochlorite, followed by further drying of the root canal. Afterwards, a calcium-hydroxide-based intracanal medication with propylene glycol was applied in order to help in the decontamination of the root canal and of the perforation.

After 15 days, the intracanal medication was removed with the purpose of closing the perforation. The material chosen for final closure of the perforation was the white MTA-Angelus, manipulated according to the manufacturer's instructions. The MTA was inserted with Paiva pressers and its final laying was carried out with cotton moistened with distilled water. The MTA was inserted into the perforation with the aid of a microscope and without exerting too much pressure in order to prevent it from extravasating to the periodontal ligament.

An intraoral periapical radiograph was performed to check the MTA laying in the perforation. Radiographically, it was observed that the MTA did not extravasate to the periodontal ligament, momentarily excluding the possibility of surgical intervention for the case (Fig 1C).

The calcium-hydroxide-based intracanal medication was applied for a period of three months and replaced every 45 days. After a period of four months (October, 2010), the root canal was filled with gutta-percha point (Fig 2A) and, afterwards, with calcium- hydroxide-based cement and secondary gutta-percha points by lateral condensation followed by means of the vertical condensation technique (Fig 2B). The pulp chamber was cleaned and temporarily sealed with sterile cotton pellet and Coltosol. The patient was asked to seek his dentist in order to request that definitive restorative procedures were performed.

Figure 2B shows the root canal filling, closure of perforation with MTA and, in the mesial apical portion, a secondary canal filling which was possible to be seen in Figure 2A.

After 10 months of endodontic treatment, the patient was asked to have the first follow up radiograph. In the intraoral periapical radiograph, it was possible to observe the integrity of the periapical region with continuous lamina dura clinically indicating periapical repair (Fig 2C).

Discussion

The success of nonsurgical root perforation procedures is directly related to the severity of the initial damage caused to the periodontal tissue, the size and location of the perforation, sealing ability and biocompatibility of the filling material, and the presence or absence of bacterial contamination.[23]

In this case report, the cervical perforation was not sealed immediately after it had occurred, as suggested by Sinai[2] and Pitt Ford et al.[13] The authors claim that the prognosis is much more favorable in

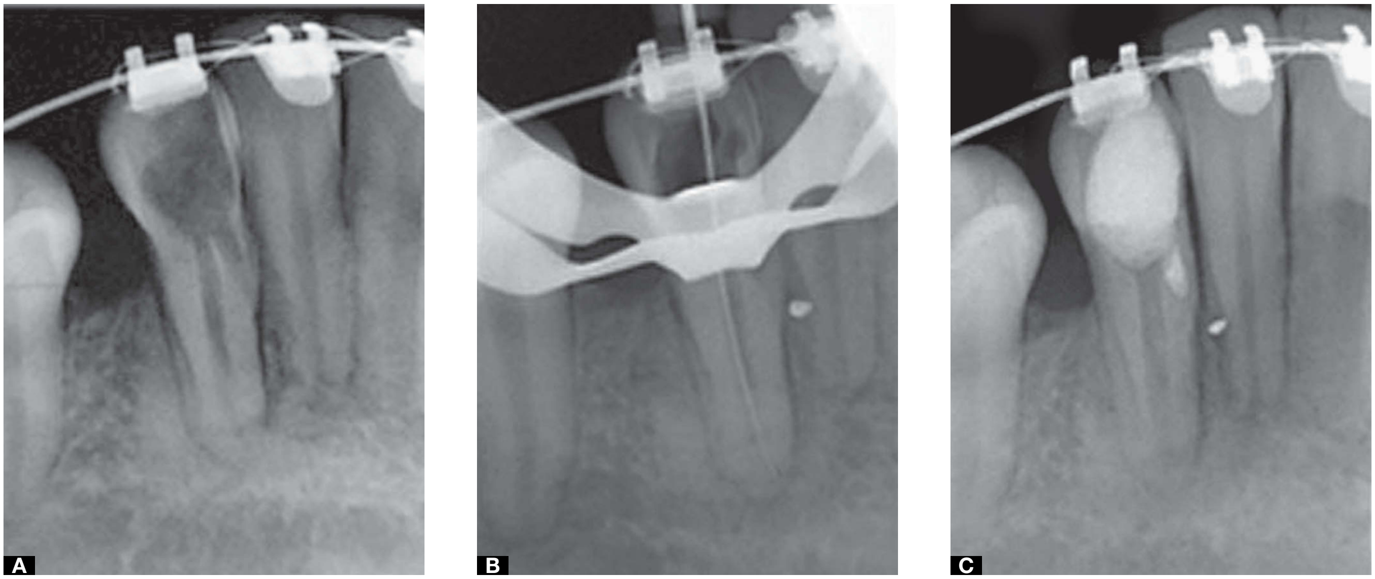

Figure 1. A) Initial radiograph: Excessive coronary abrasion, perforation path to mesial and radiopaque extraradicular point suggesting restorative material. **B**) Confirmation of the working length. **C**) Settling of the MTA in the perforation.

