ORIGINAL RESEARCH

Efficiency of Endosonic Blue, Eddy, Ultra X and Endoactivator in the removal of calcium hydroxide paste from root canals

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Abstract

We investigated the efficiency of Endosonic Blue, EDDY, Ultra X and EndoActivator in removing calcium hydroxide from artificially created apical grooves in root canal walls. In Materials and Methods: A total of 60 single-root maxillary central incisors, root canals were created and the roots were divided into two longitudinal parts. In the most suitable root piece, artificial grooves were created in the apical section and filled with calcium hydroxide. Calcium hydroxide in the grooves was removed using EDDY, Ultra X, Endosonic Blue or EndoActivator, and the remnants in the grooves were examined under a stereomicroscope. EDDY and Ultra X removed significantly more calcium hydroxide than Endosonic Blue and EndoActivator. The performance of EDDY and Ultra X or Endosonic Blue and EndoActivator was comparable. Therefore, EDDY and Ultra X are more effective than Endosonic Blue and EndoActivator in removing calcium hydroxide from apical grooves in root canal walls. No technique could achieve complete calcium hydroxide removal.

Introduction

Microorganisms play pivotal roles in the pathogenesis of pulp and periapical tissue diseases (1). The primary aim of the root canal treatment was the removal of vital and necrotic pulp residues, microorganisms and microbial toxins from the root canals through mechanical shaping, irrigation or chemical disinfection with locally applied medicaments (2). Unfortunately, however, none of the contemporary modalities allows for the complete cleansing of the root canal system (3). Therefore, the use of intracanal medicaments has been proposed to disinfect root canals (3). Among these, calcium hydroxide is the most commonly used intracanal medicament owing to its potent antimicrobial activity against majority of the endodontic pathogens (4). Despite its high antimicrobial activity, however, calcium hydroxide cannot be effectively removed from root canals, and its residue may negatively affect the success of the root canal treatment (5). Some studies in this regard have demonstrated that residual calcium hydroxide particles on the dentin walls can occlude dentinal tubules and prevent paste penetration into the tubules, ultimately leading to apical leakage following root canal (6). Therefore, calcium hydroxide must be completely removed before root canal filling (7,8).

Many modern methods for the removal of medicaments from root canals are available. Among these, EDDY (VDW, Munich, Germany) is a system designed with the goal of sonic activation. It is equipped with polyamide tips that oscillate at a frequency of 6000 Hz; the tips are 25/0.4 in size, with the diameter of 0.2 mm at the apex and length of 28 mm, and they are softer than dentine (9). EDDY is effective in removing debris and organic tissues from the canal walls (10).

EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is another sonic activation system with polymer tips of different sizes. Its operating frequency is between 33 and 167 Hz (11). The size of the yellow, red and blue polymer tips is 20/0.02, 25/0.04 and 30/0.06 respectively. EndoActivator can effectively clean medicaments in canal grooves (12).

Ultra X (Changzhou Sifary Medical Technology Co. Ltd., Changzhou, China) is a wireless ultrasonic irrigation device developed to clean the difficult and inaccessible areas of a complex root canal system. Its operating

frequency is 45 kHz. It can remove smears and biofilms, open occluded dentinal tubules, and increase irrigation efficiency (13). This system operates by creating acoustic microstreaming and cavitation during irrigation activation (14).

Endosonic Blue (Maruchi, Wonju, South Korea) is a passive ultrasonic irrigation system with Ni-Ti files produced using the R-Phase technology (15). Thanks to this technology, files have super-elasticity and high cyclic fatigue resistance (16). The Ni-Ti file of the Endosonic Blue system is 15/0.2 in size and oscillates at a frequency of 30 kHz (16).

Many studies focused on the removal of medicaments from root canals using different irrigation activation systems have been conducted (7,8). However, to the best of our knowledge, no study has evaluated the efficiency of Ultra X and Endosonic Blue in removing medication from root canals.

