Original Article

Evaluation of Apical Extrusion of Debris and Irrigant Using Two New Reciprocating and One Continuous Rotation Single File Systems

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Abstract

Objective: Apical extrusion of debris and irrigants during cleaning and shaping of the root canal is one of the main causes of periapical inflammation and postoperative flare-ups. The purpose of this study was to quantitatively measure the amount of debris and irrigants extruded apically in single rooted canals using two reciprocating and one rotary single file nickel-titanium instrumentation systems.

Materials and Methods: Sixty human mandibular premolars, randomly assigned to three groups (n = 20) were instrumented using two reciprocating (Reciproc and Wave One) and one rotary (One Shape) single-file nickel-titanium systems. Bidistilled water was used as irrigant with traditional needle irrigation delivery system. Eppendorf tubes were used as test apparatus for collection of debris and irrigant. The volume of extruded irrigant was collected and quantified via 0.1-mL increment measure supplied on the disposable plastic insulin syringe. The liquid inside the tubes was dried and the mean weight of debris was assessed using an electronic microbalance. The data were statistically analysed using Kruskal-Wallis nonparametric test and Mann Whitney U test with Bonferroni adjustment. P-values less than 0.05 were considered significant.

Results: The Reciproc file system produced significantly more debris compared with OneShape file system ($P<0.05$), but no statistically significant difference was obtained between the two reciprocating instruments ($P>0.05$). Extrusion of irrigant was statistically insignificant irrespective of the instrument or instrumentation technique used ($P>0.05$).

Conclusions: Although all systems caused apical extrusion of debris and irrigant, continuous rotary instrumentation was associated with less extrusion as compared with the use of reciprocating file systems.

Key Words: Dentin; Endodontics; Instruments; Instrumentation; Root Canal Therapy; Root Canal Irrigants

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INTRODUCTION

Cleaning and shaping of the root canal is one of the most important steps in any root canal treatment. Complete debridement of the root canal system is complicated by the presence of a complex system of isthmuses, accessory canals, fins, and deltas that can provide ideal locations for harbouring bacteria, debris and

necrotic tissue [1]. Therefore, chemical debridement via use of irrigant is a necessary adjunct to mechanical instrumentation to achieve the goals of canal preparation [2].

Numerous studies in the past have confirmed that chemomechanical debridement of the root canal results in extrusion of dentinal filings, pulp tissue fragments, necrotic tissues, microorganisms, and root canal irrigants through the apical foramen. All preparation techniques and instruments, despite maintaining working length strictly short of the apical terminus have reported to be associated with extrusion of infected debris, while some extruded less material and others extruded more [3-7].

Vande Visse and Brilliant were the first to quantify the amount of debris extruded apically during instrumentation. They found that when instrumentation with irrigation was done, there was significant extrusion of debris. Whereas, when instrumentation was done alone there was no debris extrusion [8].

A common finding of the studies examining the amount of apically extruded debris was that the techniques involving a push-pull filing motion usually tends to produce a greater mass of apical debris than those involving some sort of rotational action [3-7]. This has led to the hypothesis that rotation during instrumentation with both engine driven and balanced force techniques, results in collection of debris into the flutes of the instrument and its evacuation out of the root canal in a coronal direction [6].

Periapical inflammation and postoperative flare-ups may result from apical extrusion of debris that is also referred to as the "worm" of necrotic debris [9]. This is characterized by development of pain, swelling or both commencing within few hours or days after starting the root canal treatment. The symptoms are of sufficient magnitude that results in an unscheduled visit of a patient for emergency treatment [10].

The incidence of flare-ups during root canal treatment is reported to range between 1.4% and 16% [11]. Immunologically, debris extrusion results in the formation of an antigen-antibody complex leading to a severe inflammatory response and postoperative flare-ups [6]. Periapical extrusion of an irrigant such as sodium hypochlorite results in inflammation, hematoma, ecchymoses, and even necrosis and paresthesia in some cases, complicating the situation further [12]. The development of motor-driven nickel-titanium (NiTi) instruments has revolutionized cleaning and shaping of the root canal system in many ways. The performance of these systems is under constant evaluation due to the wide range of newer products being introduced in the market nowadays. The newer single-file NiTi systems such as WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), Reciproc (VDW, Munich, Germany), and OneShape (Micro-Mega, Besancon, France) are designed to completely prepare root canals with only one instrument. WaveOne and Reciproc files are used in a reciprocal motion and they run on special automated devices, whereas, OneShape file works in a continuous rotation.

