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Article

Effect of sonic *versus* ultrasonic activation on aqueous solution penetration in root canal dentin.

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Abstract: The aim of this study was to observe the penetration of an aqueous solution into the root canal dentin under sonic activation and ultrasonic activation. Materials and Method: This study consisted of experimental *in vitro* research. In order to achieve a closed system, the apex of 45 single-rooted teeth was sealed with wax. The step-back technique was manually performed using a K50 apical master file and 3 groups were organized according to the protocol of the final irrigant activation: Group I: non-activated Chinese ink for 30 seconds, Group II: Chinese ink sonically activated with EndoActivator for 30 seconds, and Group III: Chinese ink ultrasonically activated with Varios 350 equipment for 30 seconds. Teeth were sectioned longitudinally, and the samples obtained were observed under a stereomicroscope at 1X magnification in order to be photographed and scanned to calculate the penetration area using the Image J software. The tinted radicular area was evaluated in relation to the total area of the root dentin. The Tukey's post-hoc test and ANOVA were used for the statistical analysis ($p<0.05$). Results: Group I and II obtained 9.13% and 9.42% penetration respectively, while in group III the highest degree of dye infiltration was achieved (13.9%), being statistically significant ($p<0.001$). Conclusions: Ultrasonic activation produced a significantly higher penetration of the dye when compared to conventional activation and sonic activation.

Keywords: Passive ultrasonic irrigation; passive sonic irrigation; irrigation penetration.

INTRODUCTION.

Irrigation is the stage during endodontic treatment during which root canals are cleaned and chemically disinfected by means of aqueous solutions which, together with the use cutting instruments, contributes to the biochemical elimination of pulp residues and microorganisms.[1]

Endodontic irrigants share certain physical properties with aqueous dyes, such as Chinese ink, which has been used in endodontic treatments to compare the sealing capacity of filling materials,[2] the depth of penetration of the irrigant into the simulated lateral channels[3] and the marginal filtration in temporary filling materials.[4]

Sodium hypochlorite (NaOCl) was the irrigant of choice because of its effectiveness in eliminating microorganisms and degrading organic material;[5] it has a pH of 11.6 and is also a strong oxidizing agent.[1] However, it is difficult to combine it with aqueous dyes because of these characteristics, and it is especially difficult to observe this fluid using magnification. It is in this context that the penetration of the Chinese ink is considered analogous that of irrigation solution,[3] resulting in a practical and reproducible method.

Currently, the need to activate irrigation solutions in order to enhance their properties is emphasized.[6] One way of activation is to agitate the solution using either sonic or ultrasonic devices. The former use flexible polymer inserts at 1-10kHz frequencies, while the latter use thin metal inserts and operate at 25-30 kHz frequencies.

The effectiveness of these devices has been studied in different scenarios: the removal of dentinal smear,[6-8] the apical extrusion of sodium hypochlorite,[9] the penetration of cement sealant into dentinal tubules,[10] the removal of calcium hydroxide from the root canal,[11-13] and the reduction of microbial load.[14,15] However the results obtained are not easily comparable due to the differences in the methodologies used and the studies' aims.[16,17]

Until the present, the evaluation of the different activation systems available has been based on the observation of specific areas of the root canal with the use of different magnification levels, while the use of sonic activation or ultrasonic activation in the dentin has not been reported. The aim of this study was to observe the effect of sonic activation and ultrasonic activation on the penetration of an aqueous solution in the dentin by assessing the condition of the entire length of the root canal.

MATERIALS AND METHODS.

Design and sample

An *in vitro* experimental study was carried out. Forty-five unirradicular teeth were used, extracted due to orthodontic or periodontal reasons, free of caries and without any kind of pulpal/periapical pathologies. All procedures were performed in accordance with applicable ethical and legal provisions.

Only unirradicular teeth with closed apex, straight roots, without any previous endodontic treatment, and those that, when examined radiographically, had only one canal, were selected. The teeth were stored in 70% denatured alcohol from the time they were obtained until their use in the study. Samples were randomly divided into three groups of 15 teeth each.

Procedure

The apex of each tooth was sealed with wax in order to achieve a closed system. Access perforations were performed in all of the 45 teeth with round dental diamond burs #4 (SS White, USA), and round carbide burs #4 (SS White, USA). For the creation of the third cervical and the root medium, Gates Glidden burs were used (Dentsply Maillefer, Switzerland), progressively increasing the D0 diameter of the file to #50, at working length (1mm from the greater apical foramen). Each file was used with balanced strong movements and between each file, 1.5ml of NaOCI 2.5% was used to irrigate. After that, 10% EDTA was used to irrigate during 1 minute Followed by rinsing with 3ml distilled water.

Irrigation was performed with a 3ml disposable syringe and a 30G irrigation side discharge needle with an inactive tip (Terumo, Japan), which was introduced passively 1mm into the working length during instrumentation. Canals were dried with paper cones #50 (Dentsply Maillefer, Switzerland).

Finally, the endodontic access of the instrumented teeth was filled with Chinese ink using an irrigation needle until completely filling the crown access.

