Comparative Evaluation of Apically Extruded Debris DuringRootCanalPreparation Using Three Different File Systems Applied Under 2.5% Sodium Hypochlorite or 2% CHX Irrigation

Keywords

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ABSTRACT

The chemomechanical cleaning of the root canal system is performed using manual and rotary files. This study aimed to compare the effect of ProTaper, Reciproc and HyFlex rotary files considering 2.5% sodium hypochlorite and 2% chlorhexidine (CHX) as irrigating solutions on apical extrusion of intracanal debris. Single-canal mandibular premolars (N=165) were evaluated. The teeth were divided into 6 experimental groups (N=25) for root canal instrumentation using 3 file systems, (Reciproc, HyFlex and ProTaper) and two irrigation solutions, namely 2.5% sodium hypochlorite or 2% CHX. Fifteen teeth were also assigned into three control groups (n=5) with saline as irrigation solution. Eppendorf tubes were weighed and the teeth were placed inside. The canals were instrumented and the tubes weighed to determine the dry weight of extruded debris. Data were analyzed using one-way ANOVA and Bonferroni test (α=0.05). The mean amount of extruded debris using the sodium hypochlorite solution was significantly higher than other irrigating solutions ($p<0.001$). The mean amount of extruded debris using the Reciproc file system was significantly higher compared to ProTaper and HyFlex ($p<0.001$). The use of the sodium hypochlorite solution, single-file systems and reciprocal movement are associated with higher debris extrusion and might be associated with higher risk of postoperative pain.

INTRODUCTION

Root canal treatment is a chemomechanical procedure including root canal cleaning and shaping. Its main goal is to eliminate the pulp tissue, necrotic debris and microorganisms from the root canal system and provide a space for three-dimensional obturation of the root canal.[1] In this process, debris including dentinal chips, necrotic tissues, irrigating solutions and microorganisms may extrude through the apical foramen into the peri-radicular tissues and cause periapical inflammation, pain and flare-up and thereby delay healing.[2-4]

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Mechanical cleaning of the root canal system is performed with different file systems and techniques.[1] Although all techniques and files cause extrusion of debris through the tooth apex, it seems that the extent of apical debris extrusion is not the same when different techniques and files are used.[5-9] Evidence shows that extrusion of debris while using manual files is higher than that compared to rotary instruments.[10,11] Kutarci *et al*. reported that in use of rotary instruments, debris is accumulated in the file flutes and is therefore guided towards the coronal orifice.[5] Thus, extrusion of debris through the apex significantly decreases.[5] Moreover, mechanical preparation of the root canal system alone cannot sufficiently disinfect the root canal system, and irrigating solutions should be necessarily used to eliminate the microorganisms.[12] Several chemical agents are available for this purpose. Sodium hypochlorite (NaOCl) is the most commonly used irrigating solution in root canal treatment due to its optimal antibacterial property and dissolution of pulp tissue and organic components of the biofilm.[3] Chlorhexidine (CHX) is another root canal irrigating solution. However, CHX cannot dissolve the pulp tissue, it is used due to its optimal substantivity and long-term antibacterial effect since it bonds to hydroxyapatite. CHX is also used for a final rinse during the endodontic treatment.[13,14]

Recently, some advances have been made in the design of rotary files such as their radial land, alloy, flute depth, taper, cross-section and type of movement to increase their flexibility, cutting efficiency and fatigue resistance.[11] Such alterations in the design of files can affect apical extrusion of debris.[11] Some previous studies have assessed the apical extrusion of debris in use of different rotary systems and techniques. Silva *et al*. reported that ProTaper Universal resulted in the highest extrusion of debris from the apex compared with ProTaper Next, Reciproc and WaveOne with the use of saline irrigating solution; no significant difference was noted among other groups in this respect.[12] Uslu *et al*. compared Reciproc Blue, HyFlex EDM and XP-Endo with saline irrigating solution and reported that Reciproc Blue caused the highest extrusion of debris followed by HyFlex EDM and XP-Endo, where the difference between Reciproc Blue and XP-Endo was significant.[16] In another study, Sinha *et al*. evaluated the apically extruded debris in root canals prepared by single-file Reciproc as well as rotary instrumentation systems. They concluded that Reciproc file systems extruded more debris apically compared to rotary instrumentation systems.[17] This study aimed to provide a systematical approach comparing three different rotatory systems and two irrigation solutions. There is indeed data in the literature addressing the topic chosen, however contraindicatory data can be found as a result of varying methodologies among the studies.[18-21] Therefore, the systematic approach in this study in combining the novel rotatory system chosen with the different irrigation solution was eminent for verification of existing knowledge.