At present, WaveOne files are available in three sizes with a fixed taper over the first 3mm from the tip; small (size 21 tip and .06 taper) for fine canals; primary (size 25 tip and .08 taper) for the majority of canals; and large (size 40 and .08 taper) for large canals. Reciproc files are also available in three sizes with a fixed taper over the first 3 mm from the tip; R25 (size 25 tip and .08 taper) for narrow canals, R40 (size 40 tip and .06 taper) for medium canals, and R50 (size 50 tip and .05 taper) for wide canals. Whereas OneShape file is available as a single file with a size 25 tip and a .06 fixed taper. The aim of this investigation was to compare the amount of debris and irrigant extruded apically following preparation of extracted human mandibular premolar teeth using two new reciprocating single-file systems (WaveOne and Reciproc) and one continuous rotation single-file system (OneShape).

Fig 1. The apparatus for collection of debris and irrigant

MATERIALS AND METHODS

Sixty freshly extracted single-rooted mandibular premolar teeth were collected for this study. The teeth were disinfected in 0.5% chloramines T trihydrate solution for one week. The external root surfaces of experimental teeth were cleaned of adherent tissue tags and hard deposits using the ultrasonic scaler. The teeth were then stored in physiologic saline solution until used. All teeth were radiographed in buccolingual and mesiodistal directions to check for a single canal and single apical foramen. The teeth with root curvature between 0°-10°, completely formed apex with patent foramina, apical diameter confirming to size 15 K-file, no signs of cracks, no internal and/ or external resorption, no root caries, no root canal calcification or obstruction, and no pulp stones were selected. Teeth that deviated from such findings were excluded from the study and were replaced by similar teeth.

The degree of root curvature was calculated from the buccolingual radiographs by adopting the method suggested by Schneider [13]. Apical gauging was carried out using size 10, 15, and 20 K-file (Dentsply Maillefer, Ballaigues, Switzerland). Only the teeth in which size 10 K-file could be barely seen through the apex and size 15 K-file that snugly fits at the working length were included in the study. All teeth were decoronated with a separating disc (BEGO, Germany) at the level of 15±1 mm from the apex perpendicular to the long axis of the root canal to obtain a relatively standard root canal length. The pulpal remnants were extirpated using a broach (Dentsply Maillefer, Tulsa, OK, USA). The working length was established 1 mm shorter than the length at which a size 10 K-file was visualized at the apical foramen when observed under a microscope (Roslane Meditech, Haryana, India) at x25 magnification. All external tooth surfaces were covered with two layers of nail polish except for 1 mm around the apical foramen. The test apparatus used for collection and evaluation of debris and irrigant extruded is presented in Fig 1. Using a hot instrument, holes were made in the stoppers of Eppendorf safe-lock tubes (Eppendorf India Limited, Chennai, India). Before assembling the whole apparatus, the Eppendorf tubes were weighed by placing them in an electronic weighing machine (AY 120 Analytic Balance, Shimadzu Corporation, Tokyo, Japan) with an accuracy of +/-0.0001 g that was present within an enclosed housing with its windows closed. Three consecutive measurements were taken for each tube and the mean measurement for each tube was considered to be its weight. If these three consecutive measurements showed very different numbers, the process of weighing was continued until three similar measurements were obtained that only differed in the last digit by 1-2. The teeth were then inserted under pressure into the Eppendorf tubes through the pre-cut holes in the stoppers.

To balance the air pressure between the inside and outside of the tubes, a bent 27-gauge needle was inserted alongside the stopper.

The whole apparatus was then fitted into a glass vial so that no contact with the collecting vial was possible during instrumentation. Aluminium foils were used to cover the vials to prevent the operator from viewing debris and irrigant extrusion during the canal preparation phase. All files used in this study were set into motion with a X-Smart Plus contra angle 6:1 reduction handpiece (Dentsply Maillefer, Ballaigues, Switzerland) powered by a torque-limited electric motor (X-Smart Plus, Dentsply Maillefer, Ballaigues, Switzerland). For each WaveOne and Reciproc files, the individual torque limit and rotational speed pre-programmed in the file library of the motor were used, whereas OneShape file was used by feeding the rotational speed and torque as mentioned by the manufacturer in the programmable menu present within the endomotor. No glide path was created before instrumentation with any system because the initial size of all canals was equal to size 15.