The dye was activated as followed; Group 1: not activated (Passive), Group II: passive sonic activation, Group III: passive ultrasonic activation. For sonic activation, an EndoActivator with a blue tip was used (Dentsply Maillefer, Switzerland), at 10kHZ, and for ultrasonic activation, the Varios 350 equipment (NSK Nakanishi, Japan) was used at medium power (30 kHz), together with a 25mm 15/02 stainless steel ultrasonic file with an E10 insert (NSK).

The dye remained on the teeth for a period of 30 seconds. Subsequently, it was removed by suction and the teeth dried with Nº 50 paper cones.

Teeth were placed in silicone molds and transparent Acrylic Clear Duralay (Reliance® Dental Mfg Co. USA) was added to obtain dies, which were then cut longitudinally using a saw (IsoMetTM Low Speed

Saw, Buehler, USA) with a 15HC diamond disk of the following dimensions: 4''x0.12''x½'' (Buehler, USA).

A sagittal section was performed to observe the entire root canal (Figure 1).

Measures

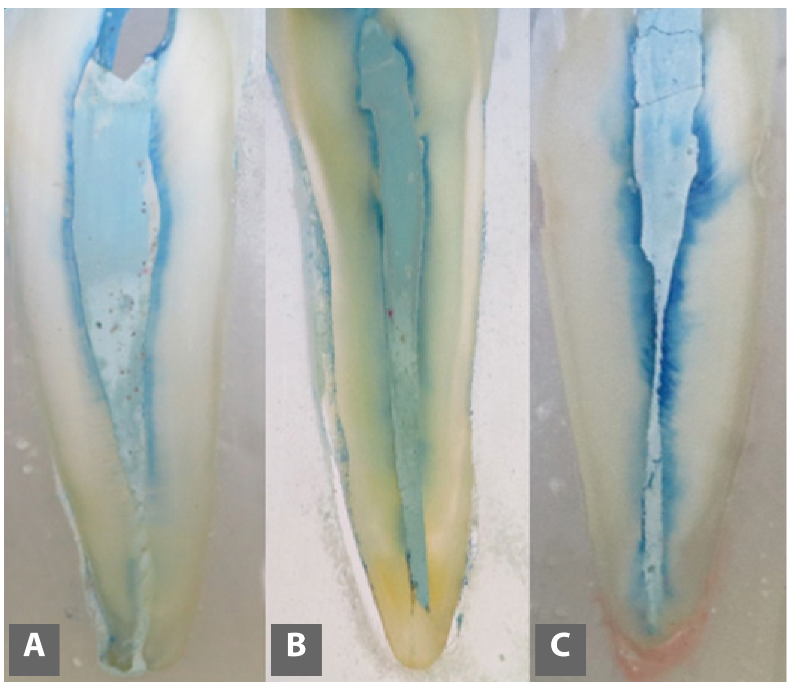
Samples were placed under a stereomicroscope to be observed at 1x magnification (Olympus SZ61, Arquimed, Chile) and photographed. Images of the sections were scanned to calculate the penetration area of the solution as followed: the total area of root dentin (from the amelocemental junction to the apex and from the cement line to the surface of the root canal), and the tinted radicular area using the Image J software (NIH, USA). This way it was possible to determine the percentage of penetration of the dye in the entire length of the root canal dentin and also in each of its thirds.

Statistic analysis

Data were tabulated by one of the researchers on an electronic Google Docs spreadsheet (Google Inc., USA), and were later analyzed using the SPSS Statistics Program version 20.0 (IBM, Chicago, USA).

The ANOVA *test* was applied to the quantitative variable "dye variation" and a comparison was made between the subgroups by means of the Tukey's post-hoc *test* (p<0.05).

Figure 1. Sagittal section. Illustrative images of each group.



A: passive irrigation; **B:** irrigation with sonic activation; **C:** irrigation with ultrasonic activation.

RESULTS.

Six samples (two from each group) were eliminated because it was not possible to visualize the entire root canal, so finally the research was performed with groups of 13 teeth.

The passive irrigation system showed 9.13% penetration, the sonic system 9.42%, and the ultrasonic system 13.09%, its superiority being statistically significant (p<0.01, Figure 2).

When comparing the penetration of the dye of each of the activation systems according to the radicular third, the ultrasonic system was observed to be significantly superior to the passive one (p=0.0081) in the three zones of the root canal (Table 1).

Figure 2. Percentage of penetration according to type of activation.