Therefore, considering the significance of apical extrusion of debris and its effect on postoperative pain, this study aimed to assess the effect of three file system namely ProTaper, Reciproc and HyFlex used with two irrigating solutions including 2.5% sodium hypochlorite and 2% CHX on the amount of extruded debris through the apical foramen.

MATERIALS AND METHOD

In this study, human single-canal mandibular human premolar teeth (N=165) were evaluated after extraction because of orthodontic and prosthodontic treatments. This project was approved by the Ethics Committee of Isfahan (Khorasgan) Azad University. The inclusion criteria were single-canal premolars with mature apices, root curvature of 0° to 10° according to the Schneider's method, minimum length of 19 millimeter (mm), non-calcified canals and Vertucci's type I root canal anatomy. The exclusion criteria were presence of root cracks or fracture and instrument fracture in the root canal during the procedure. The teeth were selected using convenience sampling. Using the statistical software SPSS version 22 (SPSS Inc., IL, USA) and according to the following formula sample size was calculated to be n=25 in each group considering $\alpha = 0.05$, $\beta = 0.2$, study power of 80% and standard deviation of 0.8.

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 (\sigma_1^2 + \sigma_1^2)}{d^2}$$

The methodology of this study for apical debris collection was adopted from a previously described model by Myers and Montgomery's.[22] All experimental procedures were performed by one calibrated endodontic specialist. Periapical radiographs were obtained from the teeth in buccolingual and mesiodistal dimensions to ensure presence of one straight canal, no calcification, no internal resorption, no dilaceration, and apex closure. The surface of the teeth was then cleaned from debris using a periodontal curette. They were then immersed in 2.5% sodium hypochlorite (Cholraxid, Cerkamed, Stalowa Wola, Poland) for 2 hours and were then placed in formalin. In order to standardize the length of all teeth at 19 mm, teeth were decoronated by a diamond disc (JOTA AG, Switzerland) under water spray. Access cavity was prepared using a diamond bur (JOTA AG, Switzerland) and high-speed hand-piece under air/water spray. In order to prevent the extrusion of debris from the lateral canals, the external root surface was coated with 2 layers of nail varnish except for a 1 mm margin around the apical foramen. The working length was determined by introducing a #15 K-file (Mani, Japan) into the canal until its tip was visible at the apex and 1 mm was subtracted from this length. Afterwards, 165 Eppendorf tubes (Q-Leb, Shanghai, China) were weighed three consecutive times by a digital scale (AND, Hong Kong, China) with 0.0001 g accuracy and the mean weight of each tube was taken to be its initial weight. A hole was then created in the rubber stop of the tubes and the teeth were placed in the tubes to the level

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of their cementoenamel junction and fixed with cyanoacrylate glue (Iceberg-glue; GMI, Barcelona, Spain). A 27-gauge needle was inserted alongside the rubber stopper in order to equalize the internal and external air pressure and the entire assembly was placed in a vial (*Figure 1*).

Figure 1: Placement of the assembly of tooth, needle and Eppendorf tube in a vial.

Specimens were then randomly divided into 6 experimental groups (n=25) and 15 teeth were assigned into three control groups (n=5). Root canal instrumentation with rotary and Reciproc files was performed with the torque and speed instructed by the manufacturers. After using each rotary file or after three pecking motions in single-file system, root canals were rinsed with 2 ml of the respective irrigating solution. For this purpose, the 27-gauge needle of the syringe (Ava, Gilan, Iran) was inserted into the canal until resistance was felt. Then the needle was pulled back by 1 mm and the irrigating solution was injected. The root canals in each group were prepared as follows:

Group 1: Root canals were prepared with nickel-titanium Reciproc single-file (VDW GmbH, Munich, Germany) with size #40 and 0.06 taper and 2.5% sodium hypochlorite (Cerkamed, Stalowa Wola, Poland) as irrigating solution.

Group 2: Root canals were prepared with nickel-titanium Reciproc single-file and 2% CHX (Cerkamed, Poland) as irrigating solution.