To this end, the present study investigated the efficiency of Endosonic Blue, EDDY, Ultra X and EndoActivator in removing calcium hydroxide from root canals. Our null hypothesis is that the four techniques do not differ in terms of their calcium hydroxide removal efficiency.

Materials and methods

Ethics

The present study was approved by the institutional ethics committee (PDCH/20/EC-234).

Inclusion and exclusion criteria

Sixty maxillary central incisors with straight roots (curvature < 5°), which were extracted as a result of periodontal diseases, were used. The teeth were collected in distilled water following extraction. Teeth with closed apices and without caries were included in the study. Teeth with fractures, cracks, internal/external resorption, restoration, caries, previous canal treatment and calcification were excluded from the study.

Sample preparation

The teeth were decoronised underwater cooling by measuring 18 mm from the root tip to standardise the canal length. The samples were prepared using a 40/0.4 taper Neoniti (Neolix, Châtres-la-Forêt, France) file system. Between each file, irrigation was performed using 2 mL of 3% NaOCl (Novo Dental Product Pvt. Ltd., Mumbai, MH, India). For the final irrigation, 2 mL of 3% NaOCl and 2 mL of 17% EDTA were used.

The samples were embedded into silicone impression material. All samples were numbered. The samples were removed from the impression material, and grooves parallel to the long axis were opened on the buccal and lingual surfaces underwater cooling with a diamond disc. The teeth were then split into two halves by hitting the scalpel tip placed in the obtained grooves with a hammer. Standard grooves (4 mm long, 0.2 mm wide and 0.5 mm deep) were created in the root apical region at a distance of 2–6 mm from the root canal using a cavitron tip attached to an ultrasonic device. Debris created during all processes was removed with a brush. Finally, the teeth were washed with 2 mL of 3% NaOCl and 2 mL of 17% EDTA and then dried using an air spray. Calcium hydroxide (Prevest Denpro Ltd., Jammu, JK, India) powder and liquid were freshly prepared at a 1:1 ratio, and the mixture was applied on the prepared grooves. Then, the teeth were combined with cyanoacrylate to prevent fluid overflow outside the canal during irrigation. During this procedure, guttapercha was placed in the root canal to prevent the possible leakage of cyanoacrylate into the canal. To allow closed-system irrigation, the separation lines and apical region of the samples were covered with wax to prevent fluid leakage, and cotton pellets were placed in the access cavity of the samples. Then, the samples were sealed with zinc oxide–eugenol cement (Cavex Holland BV, Haarlem, Holland) and returned to the silicone impression material. Finally, all samples were incubated in an oven under 100% humidity at 37°C for 7 days. Thereafter, the samples were randomly divided into four groups.

Operator calibration and standardisation

An experienced endodontist was initially trained for the standardisation of the study protocol.

Irrigation protocol

Irrigation was performed as follows: 2 mL of 17% EDTA was applied to the root canals for 20 s using a 30-G NaviTip irrigation needle (Ultradent Products Inc., South Jordan, UT, USA), followed by activation for 20 s. This sequence was repeated two times. Irrigation lasted for 2 min and required 6 mL of 17% EDTA.

Experimental grouping

The following devices were used for irrigation activation (n = 15):

- EndoActivator: Fibre tip (25/0.4) attached to the portable handpiece of the EndoActivator system
- EDDY: Flexible polyamide tip (25/0.4) providing sonic activation

- Ultra X: Tip attached (20/0.2) to Ultra X
- Endosonic Blue: Blue file (15/0.2) of the Endosonic Blue system

Irrigation activation was performed at 2 mm below the working length in all study groups. In the EndoActivator and EDDY groups, oscillations with an amplitude of 2–4 mm were performed during the procedure. In the Ultra X and Endosonic Blue groups, irrigation was completed by making short, vertical strokes. Following irrigation, the canals were dried using paper points and the roots were separated to examine calcium hydroxide remnants in the grooves. The samples were observed under a stereomicroscope at 20× magnification, and images obtained using a digital camera were transferred to a computer.