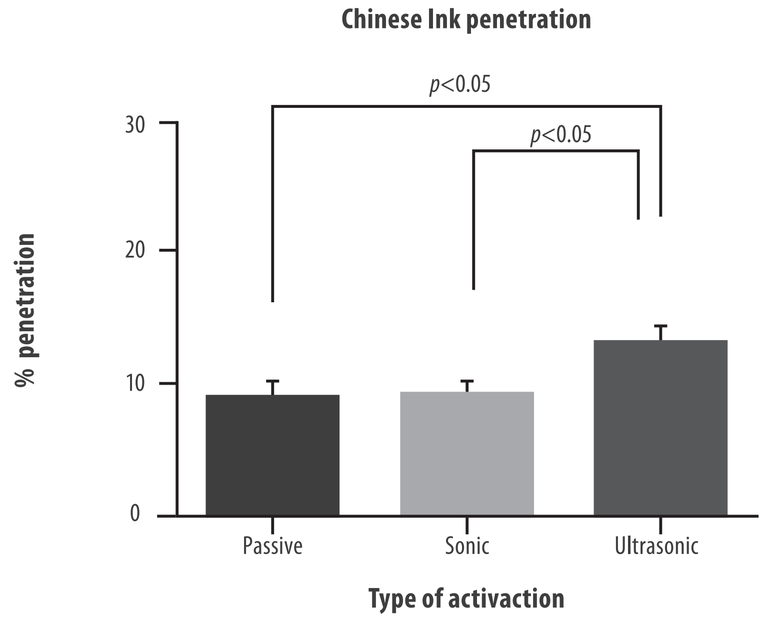


Table 1. Penetration of the dye in the thirds of the root canal according to the activation method.

Type of activation	Cervical third % (S.D.)	Middle third % (S.D.)	Apical third % (S.D.)	Total penetration % (S.D.)
Passive	11.9 (5.58)	10.4 (3.94)	5.0 (2.74)	9.13 (3.05)
Sonic	11.4 (5.8)	12.8 (7.9)	4.1 (7.15)	9.42 (6.39)
Ultrasonic	14.8 (5.2)	15.2 (6.7)	9.2 (6.97)	13.09 (5.16)

S.D.: Standard Deviation.

DISCUSSION.

In this study, the penetration capacity of an aqueous solution in the entire length of the dentin of the root canal was evaluated. The ultrasonic activation showed a dye penetration significantly higher than the sonic and the passive activation. No statistically significant difference was observed between the sonic and the passive activation.

The irrigation of the root canal is one of the critical stages of the success of endodontic therapy.[18] Mechanical instrumentation has been shown to leave 35% to 40% of untreated surface,[19] giving microorganisms the chance to penetrate into the dentinal tubules[20] even beyond 500 microns. Therefore, it is essential to maximize the benefits of the irrigant by combining solutions or activation by sonic or ultrasonic agitation.[21]

Since the introduction of activation systems, their effectiveness has been questioned in various areas due contradictory results. Kanumuru *et al.*[22] Macedo *et al.*[23] and Sáinz-Pardo *et al.*[24] have positioned ultrasound as the most efficient method, but other authors state that sonic agitation obtains similar or even better results.[10]

Pérez *et al.*,[8] compared EDTA sonic activation and ultrasonic activation for the removal of dentinal smear, obtaining no significant differences between the two groups; however Nakamura *et al.*,[17] evaluated the removal of bacteria and endotoxins from the root canal, finding that ultrasound irrigation obtained better results than passive irrigation. This difference in methodology and approach of the published studies makes it difficult to compare results and assess their direct application to clinical practice.

High subjectivity is considered an important limitation of the methods used to evaluate the effectiveness of irrigants. Examples of this aspect are studies where confocal microscopy[25] is used, and those where a specific location within the root canal is selected.[3,6] Results are obtained from the observation of a very small radicular area, which assumes a high probability of bias when added to the use of qualitative/quantitative scales.

The apical third was the area with the lowest penetration of all the irrigation systems, in agreement with the results reported by Spoorthy *et al.,*[3] and Ghorbanzadeh *et al.,*[26] These authors state that with a suitable protocol for the removal of adhered detritus, the penetration of the irrigant in the dentinal tubules will be greater.

It should be kept in mind that the apical third has the greatest impact on the result of endodontic treatment, given that it represents the communication route between the pulp cavity and the periapical tissues. Although ultrasound showed significantly greater penetration of the dye in the dentin of the apical third compared to the other systems, it should be considered that the sample of this study included teeth with straight roots and broad canals, where the ultrasonic rigid tip reaches without any difficulty.

This is not the case of teeth with a pronounced radicular curvature, where the ultrasonic system could not approach or reach the working length.

In spite of the above, Merino *et al.,*[27] and Castelo-Baz *et al.,*[28] reported better performance of ultrasound in the removal of adhered detritus in the apical third of teeth with curved canals. Additionally, the fact of having prepared the apical third to the length of a #50 file is beneficial, since according to Torabinejad *et al.,*[29] the correct irrigation of this area is achieved by using instruments longer than a #30 file.

In the present study, the penetration of the solution was not completely homogeneous, being null in some areas. This is probably caused by detritus that was not removed by the previous irrigation protocol, by the sectioning or by the orientation of the dentinal tubules. Therefore, results should be interpreted with caution where a specific area of the canal surface is measured.

Although the method used in this study allows for the observation of the entire root canal in a single image, a component of subjectivity persists due to the inherent limitations of a two-dimensional image. It would be interesting to use this same methodology to observe the effect of the activation systems on curved root canals and to specially observe the apical third, where anatomical conditions considerably limit the irrigation and disinfection procedures during endodontic treatment.

CONCLUSION.

All the systems studied showed less penetration of the irrigant in the apical third when compared to the cervical and middle thirds, however, ultrasonic activation obtained superior results in the entire length of the root canal.

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