10.5005/jp-journals-10024-1556

ORIGINAL RESEARCH

Apical Extrusion of Debris and Irrigant using Novel Preparation Systems

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ABSTRACT

Aim: The aim of this *in vitro* study was to assess the amount of apically extruded debris and irrigant using Reciproc *vs* self-adjusting file (SAF) and to investigate the effect, if any, of gravitational force via mandibular and maxillary positioning of the teeth.

Materials and methods: Forty human mandibular premolars were randomly assigned to four groups of 10 teeth each. The root canals were instrumented according to the manufacturers' instructions using the Reciproc and SAF. Sodium hypochlorite was used as the irrigant. The apically extruded debris was collected in pre-weighted glass vials using the Myers and Montgomery method, and teeth were placed in vials both in downward and upward positions. After drying, the mean weight of debris was assessed with a microbalance and statistically analyzed using two-way ANOVA with Bonferroni correction.

Results: All instrumentation techniques and positions caused measurable apical extrusion of debris. A significant difference was observed according to position and instrument used ($p < 0.05$). The Reciproc extruded significantly more debris than SAF and vial downward position extruded significantly more debris than upward position ($p < 0.05$).

Conclusion: Under the conditions of this study, all systems caused apical debris extrusion, especially in the downward position.

Clinical significance: According to results of this study, the SAF was associated with less debris extrusion compared to the Reciproc in both mandibular and maxillary positions.

Keywords: Debris extrusion, Self-adjusting file (SAF), Reciproc.

How to cite this article: Uzunoglu E, Görduysus M. Apical Extrusion of Debris and Irrigant using Novel Preparation Systems. J Contemp Dent Pract 2014;15(4):423-427.

Source of support: Nil

Conflict of interest: None

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INTRODUCTION

The main purpose of root canal treatment is to enlarge the root canal system in order to remove all residual pulp tissue, bacteria, necrotic tissue, and dentine chips from the root canal system chemomechanically. During root canal preparation, these materials and the irrigant may be extruded into the periapical tissues despite strict monitoring of the working length.[1] The extruded material has been related to periapical inflammation and postoperative flare-ups.[2] Studies examining the apical extrusion of debris have stated that procedures using the push-pull motion tend to produce more debris than those involving some sort of rotational movement. This has led to the hypothesis that engine-driven instruments produce less debris than hand filing techniques, as they have a tendency to pull the debris into their flutes, thus leading the debris out of the root canal in a coronal direction.[3,4] Vande Visse and Brilliant (1975)[5] were the first to quantify the amount of apically extruded debris during instrumentation. When instrumentation is coupled with irrigation, it tends to generate a significantly greater amount of debris than when irrigation is omitted.[5] It is possible to remove larger amounts of debris by using larger amounts of irrigant solutions. Thus, although irrigation contributes to the removal of debris from the root canal and facilitates instrumentation, it would not avoid extrusion completely. The evaluation of apically extruded debris using different instrumentation techniques indicates that all techniques result in some degree of extrusion.[6-8]

Manufacturers have introduced various types of rotary nickel-titanium (NiTi) systems. The new self-adjusting file (SAF) NiTi instrument system (ReDent-Nova, Ra'Anana, Israel) and the Reciproc (VDW, Munich, Germany) were introduced recently. The SAF is a hollow file designed as a compressible, thin-walled pointed cylinder either 1.5 or 2.0 mm in diameter composed of a 120 μm-thick NiTi lattice.[9] When inserted into a root canal, it adapts itself to the canal's shape, both longitudinally and along the cross-section. The hollow design allows for continuous irrigation throughout the procedure. A special irrigation device (VATEA, ReDent-Nova) is connected by a silicon tube to the irrigation hub on the file and provides continuous flow of the irrigant of choice at a low pressure and at flow rates of 1 to 10 ml/min.