Irrigation was performed in exactly the same manner for all specimens with bidistilled water using a 5 mL disposable plastic syringe (DispoVan, Hindustan Syringes & Medical Devices Ltd., Faridabad, India) with a 30-gauge side-port opening needle (Canal Clean Tips, Biodent Co., Ltd., Korea). After every three pecking motions, the files were withdrawn from the canal, the flutes were cleaned, and the root canals were irrigated with 2 mL bidistilled water for 2 minutes.

The samples were equally divided into three groups (20 teeth per group). The preparation sequences were as manufacturer's instructions:

Group 1. Canal preparation was done with a OneShape file in a full sequence motion.

Group 2. Canal preparation was done with a Primary WaveOne file in a reciprocation motion.

Group 3. Canal preparation was done with a R25 Reciproc file in a reciprocation motion.

All root canals were prepared by a single endodontist and one file was used for preparation of four canals. The amount of extruded debris and irrigant was assessed by a separate examiner who was unaware to the experimental groups. Once the instrumentation had been completed, the extruded irrigant was collected into a disposable plastic insulin syringe (DispoVan, Hindustan Syringes & Medical Devices Ltd., Faridabad, India). The volume of irrigant collected was quantified through 0.1 mL graduation marks supplied on the barrel of the syringe. Once this was done, the volume of the extruded irrigant was added back into the Eppendorf tube. The root surface was washed with 1 mL of bidistilled water to collect the debris adhering to the root into the receptor tube. The receptor tubes were then stored in an incubator at 70° C for 5 days in order to evaporate the moisture before weighing the dry debris. The amount of debris extruded apically was obtained by subtracting the mean weight of the pre-weighed Eppendorf tube from the mean weight of Eppendorf tube containing the dried debris obtained from three consecutive measurements.

The data obtained were statistically analyzed by Kruskal-Wallis nonparametric test and Mann Whitney U test with Bonferroni adjustment. P-values less than 0.05 were considered significant.

RESULTS

The results of this study showed that the apical extrusion of debris and irrigants occurred independent of the type of file used in canal preparation. The reciprocating single-file systems (Reciproc and WaveOne) extruded more debris (0.61 mg and 0.42 mg, respectively) and irrigant (0.81 ml and 0.78 ml, respectively) as compared to OneShape (0.25 mg debris and 0.57 ml irrigant) rotary single-file NiTi instrument.

The Reciproc single-file system showed the greatest extrusion of both irrigant and debris as compared to the other systems tested. Due to the debris extrusion, the results showed a statistically significant difference ($P < 0.05$) between Reciproc and OneShape single-file systems, whereas no statistically significant difference ($P > 0.05$) was found between Reciproc and WaveOne and between WaveOne and OneShape single-file systems. However, for apical extrusion of the irrigant, the results were statistically insignificant ($P > 0.05$) irrespective of the instrument or technique used.

DISCUSSION

In the present study, the amount of extruded debris and irrigant due to chemo mechanical preparation of the root canals using OneShape, WaveOne, and Reciproc single file systems was evaluated. The reciprocating single-file systems (Reciproc and WaveOne) produced greater apical extrusion of debris and irrigant than continuous rotary single-file NiTi instrument (OneShape). Reciproc file system showed the greatest extrusion of both irrigant and debris than all other files. Apical extrusion of debris and irrigant is an inherent limitation associated with cleaning and shaping of root canals.

Many factors such as instrument size, type, canal preparation technique and endpoint, apical stop, irrigation solution, and irrigation delivery system play an important role in affecting the amount of debris and irrigant extrusion [5, 8,14-18]. Over the years, a variety of NiTi instruments have evolved all aiming at improving over the limitations presented in earlier systems [19]. The recently introduced WaveOne, Reciproc, and OneShape NiTi instruments have broken some paradigms related to root canal preparation. Unlike other instruments, these instruments do not require a sequential enlargement of the canal with different files of varying size and taper. Only one file is sufficient for entire enlargement of the root canal to a desired canal shape and size. In addition, providing a glide path with smaller files is not mandatory with these files, hence reflecting a paradigm shift. WaveOne and Reciproc files are designed to work in an unequal reciprocal motion with a large rotating angle in the cutting direction (counter clockwise) and a smaller rotating angle in the disengaging direction (clockwise). WaveOne files work in a 170° counter clockwise and 50° clockwise reciprocating motion, whereas Reciproc files are designed to function in a 150° counter clockwise and 30° clockwise rotation [20].