Researcher blinding and outcome assessment

The amount of calcium hydroxide remaining in the grooves was evaluated by two trained endodontists, who were blinded to the study groups. The evaluations were performed as described by van der Sluis *et al.* (12). Each evaluator examined the samples two times, and the results were scored as follows: 0 = groove is empty; 1 = less than half the groove is filled with calcium hydroxide; 2 = more than half the groove is filled with calcium hydroxide; and 3 = groove is completely filled with calcium hydroxide (Fig. 1).

Statistical analysis

To test the reliability between examiners, 60 random images were re-evaluated a week later and analysed using the Kappa test. Statistical analyses were performed using Kruskal–Wallis and Mann–Whitney U-tests at 95% confidence level ($P = 0.05$). All analyses were performed using SPSS (SPSS Inc., Chicago, IL, USA).

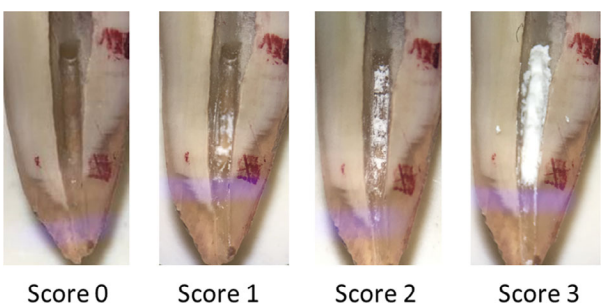

Figure 1 Stereomicroscope images representing the scores. Score 0: The groove is empty. Score 1: Groove has less than half of $Ca(OH)_2$. Score 2: Groove has more than half of $Ca(OH)_2$ but not completely full. Score 3: Groove completely filled with $Ca(OH)_2$.

Results

The results of the two examiners were in good agreement (kappa value = 0.977). The intra-examiner reproducibility was 96% for the first evaluator and 94% for the second one.

Figure 2 presents the score distribution of the four irrigation activation systems. Table 1 presents the statistics (P values) of paired comparisons using the Mann–Whitney U-test. EDDY and Ultra X were significantly more efficient than EndoActivator and Endosonic Blue in removing calcium hydroxide from artificially created grooves in root canal walls ($P < 0.05$). However, there were no significant differences between EDDY and Ultra X or between EndoActivator and Endosonic Blue ($P > 0.05$).

Discussion

Although most of the bacteria and their by-products can be cleaned from the root canal system through mechanical cleansing, the use of irrigation and intracanal medicaments is recommended to ensure antimicrobial effectiveness (17). In endodontics, calcium hydroxide is the most commonly used medicament for this purpose (18).

Calcium hydroxide is a medicament used the longest to disinfect the root canal system (18). Despite its antimicrobial efficiency, however, the use of this medicament remains controversial owing to the possibility of apical leakage due to the poor bonding of the obturation material to the root canal and hindrance in the penetration of root canal sealer. While some studies have claimed that there is little or no apical leakage with calcium hydroxide, others have reported that calcium hydroxide failed to provide effective sealing (12). Therefore, calcium hydroxide must be completely removed before root canal filling (19,20).

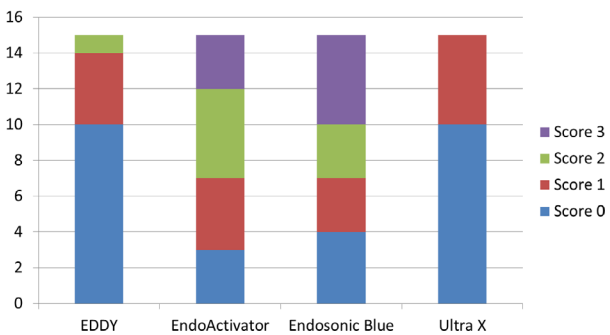

Figure 2 Calcium hydroxide scores left for all groups in the canals.

Table 1 The results of The Mann–Whitney U-tests between groups

	Pairwise comparisons, *P* values			
Groups	EDDY	EndoActivator	Endosonic Blue	Ultra X
EDDY	–	**0.004**	**0.009**	0.935
EndoActivator	**0.004**	–	0.744	**0.002**
Endosonic Blue	**0.009**	0.744	–	**0.006**
Ultra X	0.935	**0.002**	**0.006**	–

Bold values are significantly different.