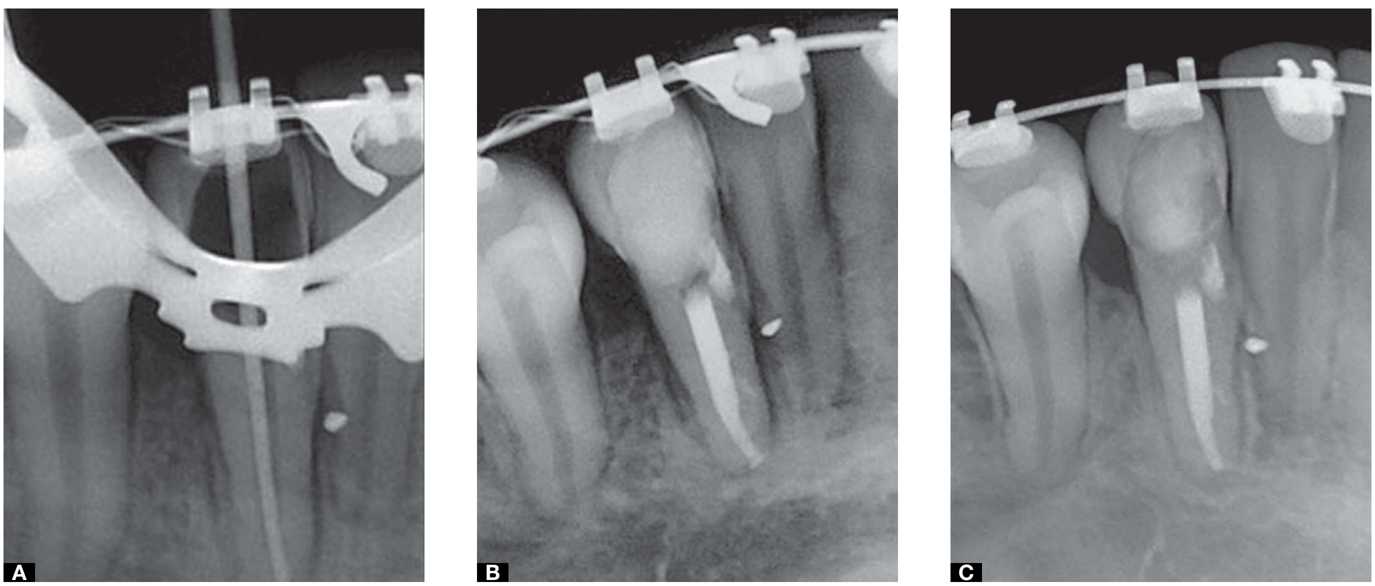

Figure 2. A) Master cone and presence of accessory mesial canal. **B**) Final radiograph. **C**) 10-month follow up.

this case due to lack of bacterial contamination. There was the option of treating the perforation and the root canal by means of exchanging the intracanal medication and irrigating the site with sodium hypochlorite, since the pulp chamber and the root canal were exposed to the oral cavity. Thus, based on the studies carried out by Estrela and Estrela[1] who claim that fighting bacterial infection through copious irrigation with sodium hypochlorite solution, due to its organic material and antibacterial solvent properties, completes the sanitation promoted by biomechanical preparation. Applying the calcium-hydroxide-based intracanal medication with propylene glycol, between sessions, in order to supplement disinfection and/or deposition of mineralized tissue through its antiseptic effect, bactericidal action and high pH, corroborate Holland et al[24], Holland et al.[25,26]

Estrela and Estrela[1] have stated that there is inactivation of enzymes intra and extra-cellular due to the release of hydroxyl ions, which hinders bacterial survival.

However, studies carried out by Felippe et al[27] claim that there is no advantage in exchanging the calcium hydroxide paste when treating contaminated canals and pulpless teeth.

The choice of propylene glycol as a carrier for the calcium hydroxide is based on studies carried out by O'Neil[28] which demonstrate that the substance has a great capacity to solubilize organic materials. Additionally, Seidenfeld and Hanzlik[29] claim that the propylene glycol has approximately the same density of water and causes no demonstrable cumulative effect.

The propylene glycol antimicrobial activity for systemic use has been studied by Olitzky[30] who reported that concentrated solutions of this compound have demonstrated germicidal efficiency and its use as a carrier can work in the prevention or treatment of bacterial infection. Walkevar, Bhat;[31] Thomas, Kotian and Bath[32] reported that in addition to the fact that propylene glycol has been well recognized as a carrier for medications, it has also been considered to be less cytotoxic than other carriers commonly used for intracanal medications. Moreover, it presents antibacterial properties highly beneficial in endodontic treatment, although the results found by Nakayama and Safavi[33] showed that calcium hydroxide does not dissociate from propylene glycol because it needs water to be dissociated.

In order to remove the smear layer, the EDTA at 17% was used for 3 minutes before the intracanal medication was applied in all sessions as well as before final filling of the root canal, since several studies have demonstrated that removal is achieved with the use of this drug.[34,35]

After 15 days, the root perforation closure was performed with MTA because, according to Torabinejad and Chivian,[20] this material is capable of forming mineralized tissue due to its sealing ability, biocompatibility, and alkalinity. Furthermore, according to Sluyk et al[17] the humidity present in periodontal tissues can provide the necessary means for adaptation of MTA on the walls of the perforation and also for setting expansion,[20,36] which explains its use in this case report, a case of cervical perforation in which humidity is difficult to control.