The effective replacement of irrigant in the apical part of the canal occurs with no clinically significant positive pressure. It is reported that no pressure builds up in the canal during the SAF operation, because the metal mesh allows the SAF to be operated with continuous irrigation.[10]

It is claimed that the single-file NiTi system Reciproc facilitates the complete preparation of root canals with only one instrument. This file is composed of a special NiTi alloy called M-wire, which is created by an innovative thermal treatment process.[11] The benefits of this M-wire alloy include increased flexibility and improved resistance to cyclic fatigue of the instruments.[12,13] The Reciproc has an identical S-shaped cross-sectional design with sharp cutting edges and is used in a reciprocal motion that requires special automated devices. The reciprocating movement relieves stress on the instrument by special counterclockwise (cutting action) and clockwise (release of the instrument) movements and, therefore, reduces the risk of cyclic fatigue caused by tension and compression.[14,15] The angles of reciprocating movements are specific to the design of the particular instruments. It is also reported that the Reciproc extruded debris apically.[7,8]

The aim of this study was to compare the amount of apically extruded debris using either Reciproc or the SAF system as well as to investigate the effect, if any, of gravity. The null hypothesis was that there are differences in the amount of apically extruded debris according to (i) instrumentation technique and (ii) teeth position.

MATERIALS AND METHODS

The study was approved by the Research Ethics Committee of University (Approval number: B.30.2.HAC.0.20.05.04/520, Decision number: LUT 12/49-34). Forty freshly extracted mandibular premolar teeth were selected. All teeth were analyzed with radiographs in buccal and proximal directions to confirm noncomplicated root canal anatomy, single straight root canals, and mature root formation. The teeth were cleaned of debris and soft tissue remnants and stored in distilled water. Coronal access was achieved using diamond burs, and the canals were checked for apical patency with a size 15 K-file (VDW). To achieve uniformity, the canal patency was controlled with a size 15 K-file (Dentsply Maillefer). The working length (WL) of each canal was determined as 1 mm short of the length of a size 15 K-file that was visible at the major diameter of the apical foramen. The teeth were allocated into four identical groups based on the measured distances from the cementoenamel junction to the apex. The homogeneity of the four groups with respect to this parameter was assessed using Kruskal-Wallis test, and there was no significant different between the groups. Holes were created in the rubber cap of the Eppendorf tubes with a heated instrument, and teeth were inserted under pressure through these rubber caps, which were affixed to the teeth with cyanoacrylate. A rubber dam sheet was used to prevent leakage of overflowing irrigant, and it also served to shield the operator from seeing the root apex during the instrumentation procedure. This set-up was placed into an Eppendorf tube, and the Eppendorf tubes were then fitted into vials. The apical part of the root was suspended within the Eppendorf tube, which acted as a collector for extruded debris. A bent 27-gauge needle was also forced alongside the stopper to equalize the internal and external air pressure. One Eppendorf tube for each tooth was weighed to an accuracy of 0.0001 g using an electronic balance (Sartorius basic, Sartorius AG, Gottingen, Germany). Three consecutive measurements were taken, and the average measurement of each tube was considered to be its initial weight. Canal preparation and irrigation were conducted by one operator. The 40 teeth were divided into four groups as follows:

Group 1a: The teeth were instrumented with SAF simulating the mandibular position, with vials in downward position.

Group 1b: The instrumentation procedure was similar to that in Group 1a. The teeth were instrumented with SAF simulating the maxillary position (Set-up held inverted to upward position to simulate a maxillary tooth).

Group 2a: The teeth were instrumented with Reciproc simulating mandibular position.

Group 2b: The instrumentation procedure was similar to that in Group 2a. The teeth were in inverted position simulating maxillary position similar to Group 1b.

Preparation Procedures

Group 1 (a, b) SAF: The SAF system was used with the 2.0-mm-diameter (size 30) instrument operated by an in-and-out vibration handpiece (GENTLEpower; KaVo, Bieberach, Germany) combined with a RDT3 head (ReDent-Nova) at 5000 rpm and a vibration amplitude of 0.4 mm. Each root canal was instrumented with a single SAF. The SAF instrument was inserted in the canal and operated with an in-and-out motion to working length for a total of 4 minutes (min). The irrigant—sodium hypochlorite (NaOCl) was continuously delivered by a special irrigation device (Vatea, ReDent-Nova) at a flow rate of 3 ml/min. Canals were first prepared with a K-file until #30 at the working length, and then the SAF was used (a 2.0 mm file, corresponding to an apical size of 30).