In this study, a total volume of 10 mL of bidistilled was used to irrigate the root canal between withdrawal and successive insertion of respective files during canal instrumentation. Bidistilled water was chosen for this study to reduce the chance that particulate matter indwelling in other irrigants might add to the amount of extruded debris. The passive injection of 2mL of irrigant over a period of 2 minutes using a monojet irrigating syringe with 30-gauge side-port opening needle was selected for use because this method would minimize forcing irrigant out of the canal [21]. In addition, it has also been documented that a size 30 gauge irrigation needle fits freely at depths just short of the physiologic terminus providing sufficient volume of irrigant for efficient flushing action [22]. The variations recorded in terms of weight of debris and irrigant extruded is a function attributed entirely to the different types of instruments, its cross-sectional design, and instrumentation techniques used in canal preparation while keeping the irrigation protocol constant. The Reciproc and WaveOne files due to their reciprocating and in-and-out filing motion, may act as a piston, extruding more debris and irrigant than OneShape instrumentation technique. While the file with continuous rotation act like a screw conveyor improving transportation of dentin chips and debris coronally [7].

The instrument design also plays a major role in the variations recorded in the apical extru-

sion of the debris by different instrumentation techniques [3]. Reciproc has S-shaped cross-sectional design with sharp cutting edges, whereas WaveOne is characterized by a triangular or modified triangular cross-section resulting in lower cutting efficiency [23]. OneShape file has three variable cross-sections along the length of the blade. Towards its tip, the file has a variable three-cutting-edge design. In the middle, the cross-section progressively changes from three to two cutting edges, and towards the shaft the blade has two cutting edges. The files with aggressive cutting ability remove a substantial amount of dentin in a relatively shorter period of time, but they are unable to displace the debris coronally and hence, enhance apical extrusion of debris when used in combination with a reciprocal motion [7]. In addition, OneShape instrument with variable cross-section that present along the length of the blade may provide more space for better elimination of debris. The presented results are consistent with the investigation carried out by Bürklein and Schäfer who reported that among the reciprocating single-file systems, Reciproc produced significantly more debris compared to WaveOne [7]. Though great care was taken to standardize the experimental groups and procedures, it must be emphasized that the results of this study should not be directly extrapolated to the clinical situation. In a histopathological study conducted by Bidar et al., no significant correlation in periapical inflammation following preparation of the root canal with conventional and rotary instrumentation was found [24]. But in an in vivo model, the presence of periapical tissues serves as a natural barrier providing a physical back pressure thereby limiting the apical extrusion of debris and irrigant [25]. While some have suggested to use floral foam to simulate resistance offered by periapical tissues [18,26], in this study no such attempt was made. Because of the lack of back pressure in this study, gravity may have played an important role in carrying the irrigant out of the canal. Besides, in a clinical setting, a positive or a negative pressure at the apex associated with normal or pathological periapical tissues plays an important role in determining the extent to which debris and irrigants extrude periapically [27]. Chemomechanical instrumentation of vital and necrotic teeth also plays an influential role in apical extrusion. In vital teeth, the pulp stump present serves as a barrier preventing the extrusion of debris. While in necrotic teeth no such resistance can be found [28]. In an *in vivo* study, Salzgeber and Brilliant found that in vital teeth, pulp tissue present apically and in lateral canals prevented extrusion of the irrigant out of the root canal. In cases of necrosis, the solution disperses when it reaches the apical region [29].

Curvature and presence of more than one canal are other factors that may affect the final amount of apical extrusion [6]. Furthermore, this study was limited to teeth with mature root morphology**.** Hence, the results observed in this study should not be generalized to teeth with incomplete root development and open apices. Dentin mineralization is less intense in young teeth than in teeth in older people, therefore these teeth would also be expected to be more liable to wear, causing greater extrusion [6].The association of extruded debris and irrigant apical with various instruments and techniques suggests reassessment of the creation of an apical dentinal plug or of the maintenance of patency approach. If apical plugs are formed, it is likely that the amount of debris and irrigants extruded would be far less than observed otherwise. In addition, apical plug formation would also prevent over instrumentation and extrusion of filling materials.

CONCLUSION

Based on the result of this study, both reciprocating as well as continuous rotation single-

file systems (with less amounts than the two others) produced apical extrusion of debris and irrigant. Extrusion of the irrigant is not influenced by the type of instrument or techniques used in canal preparation. It may be necessary to find instruments and techniques that would minimize the extrusion of such elements and help to reduce the incidence of flare-ups in endodontics.

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