In this case, MTA was also used because its radiopacity is superior to that of the dentin and bone tissue, the IRM, Super Eba and gutta-percha, thus, providing diagnostic observation, which makes it the material of choice.[6] Moreover, studies carried out by Holland et al,[26] of which aim was to explain the mechanism of inducing mineral formation of MTA, found that MTA without calcium hydroxide in its composition is capable of forming mineralized tissue due to the presence of calcium oxide which forms calcium hydroxide when reacted with periapical tissues.

The authors of this study agree with Marion[37] about the difficulties of working with MTA and aqueous carrier (distilled water) together, due to its initial setting time and also its difficulty to be inserted, because when MTA is handled with this carrier, it seems to be little bondable and sandy.

According to Namazikhah,[38] it is important to emphasize that when the MTA is used in environments with inflammation, its physicochemical properties may suffer some interferences, causing its acid pH to prevent the MTA setting and reduce its strength and hardness. However, once the factors that initiate or perpetuate the inflammatory process have been removed, as in the case presented, the environment is able to return to normality within a short period of time.

Despite the advantages and limitations of the MTA, which have been previously mentioned, studies carried out by Balto,[39] Holland et al,[11] Juárez Broon et al,[3] showed that when analyzing the biological behavior of materials used in sealing root perforations, the MTA has shown similar or less toxic behavior than the others. Therefore, MTA proves to have great ability of repair and the aforementioned information explains its use in the treatment of cervical root perforations.

Conclusion

After being clinically applied, the MTA proved to be effective as a filling material of cervical root perforation, since after a 10-month follow-up, the tooth continued to perform its primary functions, esthetic and masticatory, in the oral cavity.

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Book chapter

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Book chapter with editor

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1. Registration of clinical trials

Clinical trials are among the best evidence for clinical decision making. To be considered a clinical trial a research project must involve patients and be prospective. Such patients must be subjected to clinical or drug intervention with the purpose of comparing cause and effect between the groups under study and, potentially, the intervention should somehow exert an impact on the health of those involved.

According to the World Health Organization (WHO), clinical trials and randomized controlled clinical trials should be reported and registered in advance.

Registration of these trials has been proposed in order to (a) identify all clinical trials underway and their results since not all are published in scientific journals; (b) preserve the health of individuals who join the study as patients and (c) boost communication and cooperation between research institutions and with other stakeholders from society at large interested in a particular subject. Additionally, registration helps to expose the gaps in existing knowledge in different areas as well as disclose the trends and experts in a given field of study.

In acknowledging the importance of these initiatives and so that Latin American and Caribbean journals may comply with international recommendations and standards, BIREME recommends that the editors of scientific health journals indexed in the Scientific Electronic Library Online (SciELO) and LILACS (Latin American and Caribbean Center on Health Sciences) make public these requirements and their context. Similarly to MEDLINE, specific fields have been included in LILACS and SciELO for clinical trial registration numbers of articles published in health journals.

At the same time, the International Committee of Medical Journal Editors (ICMJE) has suggested that editors of scientific journals require authors to produce a registration number at the time of paper submission. Registration of clinical trials can be performed in one of the Clinical Trial Registers validated by WHO and ICMJE, whose addresses are available at the ICMJE website. To be validated, the Clinical Trial Registers must follow a set of criteria established by WHO.

2. Portal for promoting and registering clinical trials

With the purpose of providing greater visibility to validated Clinical Trial Registers, WHO launched its Clinical Trial Search Portal (http://www.who.int/ictrp/network/en/index.html), an interface that allows simultaneous searches in a number of databases. Searches on this portal can be carried out by entering words, clinical trial titles or identification number. The results show all the existing clinical trials at different stages of implementation with links to their full description in the respective Primary Clinical Trials Register.

The quality of the information available on this portal is guaranteed by the producers of the Clinical Trial Registers that form part of the network recently established by WHO, i.e., WHO Network of Collaborating Clinical Trial Registers. This network will enable interaction between the producers of the Clinical Trial Registers to define best practices and quality control. Primary registration of clinical trials can be performed at the following websites: www.actr.org.au (Australian Clinical Trials Registry), www.clinicaltrials.gov and http://isrctn.org (International Standard Randomized Controlled Trial Number Register (ISRCTN). The creation of national registers is underway and, as far as possible, the registered clinical trials will be forwarded to those recommended by WHO.

WHO proposes that as a minimum requirement the following information be registered for each trial. A unique identification number, date of trial registration, secondary identities, sources of funding and material support, the main sponsor, other sponsors, contact for public queries, contact for scientific queries, public title of the study, scientific title, countries of recruitment, health problems studied, interventions, inclusion and exclusion criteria, study type, date of the first volunteer recruitment, sample size goal, recruitment status and primary and secondary result measurements.

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Consequently, authors are hereby recommended to register their clinical trials prior to trial implementation.

Yours sincerely,

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