Group 3: Root canals were prepared with nickel-titanium HyFlex rotary file (Coltene-Whaledent, Switzerland) with the following sequence: #20/0.06, #25/0.06, #30/0.06, #35/0.05, and #40/0.05 and 2.5% sodium hypochlorite as irrigating solution.

Group 4: Root canals were prepared with nickel-titanium HyFlex rotary file with the following sequence: #20/0.06, #25/0.06, #30/0.06, #35/0.05, and #40/0.05 and 2% CHX as irrigating solution.

Group 5: Root canals were prepared with nickel-titanium ProTaper rotary file (Dentsply, Switzerland) with the following sequence: SX, S1, S2, F1, F2, F3, F4 and 2.5% sodium hypochlorite as irrigating solution.

Group 6: Root canals were prepared with nickel-titanium ProTaper rotary file with the following sequence: SX, S1, S2, F1, F2, F3, F4 and 2% CHX as irrigating solution.

After completion of root canal preparation, each tooth with its corresponding rubber stopper was removed from the Eppendorf tubes. In order to collect the residual debris, the apical part of the teeth was rinsed with 1 ml of distilled water into the Eppendorf tubes. The Eppendorf tubes were then incubated at 70°C for 5 days. After evaporation of the irrigant, the Eppendorf tubes and the collected debris were weighed again three consecutive times using the same digital scale to obtain the final mean weight. The weight of the empty Eppendorf tube was subtracted from this value to determine the net weight of the collected debris.

Data were analyzed using SPSS version 22 (SPSS Inc., IL, USA). Descriptive statistics including the mean and standard deviation values were reported. Normal distribution of data by use of Shapiro-Wilk test, and homogeneity of variances by use of Levene's test were evaluated. Comparisons were made using one-way and two-way ANOVA and Bonferroni test. Level of significance was set at 0.05.

RESULTS

Table 1 shows the mean amount of extruded debris in different groups. Considering two different irrigation solution, the maximum amount of extruded debris was noted following the use of sodium hypochlorite while the minimum value was noted following irrigation with saline (control group). Regarding the application of different file systems, the maximum amount of extruded debris belonged to the group where Reciproc file was used and the minimum amount belonged to the group where HyFlex file was used. Two-way ANOVA showed that the effect of type of file ($P<0.001$) and type of irrigating solution ($P<0.001$) was significant on the amount of extruded debris. However, the interaction effect of type of solution and type of file was not significant ($P=0.109$).

Table 2 shows pairwise comparisons of the irrigating solutions with regard to the mean amount of extruded debris following the use of three file systems. The Bonferroni test revealed no significant difference in the amount of extruded debris between the saline and CHX in the three file systems ($P>0.05$).

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Table 1. Mean amount of extruded debris in the groups.

Solution	File type	Number	Minimum	Maximum	Mean (µg)	SD
Chlorhexidine	ProTaper	25	0.0053	0.0116	0.0092	0.0014
	Reciproc	25	0.0124	0.0169	0.0151	0.0011
	HyFlex	25	0.0027	0.0082	0.0054	0.0014
Sodium hypochlorite	ProTaper	25	0.0100	0.0147	0.0123	0.0010
	Reciproc	25	0.0150	0.0214	0.0192	0.0016
	HyFlex	25	0.0071	0.0125	0.0092	0.0013
Control (saline)	ProTaper	5	0.0083	0.0110	0.0097	0.0010
	Reciproc	5	0.0142	0.0174	0.0156	0.0012
	HyFlex	5	0.0024	0.0167	0.0047	0.0017

However, the mean amount of extruded debris following the use of sodium hypochlorite was significantly higher than that following the use of saline (control) and CHX (P<0.001).

Table 3 shows pairwise comparisons of file systems in terms of the mean amount of extruded debris. As shown, in use of all three irrigating solutions, the mean amount of extruded debris by Reciproc file was significantly higher than that of ProTaper and HyFlex files (P<0.001). Also, the mean amount of extruded debris by ProTaper file was significantly higher than that of HyFlex file (P<0.001).

The mean amount of extruded debris in different combination of file types and irrigating solutions are shown in Table 4. The Bonferroni test revealed that the mean amount of extruded debris in the hypochlorite/Reciproc group was significantly higher than in the remaining 8 groups (P<0.05).