Group 2 (a, b) Reciproc: The Reciproc files were attached to a VDW Silver endodontic motor (VDW) and driven at the recommended setting for Reciproc instruments (‘Reciproc

ALL' mode). A R25 Reciproc file with a size 25 at the tip and a taper of 0.08 over the first 3 mm was used in a reciprocating, slow in-and-out pecking motion according to the manufacturer's instructions. First, the instrument was used until it had reached two-thirds of the established working length; then, the instrument was removed from the canal, the canal was irrigated with 4 ml of 2.5% NaOCl, and then it was reused in the same manner along the working length. The side-vented irrigation needle (Endo-Eze, 27-G, Endo-Eze, Ultradent South Jordan, UT) was placed as deep into the canal as possible without resistance but not deeper than the predetermined working length minus 1 mm. The flutes of the instrument were cleaned with 1% NaOCl after each set of three pecks.

During root canal instrumentation, 12 ml of 2.5% NaOCl was used for each tooth. No attempts were made to remove the smear layer.

On completion of the preparation, the canals were dried with paper points and each tooth was removed from the centrifuge tube. The debris adhering to the root surface was collected by washing off the apical area of the tooth with 1 ml of distilled water into the centrifuge tube. The centrifuge tube was stored in an incubator at 37°C for 21 days to allow the moisture to evaporate, before weighing the dry debris using an electronic balance. After the incubation period, the tubes were weighed again three times. The average of these measurements was considered to be the weight of the tube plus the debris. The difference between pre- and post-weights was calculated, and statistical evaluation was performed using two-way ANOVA with Bonferroni correction at 0.05 level of significance using the statistical package for the social sciences (SPSS) software program (version 20, SPSS, Inc., Chicago, IL, USA).

RESULTS

The mean weight and standard deviation for each group are presented in Table 1. The results indicated that all instrumentation techniques and positions caused measurable apical extrusion of debris and irrigant. A significant difference was observed between positions ($p < 0.05$) and files. The Reciproc extruded significantly more debris than the SAF and mandibular position extruded significantly more debris than maxillary position ($p < 0.05$).

DISCUSSION

Irrigation is a necessary and important phase of cleansing the canal. Sodium hypochlorite has been systematically used as an endodontic irrigant since the 1970s at concentrations ranging from 0.5 to 5.25%.[16] It is speculated that the use of NaOCl instead of water might have a positive impact on the amount of extruded debris.[17] In the present study, all canals were irrigated with 12 ml of a 2.5% NaOCl solution to reflect the clinical irrigation protocol. Vande Visse and Brilliant (1975)[5] reported that root canal instrumentation without irrigation did not produce a collectible amount of debris; however, a collectible amount of debris was extruded when an irrigant was used. They used 5 ml of the irrigant, 5.25% NaOCl, pertreatment of the canal, and concluded that, although irrigation was necessary, it led to extrusion. Sodium hypochlorite crystals that occurred after evaporation of the NaOCl were neglected. In this *in vitro* study, apically extruded irrigant and debris values were greater than in previous studies.[7,8,18] This discrepancy may be attributed to the total amount as well as the type of irrigant used, since much more irrigant volume was used when compared to other studies, and NaOCl was used instead of distilled water.

In this study, the method used for debris collection was that used by Myers and Montgomery (1991).[18] A certain degree of caution should be taken when transferring the present results to the clinical situation. Because of the absence of a physical back pressure provided by periapical tissues, apical extrusion was not limited.[19] Further, because of the zero back pressure used in this study design, gravity may have carried the irrigant out of the canal. This is an imminent shortcoming of *in vitro* designs with no periapical resistance, as already discussed by Myers and Montgomery (1991).[18] If the quantities of debris extruded in this study were extruded routinely in clinical practice, a higher incidence of postoperative pain might be anticipated. Furthermore, this study was limited to teeth with mature root morphology. The observed results should not be generalized to teeth with immature root development and open apices.

