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An *in vitro* evaluation of the degree of pulp tissue dissolution through different root canal irrigation protocols

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Abstract

Aim: The aim of this study is to evaluate *in vitro*, using artificial lateral canals, the rate of dissolution of the pulp tissue through different protocols of canal irrigation. **Materials and Methods:** One hundred artificial canals provided with lateral canals have been used. Each lateral canal was filled with pulp tissue and calibrated to 0.002 mg. All canals were irrigated using five different protocols. Five groups have been used for the experiment: Group A, distilled water (control); Group B, preheated NaOCl; Group C, NaOCl heated inside the canal; Group D, NaOCl ultrasonically activated; and Group E, NaOCl heated inside the canal with ultrasonic activation. All samples were weighed through professional microbalance in three different phases: before insertion of the pulp tissue into the lateral canal, after insertion of the pulp tissue and, finally, after different protocols of irrigation. A statistical analysis with Kruskal–Wallis test and Mann–Whitney test was performed. **Results:** The partial dissolution of the pulp tissue inside the artificial lateral canal occurs only using the protocol with NaOCl heated inside the canal with ultrasonic activation. Other irrigation protocols are not able to dissolve the pulp tissue. **Discussion and Conclusions:** The main objective of endodontic therapy is the removal of damaged tissues and bacteria. Modern literature highlights that it is impossible to remove all the pulp tissues and bacteria from the whole endodontic space. Hence, to achieve excellence and get positive results in the short and long term, it is necessary to use techniques and technologies that may increase the degree of root canal detersion.

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Full Text

Introduction

The goal of root canal treatment consists of the complete removal of all the damaged tissues and bacteria and their toxins, from the complex radicular system.[1] The endodontic space should not be considered in a single dimension, the main canal, but it must be considered as a complex of structures and ramifications on three dimensions [Figure 1] and [Figure 2].[2], [3]{Figure 1}{Figure 2}

In addition to the main canal, there are several configurations organized to complete it: lateral canals, loops, isthmus, delta, and ramifications. Lateral canals could be of different sizes and leave from the main canal at different heights. The loops are small extensions that are detached from the main canal and then reconnected to the same.[4] The isthmuses are the connections between the two main canals. The apical delta is a doubling of the main canal at the level of the apical third. The ramifications are microscopic extensions of the main canal and they can be positioned at any height. This complexity, sometimes, may be inside the main canal.[5],[6]

These spaces, well known in the literature, cannot be reached by common manual and rotary files. During the step of mechanical shaping, some of these anatomies are removed, but the remaining hidden areas remain untouched, so residual biofilms can accumulate and act as a potential source of infection leading to treatment failure. In addition to these endodontic anatomies, another challenge in the root canal cleaning are the dentinal tubules, microscopic structures easily inhabitant by bacteria.[7],[8]

Following chemomechanical preparation, a smear layer 1–2-mm-thick is formed and it covers the walls of the root canal. It consists of inorganic dentin debris and organic substances containing fragments of odontoblastic processes, microorganisms, their byproducts, and necrotic pulp tissues.[9] This smear layer is responsible for harboring remnants of necrotic pulp tissues along with biofilms.[10],[11]

In addition, the smear layer could inhibit penetration of the root canal irrigation solutions and medicaments into dentinal tubules. Moreover, it has been betokened that abstraction of the smear layer may increase the bond strength of filling material to canal walls.[12]

Finally, during endodontic treatments, inside the root canal, gaseous blocks could be formed, defined vapor lock, which can compromise the detersion phase, if not removed. This can occur because these gaseous blocks can prevent the contact of irrigating with tissues and/or bacteria.[9],[13]

The irrigation of the root canal is an essential procedure in the endodontic treatment for the abstraction of the smear layer. Currently, the alternate utilization of sodium hypochlorite and ethylenediaminetetraacetic acid (EDTA) irrigants is recommended to abstract both the inorganic and organic components of the smear layer.

The action mechanism of sodium hypochlorite is well known and well-known are its antibacterial action characteristics and dissolution of vital and necrotic organic tissues, although its action is reduced on vital tissues.[8],[14]

The traditional irrigation, with a simple or endodontic needle, does not allow irrigant to reach the three-dimensional anatomy. Through activation, on the other hand, the irrigants are able to flow in the different lateral anatomies [Figure 3].[2],[3]{Figure 3}

There are several techniques of irrigant activation, the most commonly used techniques are the subsonic sonic and ultrasonic activation, and preheating of the irrigant at 50°C. Recently, an improved technique to activate and maximize the characteristics of sodium hypochlorite has been proposed, the controlled heating technique, directly inside the root canal.