DISCUSSION

This study assessed the effect of three rotatory file systems ProTaper, Reciproc and HyFlex using two different irrigation solutions, 2.5% sodium hypochlorite and 2% CHX on the amount of extruded apical debris. The results showed that in use of all three irrigating solutions, the amount of extruded debris following the use of Reciproc was significantly higher compared to ProTaper and HyFlex files. Also, the mean amount of extruded debris in use of ProTaper file was significantly higher than that following the use of HyFlex file. Greater extrusion of debris following the use of Reciproc may be due to the fact that Reciproc is a single-file system, and coronal flaring is not performed upon initiation of treatment. As a result, extrusion of debris from the coronal orifice would be lower. In canal preparation with the use of Reciproc system, the #40 Reciproc file with high diameter and 0.06 taper works as a piston and pushes the debris towards the apical foramen. Therefore, higher amount of debris is extruded through the apex.[23] However, in ProTaper Universal rotary file system in which, the files are used in a sequence according to the crown-down technique, use of SX orifice shaper file at the onset of treatment flares the coronal region and provides a space for further extrusion of debris through the coronal orifice.[24] Lower amount of debris extruded from the apex in use of HyFlex file can be attributed to the lower cutting efficiency of this file.[24] Also, during root canal preparation with HyFlex file, opening of file flutes increases the distance between the flutes and creates a space for accumulation of debris. By the movement of file, debris is extruded through the coronal orifice.[24] The current results are in agreement with some of the previous studies.[2,24,25] Moreover, a systematic review by Caviedes-Bucheli *et al.* reported that the amount of debris extruded through the apex with the use of rotary file systems with consecutive use of files was lower than that in use of single-file systems with reciprocal movement.[26] They explained that rotary files have a screw-like function and therefore, result in greater transfer of debris towards the coronal orifice compared with reciprocal movement.[26] This also in accordance with the result of Sinha *et al.* that revealed less apical extrusion after the use of rotary file systems in comparison with the Reciproc file system.[17] It could also be related to the complex kinematic of Reciproc files, while they represent both clockwise and counterclockwise rotation and therefore dis-/engaging of cutting edges is seen during instrumentation.[27]

The irrigating solution is another important factor affecting the success of endodontic treatment. Sodium hypochlorite has tissue dissolving and antimicrobial properties and is the most commonly used irrigating solution by dental clinicians.[28,29] CHX is another commonly used irrigating solution with optimal antimicrobial properties and favorable substantivity in the root canal system. However, it cannot dissolve the organic debris.[10]

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Table 2. Pairwise comparisons of the irrigating solutions with regard to the mean amount of extruded debris following the use of the three file systems.

Rotary files	Solution (1)	Solution (2)	Mean difference	Pvalue
ProTaper	Control (saline)	Chlorhexidine	0.004	1.00
	Control (saline)	Hypochlorite	- 0.0026	< 0.001
	Chlorhexidine	Hypochlorite	- 0.0030	< 0.001
Reciproc	Control (saline)	Chlorhexidine	0.005	1.00
	Control (saline)	Hypochlorite	- 0.0037	< 0.001
	Chlorhexidine	Hypochlorite	-0.0041	< 0.001
HyFlex	Control (saline)	Chlorhexidine	-0.0007	0.768
	Control (saline)	Hypochlorite	- 0.0045	< 0.001
	Chlorhexidine	Hypochlorite	- 0.0038	< 0.001

Table 3. Pairwise comparison of rotary files in terms of the mean amount of extruded debris.

Solution	File (1)	File (2)	Mean	Pvalue
Control (Saline)	ProTaper	Reciproc	-0.0070	<0.001
	ProTaper	HyFlex	0.0031	<0.001
	HyFlex	Reciproc	-0.0100	<0.001
Chlorhexidine	ProTaper	Reciproc	-0.0059	<0.001
	ProTaper	HyFlex	0.0038	<0.001
	HyFlex	Reciproc	-0.0097	<0.001
Hypochlorite	ProTaper	Reciproc	-0.0059	<0.001
	ProTaper	HyFlex	-0.0050	<0.001
	HyFlex	Reciproc	-0.0109	<0.001