Many factors affect the amount of extruded intracanal materials, such as the instrumentation technique, instrument type and size, preparation endpoint and irrigation solution.[5,20] Even though, instrumentation techniques extrude some debris apically, there are differences among them. An increased cutting ability is usually associated with an increased cleaning efficacy,[19,21] but it may enhance debris transportation toward the apex when used in combination with a reciprocal motion. The SAF removes dentin with a

Table 1: Amount of apically extruded debris according to the instrument and position used (mean and standard deviations in grams)*

	Preparation methods	
	SAF (n = 10)	*Reciproc (n = 10)*
Teeth positions		
Upward (maxilla)	0.0000 ± 0.0000^{a}	0.3410 ± 0.1255^{c}
Downward (mandibula)	0.3542 ± 0.1210^{b}	1.7977 ± 0.2355^{d}

*Means followed by the different superscript letter (a, b, c, d) in same columns and rows are significantly different ($p < 0.05$)

back-and-forth grinding motion.[9] It can be speculated that a faster, aggressive Reciproc file with its characteristic design features, which removes a substantial amount of dentin in a shorter period of time, is unable to coronally displace the debris with the same efficiency as it cuts, and thus poses a risk of increased apical extrusion of debris.[2,22] According to the present results, the amount of extruded debris with SAF was significantly lower compared to that observed with the Reciproc, regardless of gravity, presumably due to its hollow design, which allows more space to carry debris out toward the orifice, thus avoiding its compaction in the root canal. The Reciproc instrument produced significantly more apically extruded debris and irrigant than the SAF system in both positions, and there may be several reasons for the observed differences. The Reciproc has a reciprocal motion that causes the instrument to progress forward continuously, which may push debris toward the apex. The Reciproc file has a noncutting tip, which may push debris toward the apex. Further, the obtained differences may have been caused by the preparation technique and the cross-sectional design of the instruments. The Reciproc has an identical S-shaped cross-sectional design with sharp cutting edges, whereas the SAF adapts itself to the cross-section of a given canal.[9] Bürklein and Schäfer (2012)[7] compared reciprocating single-file systems with the full-sequence rotary NiTi instruments and reported that the Reciproc extruded significantly more debris than all other files. The extrusion of apical debris using the SAF in the maxillary position was zero, however, in the mandibular position, the amount of extruded irrigant was not zero, and this result was different from a previous study,[10] in which the authors reported that there was no irrigant extrusion when teeth were placed vertically, apex down. It should be noted, however, they did not identify the irrigation solution or the amount of solution used.

During this study, the Reciproc was combined with manual needle irrigation. The needle was placed without binding to the root canal walls to direct the debris coronally. It has been shown that the penetration depth of the irrigation needle affects the extrusion of irrigants, with better cleaning when the irrigation needle is placed.[23,24] The 27-gauge side-vented needle tip was inserted passively and never allowed to bind as the irrigant was being deposited into the canal. However, the SAF's hollow design allows for continuous irrigation throughout the procedure. A special irrigation device (VATEA, ReDent-Nova) is connected by a silicon tube to the irrigation hub on the file and provides continuous flow of the irrigant of choice at a low pressure and at flow rates of 1 to 10 ml/min.

In most of the extrusion studies in the literature, all the apices of the teeth were positioned downward in the vial, representing a mandibular tooth. However, gravity may affect the amount of extruded solutions from the apex. Gravity may play a role in the accessibility of the irrigation solutions to the apex and also on their extrusion from the apex. Currently, to the best of our knowledge, only two studies in the literature have investigated the effects of gravity.[25,26] Despite this gravitational force, the irrigant was extruded in the maxillary position when manual needle irrigation was used, as in previous studies.[26] There was a significant difference between these two positions irrespective of instruments. In the current study, significantly more debris was extruded in the mandibular position than the maxillary position. The results of our study were consistent with the study of Williams et al (1995).[26]

Summary and Conclusion

In conclusion, under the conditions of this study, the hypothesis of the study was accepted: both gravity as well as the instrumentation system affected the amount of debris extrusion. The SAF was associated with less debris extrusion compared to the Reciproc in both mandibular and maxillary positions. SAF is more reliable system in terms of the amount of irrigant extruded related with gravity.

ACKNOWLEDGMENT

This study was supported by Hacettepe University Scientific Research Foundation Project No: 012D0720100.

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