NaOCl alone is not suitable for removing calcium hydroxide from root canal walls due to its inability to dissolve inorganic materials (21). In their study investigating the calcium hydroxide removal efficiency of different irrigation solutions, Rödig *et al.* (22) found that chelating agents, such as EDTA and citric acid, were more efficient, although the use of NaOCl in addition to chelating agents did not enhance removal efficiency. In the present study, calcium hydroxide was removed with Endosonic Blue, EDDY, Ultra X or EndoActivator using 17% EDTA as the chelating agent. EDDY and Ultra X were more efficient than Endosonic Blue and EndoActivator in removing calcium hydroxide from artificial grooves in root canal walls; thus, our null hypothesis was rejected.

The Ultra X ultrasonic activation system operates at an oscillation frequency of 45 kHz and creates acoustic streaming in the liquid during irrigation. This acoustic streaming leads to the rapid, circular or vortex-like movement of fluid around the vibrating file. This effect occurring in the root canal during ultrasonic irrigation is called acoustic microstreaming (23). The greater efficiency of Ultra X than that of EndoActivator and Endosonic Blue can be explained by the occurrence of acoustic microstreaming and rapid fluid movement.

In a previous study, Donnermeyer *et al.* (7) found no significant difference between EDDY and ultrasonic irrigation in terms of calcium hydroxide removal from root canals. This finding is consistent with our results. The flexible polyamide tips of EDDY, which are resistant to fracture, may produce acoustic currents, creating spiral eddies along the tip. Although EndoActivator is equipped with flexible polymer tips, they are not as effective as the polyamide tips of EDDY. The higher efficiency of EDDY in removing calcium hydroxide may be explained by the greater operating oscillation frequency (5000–6000 Hz) of the system than that of the other sonic systems (9).

In contrast, a study comparing the debris removal efficiency of Ultra X and EndoActivator did not find significant differences (13). Moreover, Park *et al.* (15) evaluated debris and smear layer removal using EDDY and Endosonic Blue and found that the two techniques showed similar efficiency. In the present study, EDDY and Ultra X were more efficient in calcium hydroxide removal than Endosonic Blue and EndoActivator. To our best knowledge, no previous study has compared Endosonic Blue and Ultra X. Therefore, we cannot draw definite conclusions from the present findings, and additional studies on these techniques are warranted.

Various methods have been used to measure the amount of calcium hydroxide remaining in root canals, such as the calculation of the surface area of the canal wall and residues in mm^2, scoring methods, scanning electron microscopy and volumetric analysis using computed tomography (24–26). Since only the superficial layer of calcium hydroxide is reflected in calculations based on area measurements, the precise amount of residue cannot be determined. Furthermore, high cost and low availability limit the use of computed tomography. In the present study, a stereomicroscope was preferred due to its advantages such as the ease of access, ability to visualise the whole and requirement of no additional material.

In a previous study, using a model created based on the apical third region, the inaccessible canal extensions were imitated and the data before and after irrigation were compared by separating the root into two fragments (12). The size of the grooves created in the apical third region was in accordance with the apical root canal anatomy. Using this model, the areas that the endodontic files could not reach or shape and that could only be reached by agitating irrigation solutions were simulated. Simultaneously, the status of intracanal medication before and after removal could be evaluated. Another advantage of this method is that high inter-observer repeatability could be achieved, thanks to defined localisation. The only disadvantage of the design is that it cannot accurately reflect the complexity of the root canal anatomy.

Conclusion

EDDY and Ultra X are significantly more efficient than Endosonic Blue and EndoActivator in removing calcium hydroxide from artificially created apical grooves in root canal walls. Nonetheless, the complete removal of calcium hydroxide could not be achieved with any of the four irrigation techniques tested.

Author contributions

All the authors have contributed significantly and are in agreement with the submitted manuscript.

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