Iandolo et al. showed how sodium hypochlorite preheated to 50°C, 60°C, and 70°C and inserted into the root canal stabilizes at body temperature in a few seconds and in the apical and medium third never exceeds 40°C. Sodium hypochlorite at boiling temperature is capable of breaking up the pulp tissue at a speed of about 210 times higher compared to the same irrigant at room temperature.[15]

The aim of this study is to evaluate in vitro, using artificial lateral canals, the rate of dissolution of the pulp tissue through different protocols of canal irrigation.

Materials and Methods

One hundred artificial canals with lateral canals were used (Thermafil blocks, Dentsply Maillefer). Each main canal was equipped with two lateral canals (coronal third and middle third). For the test, the lateral canal located in the middle third of the main canal to 13 mm from the surface of the resin block has been used.

Each lateral canal had three cylindrical sections, starting from the main canal measurements as follows: the inner one had a diameter of 0.5 mm and a length of 0.2 mm, the central section had a diameter of 0.7 mm and a length of 1 mm, and the final part had a diameter of 1 mm and a length of 2 mm. The main canal length was 18 mm from the surface of the resin block. The diameter of the endpoint of the main canal was 0.3 mm with a taper of 4%. The curvature of the main canal was 25° following Schneider's method.

The patency of all the main and side canals has been verified using a K-File 0.15.

Twenty-five teeth have been extracted and selected for this study, 12 vital molars and 13 vital lower premolars, with severe periodontal problems.

Immediately after extraction, with a lab diamond disc, dental crown has been removed and with micro forceps the dental pulp has been withdrawn.

All the teeth pulp, through a microblade, was cut into small pieces and calibrated by professional scale with a resolution of 0.001 mg (Pro Explorer Ohaus) to 0.002 mg.

All resin blocks were first weighed empty (Pro Ohaus Explorer) and the measurement was recorded. Then, through ×20 stereomicroscope, each small part of dental pulp, calibrated to 0002 mg, was inserted with the aid of a plugger of 0.40 mm in diameter, in the lateral canals placed in the middle third of the resin blocks [Figure 4].{Figure 4}

In each block, there are 4 main canals and 2 lateral canals for each primary canal, so a pulp calibrated to 0002 mg has been inserted. The pulp in the central and external part of the lateral has been inserted.

After each insertion of calibrated dental pulp, the resin blocks, sealed with wax in their output to simulate a closed system, were again weighed and the measurements recorded [Figure 5].{Figure 5}

One hundred resin blocks were divided into five groups, each group included 20 resin blocks with 10 canals: Group A was composed by saline solution (control group), Group B 6% NaOCl (Chlor-xtra, Vista Dental) preheated to 50°C, Group C 6% NaOCl (Chlor-xtra, Vista Dental) heated at a controlled temperature inside the main canal (180°C), Group D 6% NaOCl (Chlor-xtra, Vista Dental) ultrasonically activated, and Group E 6% NaOCl (Chlor-xtra, Vista Dental) heated at a controlled temperature inside the main canal (180°C) and ultrasonically activated.

For each block, the irrigation protocol was 20 min long.

For all groups, the main canal was irrigated by an endodontic needle (Vista probe 0.30 mm). The needle was positioned at 2 mm from the end of the main canal. The main and the lateral canal were sealed with wax to simulate a closed system.

For Group A, 12 cc of saline solution has been used, and the solution was renewed every 2 min.

For Group B, 12 cc of 6% NaOCl preheated to 50°C has been used, and the solution was renewed every 1.5 min.

For Group C, 12 cc of 6% NaOCl heated at a controlled temperature has been used. For the intracanal heating, a heat source (System-B) has been used set to 180°C. The heat carrier used was the tip X-Fine 30/04 lead at 3 mm from the end of the main canal. Each activation cycle (8 s) was alternated with 10 s of rest. After each activation cycle, the NaOCl was renewed. Ten cycles were carried out. During the activation cycle by heating, X-Fine tip performed movements of up and down of about 2–3 mm. After 10 cycles of activation by heating, NaOCl solution was renewed every 1.5 min.