To date, many studies have assessed the effect of different type of files used for root canal instrumentation on the amount of debris extruded through the apex. However, to the author's best knowledge, only one previous study by Parirokh *et al.*[30] was performed evaluating the effect of type and concentration of irrigating solutions on apical extrusion of debris. In the present study, we assessed the effect of type of file as well as the type of irrigating solution on the amount of debris extruded through the apex. In use of all three ProTaper, Reciproc and HyFlex rotary systems, no significant difference was noted in the amount of extruded debris between the control (saline) and sodium hypochlorite irrigating solutions. However, the mean amount of extruded debris was significantly higher in use of sodium hypochlorite. This result was in agreement with that of Parirokh *et al.*[30] who compared the amount of extruded debris through the apex following the use of three irrigating solutions namely 5.25% sodium hypochlorite, 2.5% sodium hypochlorite and 2% CHX with the same rotary system. They found that the amount of debris extruded through the apex following the use of 5.25% sodium hypochlorite was significantly higher than in the other two groups. Greater extrusion of debris through the apex following the use of hypochlorite can be due to its tissue dissolving property. In our study, maximum extrusion of debris was noted in Reciproc/hypochlorite group.

One limitation of the current study is the execution of all experimental procedures by only one but calibrated operator, which does not allow interoperator reliability comparison.

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Table 4. Mean amount of extruded debris in different combinations of file types and irrigating solutions.

Group (1)	Group (2)	Mean	P value
Hypochlorite/ Reciproc	Control (saline)/Reciproc	0.0037	<0.001
	CHX/Reciproc	0.0041	<0.001
	ProTaper/hypochlorite	0.0070	<0.001
	Control (saline)/ProTaper	0.0096	<0.001
	CHX/ProTaper	0.0100	<0.001
	Hypochlorite/HyFlex	0.0100	<0.001
	CHX/HyFlex	0.0138	<0.001
	Control (saline)/HyFlex	0.0145	<0.001
Control (saline)/ Reciproc	CHX/Reciproc	0.0005	1.00
	ProTaper/hypochlorite	0.0033	<0.001
	Control (saline)/ProTaper	0.0059	<0.001
	CHX/ProTaper	0.0063	<0.001
	Hypochlorite/HyFlex	0.0064	<0.001
	CHX/HyFlex	0.0101	<0.001
	Control (saline)/HyFlex	0.0109	<0.001
CHX/Reciproc	ProTaper/hypochlorite	0.0028	<0.001
	Control (saline)/ProTaper	0.0054	<0.001
	CHX/ProTaper	0.0059	<0.001
	Hypochlorite/HyFlex	0.0059	<0.001
	CHX/HyFlex	0.0097	<0.001
	Control (saline)/HyFlex	0.0104	<0.001
Hypochlorite/ ProTaper	Control (saline)/ProTaper	0.0026	0.003
	CHX/ProTaper	0.0030	<0.001
	Hypochlorite/HyFlex	0.0031	<0.001
	CHX/HyFlex	0.0068	<0.001
	Control (saline)/HyFlex	0.0076	<0.001
Control (saline)/ ProTaper	CHX/ProTaper	0.0004	1.00
	Hypochlorite/HyFlex	0.0005	1.00
	CHX/HyFlex	0.0042	<0.001
	Control (saline)/HyFlex	0.0050	<0.001
CHX/ ProTaper	Hypochlorite/HyFlex	0.0001	1.00
	CHX/HyFlex	0.0038	<0.001
	Control (saline)/HyFlex	0.0045	<0.001
Hypochlorite/ HyFlex	CHX/HyFlex	0.0038	<0.001
	Control (saline)/HyFlex	0.0045	<0.001
CHX/HyFlex	Control (saline)/HyFlex	0.0007	1.00

In vitro studies on the extrusion of debris through the apical foramen lacks the apical resistance against the extrusion of debris and irrigating solutions. Thus, the results of such *in-vitro* studies should be verified with clinical findings. A Styrofoam can be used to simulate apical resistance.[31] However, the Styrofoam may absorb the extruded debris and therefore was not used in this study. Future clinical studies are required to consider the effect of cross section of the instrument, as well as irrigation volume and concentration used during the preparation process of the root canals to recommend an ideal clinical protocol.

CONCLUSIONS

From this study, the following could be concluded:

1. Apical extrusion of debris could not be avoided with all three tested root canal file systems.
2. Type of irrigating solution had a significant effect on the amount of extruded debris and it seems that solutions with higher tissue solving capability cause greater apical extrusion of debris.
3. Particularly reciprocal file movement and the single-file systems cause greater apical extrusion of debris.

DISCLOSURE

The authors declare no conflicts of interest.

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