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The effect of ultrasonic file sizes on smear layer removal in passive ultrasonic irrigation

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ABSTRACT

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Objectives: The aim of this study was to evaluate the efficacy of CK files as an ultrasonic instrument, and to determine most efficient file size for smear layer removal.

Materials and Methods: Thirty-six extracted human mandibular premolars with single, straight root canals and mature apices were mechanically prepared and randomly divided into three groups. Group 1 (Control) underwent conventional needle irrigation, Group 2 (CKS) underwent passive ultrasonic irrigation with a #20 CK file, and Group 3 (CKL) underwent passive ultrasonic irrigation with a #30 CK file. After preparation and irrigation, all teeth were dried and split with a chisel to obtain the mesial and distal half of their roots. Each sample was evaluated using a scanning electron microscope, and data were analyzed using the Kruskal-Wallis and Mann-Whitney rank sum tests ($p<0.05$).

Results: The CKS group showed less debris in the apical third than the other groups ($p<0.05$). In this section, no significant difference was observed among the other groups. And, there was no significant difference among any groups for the middle third section.

Conclusion: This study showed that PUI with #20 CK file removed more smear layer compared to using #30 CK file at the apical third of the root canal.

Key words: EDTA, Passive ultrasonic irrigation, Smear layer, Sodium hypochlorite

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I. Introduction

Cleaning of the root canal plays a critical role in the success of endodontic therapy[1]. Typically, this is achieved by combining instrument-based preparation with antiseptic irrigating solutions[2]. The drawback of using instrument-based preparation is the creation of debris[3] as well as a smear layer[4]. Debris on root canal surfaces can prevent the complete removal of both tissue and microorganisms, making complete disinfection difficult[5,6]. The smear layer can be potentially infected; in addition, its removal allows for more efficient penetration of intra-canal medication into the dentinal tubules as well as for a better interface between the filling material and the root canal walls[7].

The recently introduced nickel-titanium (NiTi) files, such as the WaveOne (Dentsply Mailefer, Ballaigues, Switzerland) and Reciproc (VDW GmbH, Munich, Germany), have been shown to completely prepare and clean the root canals without need for other instruments. Additionally, their use may decrease the preparation time by up to 60% when using single file systems and simultaneously reduce the time available for irrigation as well as chemical debridement of the root canal system[8]. Hence, improvement of irrigation protocols is essential during root canal treatment with these instruments to compensate for the decreased irrigation time.

Among various irrigation methods, ultrasonic irrigation was most recommended as a final irrigation[9-15]. Passive ultrasonic irrigation (PUI) methods showed better results than conventional methods for the removal of the smear layer from root canal walls[16, 17].

CK file (B&L Biotech, Ansan, Korea) was one of available instrument for ultrasonic activation. In this study, this file system was connected to the hand piece of an ultrasound generator via a 90°or 120° file holder. CK file system was composed of four different sizes (#20, #25, #30 and #35), however, there is no recommendation for which size should be used under which circumstances.

Therefore, this study aimed to evaluate the efficacy of the CK files as an ultrasonic instrument for removing the smear layer, and further, to compare smear layer removal capacity of different size CK files.

II. Materials and Methods

1. Sample selection

Thirty-six extracted human mandibular premolars with single, straight root canals and mature apices were selected. All teeth were examined with a standard radiograph in both bucco-lingual and mesio-distal orientation to ensure similar canal morphology. Teeth were stored in 0.9% physiologic saline at 4℃ following extraction. Anatomical crowns were removed with a diamond disk to simplify experimental procedures.

2. Root canal preparation

The working length was determined by measuring the length of a #10 K-type file at the apical foramen minus 1 mm. The apex was sealed with melted wax to close the apical foramen[18] and the purpose of this procedure was to prevent the irrigant from escaping through the apex to simulate actual in vivo conditions[19]. The root canals of teeth in all groups were prepared using #40 WaveOne file (Dentsply Mailefer, Ballaigues, Switzerland) to the working length, and then irrigated with 1 mL of 2.5% NaOCl. The irrigation solution was delivered in a 10 mL syringe, with a 27-gauge side-vented needle. The needle tip was inserted as deep as possible into the root canal without binding. After drying with air syringe to remove surplus irrigation solution, a #45 hand file was used to confirm foramen diameter to standardize apical size as #45. Upon completion of instrumentation, the teeth were randomly divided into one control group and three experimental groups with 12 teeth in each.

3. Final irrigation protocols

After completion of root canal preparation, all root canals were dried with paper points, and irrigated with different protocols for each group. The final irrigation protocols for each group are as follows.