For Group D, 12 cc of 6% NaOCl ultrasonically activated has been used.

The ultrasonic activation (EndoUltra, Vista Dental) was carried out for 30 s for 10 cycles. The tip of the ultrasonic source was positioned 2 mm from the end of the main canal during the activation cycle. The solution was renewed every 1.5 min.

For Group E, 12 cc of 6% NaOCl heated at a controlled temperature and ultrasonically activated has been used. For the intracanal heating, a heat source (System-B) has been set to 180°C. The heat carrier used was the tip X-Fine 30/04 lead at 3 mm from the end of the main canal. Each activation cycle (8 s) was alternated with 30 s of ultrasonic activation (EndoUltra, Vista Dental). The tip of the ultrasonic source was positioned 2 mm from the end of the main canal during the activation cycle. After each cycle of activation (heat + ultrasound), NaOCl was renewed. Ten cycles were carried out. During the activation cycle by heating, X-Fine tip performed movements of up and down of about 2–3 mm. The solution was renewed every 1.5 min.

For all the groups, after 20 min, both the main and the empty lateral canal located in the coronal third were carefully dried with paper cones and the resin block was definitively weighed (Pro Explorer Ohaus).

Through all measurements by subtraction, dissolved pulp tissue was calculated.

Mean and standard deviation were calculated [Table 1]. All data were recorded and subjected to statistical evaluation with Kruskal–Wallis and Mann–Whitney tests. Statistical significance

was set at P < 0.05.{Table 1}

Results

The blocks were weighed into three different phases: empty block (T1), block with 0.002 mg of pulp tissue (T2), and block after irrigation protocol and drying (T3).

Mean and standard deviation showed how only Group E with 6% sodium hypochlorite heated at a controlled temperature and ultrasonically activated was able to dissolve a moderate amount of pulp tissue.

Kruskall–Wallis test with P ≤ 0.001 indicated no significant differences among the tested protocols. Mann–Whitney significance test was set at P < 0.05, and also in this case, there were no statistically significant differences between the tested groups.

Discussion

Bacteria and their products are the major etiologic agents of pulp periapical infection. Modern literature shows that it is impossible to completely remove all the pulp tissue and bacteria from the whole endodontic space.[2],[16]

To get short- and long-term positive results, it is necessary to use techniques and technologies that increase the degree of root canal cleaning. The protocol proposed in this study, controlled heating of NaOCl inside the root canal associated with ultrasonic activation, appears to yield promising results.[17],[18],[19]

Ultrasonic activation has been described to enhance irrigant delivery and agitation by the physical phenomena of stream and cavitation. In vitro, canal cleanliness, irrigant transfer to the canal system, soft-tissue debridement, and removal of smear layer and biofilms can be improved.[20] The additional use of EDTA has been related to further enhancement of smear layer removal. Furthermore, both transferability to in vivo and the impact of these findings on relevant clinical outcome parameters remain partially uncertain. As a consequence, the use of ultrasounds in endodontics is controversial.[21],[22],[23],[24]

Most chemical reactions are accelerated by temperature increase. The irrigation protocols presented here are effective when the kinetic energy increases and intensifies the boiling motion of the irrigant solution. In fact, irrigated canals using this techniques appear well cleansed when viewed through an operating microscope.[25]

For the authors, the ideal solution of heating consists of a heating of the intracanal irrigant solution of sodium hypochlorite through the heat source System B. Such a heat source allows the clinician to reach and keep carefully under control the preset temperatures with the tips of a plugger of System B.[26]

As elaborate irrigation protocols are both costly and time-consuming, their efficacy has to be assessed critically.

However, the results gained in this study should be confirmed by prospective clinical trials. If the findings would be confirmed, costs and time might be saved in the future.

Conclusions

Only the protocol with intracanal controlled heating of NaOCl associated with ultrasonic activation is able, partially, to dissolve the pulp tissue inserted into the artificial lateral canal. Other protocols, together with the control group, are not able to dissolve pulp tissue located inside the artificial canal.

None of the protocols is able to dissolve completely the pulp tissue inserted in the lateral canals.

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Conflicts of interest

There are no conflicts of interest.

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