1) Group 1(Control; Conventional needle irrigation)

The canals were rinsed with 2.5 mL of 17% ethylenediaminetetraacetic acid (EDTA), which was left in place for 60 seconds with no agitation. The canal was flushed again with 2.5 mL of 17% EDTA. After aspiration, the canal was rinsed with 2.5 mL of 2.5% NaOCl, which was left in place for 30 seconds and then flushed with 2.5 mL of 2.5% NaOCl.

2) Group 2 (CKS; Passive ultrasonic activation with #20 CK file)

The canals were rinsed with 2.5 mL of 17% EDTA and ultrasonically activated for 60 seconds with a #20 CK file at the manufacturer's recommended power setting, placed 2 mm short of the working length. To get passive activation, the file was centered in the canal so that it would not be in contact with the canal walls. During activation, the file was moved continuously up and down by 2 to 3 mm within 2 mm of the apex. Following this, specimens were then flushed with 2.5 mL of 17% EDTA. After aspiration, the canal was flushed with 2.5 mL of 2.5% NaOCl, with similar activation for 30 seconds, followed by flushing with 2.5 mL of 2.5% NaOCl.

3) Group 3 (CKL; Passive ultrasonic activation with #30 CK file)

The irrigation was carried out using a similar protocol as was used for Group 2, but instead using a #30 CK file.

4. SEM evaluation

After final irrigation, all roots were dried using

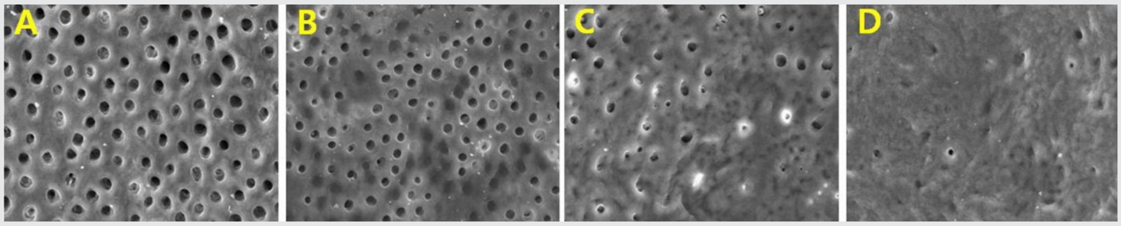

Fig. 1. SEM images demonstrating the scale used to evaluate smear layer score (Magnification: 1,000x). (A) Score 0: all tubules were visible. (B) Score 1: more than 50% of tubules were visible. (C) Score 2: less than 50% of tubules were visible. (D) Score 3: no tubules visible.

paper points. Colored Gutta-percha cones were fitted and used as markers to best gauge groove depth with the objective to prevent any intrusion of the cutting disk into the canals, as this would pollute the samples by splattering cutting debris into the root canal system. A longitudinal groove was made with a diamond disk on the buccal and lingual surface of the root, following this, horizontal grooves were made at 3 mm and 6 mm from apex of the roots. A continuous supply of air was delivered to improve cutting precision, eliminating the potential of debris introduction into this region of the canal. The roots were then split with a chisel, resulting in a mesial and distal half for each root. All intact halves were used for evaluation, and to avoid any contamination, the coronal thirds were discarded[2]. Each sample was dehydrated in a graded series of ethanol solutions, then coated with gold before being examined with a scanning electron microscope (SEM; S4700, Hitachi, Japan) at 15 kV. Each fragment was at first examined at low magnification (100x) to obtain an overview of the sample. Image of the most typical zones of the sample was acquired at a higher magnification of 1,000x to assess the presence of smear layer. The smear layer of the root canal surface was evaluated in two areas; the apical and middle third of the root. A total of 96 images were independently analyzed by two trained evaluators with no inside knowledge of the operative procedures, who were trained on qualitative analysis of root canal surface images produced by SEM. Each image was scored to evaluate the amount of smear layer by two independent evaluators using a 4-step scale[20]; a score of zero if all tubules were visible, a score of one if more than 50% of tubules were visible, a score of two if less than 50% of tubules were visible, and a score of three if no tubules visible (Fig. 1).

5. Statistical analysis

Mean smear layer scores of each group were analyzed using the Kruskal-Wallis test and the Mann-Whitney rank sum test for pair-wise comparisons. The significance level was set at $p \leq 0.05$.

Ⅲ. Results

The results for smear layer removal in the apical third and middle third are presented in Table 1 and Fig. 2.

The mean smear layer scores were tended to increase from the middle to the apical third, with the exception of the CKS group (Fig. 2). When comparing the experimental groups in the apical third section, CKS group was showed significantly better result than the other groups ($p < 0.05$), while no significant differences were obtained among the other groups. For the middle third section, there were no significant differences among all groups.

Table 1. Mean smear layer scores of each group (Mean ± SD)

Group	N	Apical third (3 mm)	Middle third (6 mm)
(1) Control	12	2.00±0.603	1.50±0.674
(2) CKS (#20 CK file)	12	1.33±0.621	1.67±0.577
(3) CKL (#30 CK file)	12	1.83±0.577	1.58±0.668

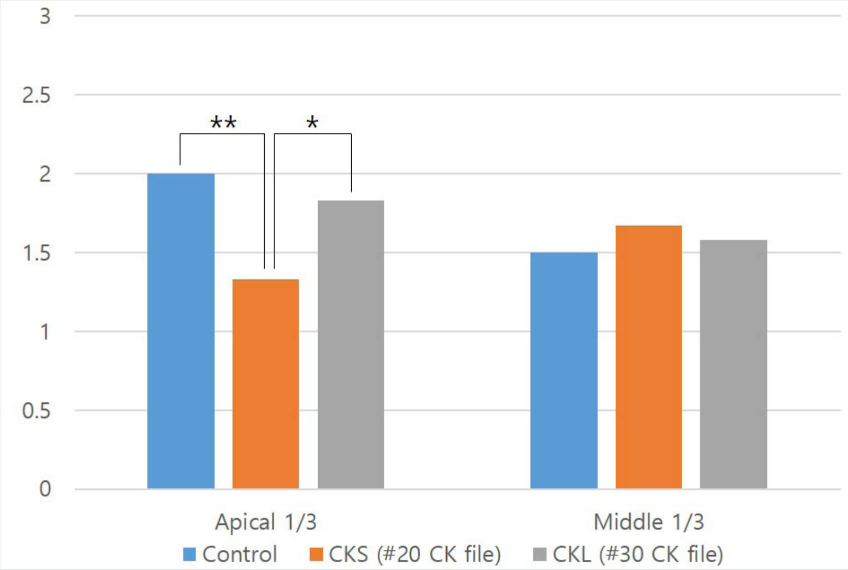

Fig. 2. Mean smear layer scores of each group.
Significant differences between each group are indicated as * $p < 0.05$ or as ** $p < 0.01$.

IV. Discussion

Ultrasonic activation is known to produce acoustic streaming fields in the irrigant around the file, which may help to move irrigant around the root canal. Passive ultrasonic irrigation (PUI) techniques are known to use this principle[21]. PUI involves placing a thin file into the root canal, which is then driven to oscillate freely, without contacting any root canal walls, at ultrasonic frequencies in the present of an irrigation solution[22]. The use of ultrasonic activation increases the effectiveness of the final rinse procedure in the apical third of the canal wall[23]. This study found that ultrasonic activation removed more smear layer in the apical third than conventional needle irrigation. It is in contrast to previous studies reporting little effect of ultrasonic irrigation at the apical third because of limited canal[24].

In the results of this study, #20 CK file was found to be more effective than #30 CK file for smear layer removal. The smaller file could generate greater acoustic streaming because of the increased amplitude of the file[25]. Smaller sized-files were recommended to be used within the canal space, to maximize the effects of acoustic streaming[11].

In the middle part of the canal, significant differences were not detected between the experimental groups. This could be explained by larger canal size enabling the irrigation needle to penetrate deeply so that the smear layers were fully removed with only syringe irrigation[26, 27]. The size of root canal may influence the binding of the ultrasonic file to the root canal wall as well as the irrigation volume, thereby affecting the debridement efficacy of the instrument.

Passive activation of ultrasonic files implies that no attempt is made to instrument, plane, or contact the canal walls with the file[28]. When a file is introduced into the root canal and in contact with the dentin wall, it could influence its oscillation amplitude, and its clinical performance[29]. Despite multiple techniques, file contact with the canal wall may be unavoidable in curved root canals, straight root canals were used in this study to evaluate truly passive ultrasonic effects. Further studies with curved root canals are needed to evaluate the smear layer removal efficacy of ultrasonic activation systems.

A scoring method has been used to evaluate the remaining amount of smear layer on the root canal walls after treatment[20]. In this study, one image with 1,000x magnification was evaluated for scoring the residual smear layer at each level, which is the limitation of this study. To represent the area, more images should have been evaluated for scoring. In addition, to overcome this limitation of scoring method, it is recommended that a grid be superimposed over the photomicrographs under lower magnification, and the amounts of smear layer be evaluated in each assessment unit using the grid[30].

Although passive ultrasonic activation with a #20 CK file during final irrigation produced cleaner canal surfaces than conventional needle irrigation alone, it was impossible to debride the canal system completely. Though technological advances have created several devices which rely on different mechanisms, all current appliances are not able to fully remove the intra-canal debris[31]. To compensate this clinical limitation, it is recommended to employ sufficient volume of irrigation solutions as well as sufficient irrigation time.

VI. Conclusion

This study showed that PUI with #20 CK file removed more smear layer compared to using #30 CK file at the apical third of the root canal.

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