ABSTRACT

Introduction: One of the most important factors which form the foundation of successful root canal treatment is cleaning and shaping without extruding significant amount of debris in periradicular tissues.

Aims: The objective of this study is to evaluate and compare the amount of apically extruded debris during root canal preparation with three different instrumentation systems.

Materials and Methods: The mesiobuccal canals of ninety mature, human mandibular molars were randomly divided into three groups \((n=30\) teeth/group). Each group was instrumented using one of the three different instrumentation systems: WaveOne Gold (WOG), self-adjusting files (SAFs), and Hyflex EDM (HEDM). The canals were irrigated using bidistilled water. Debris extruded was collected in preweighed Eppendorf tubes, and the extruded irrigant was evaporated. The weight of the dry extruded debris was established by comparing the pre- and post-instrumentation weight of Eppendorf tubes for each group.

Statistical Analysis: The debris extrusion was compared and statistically analyzed using the analysis of variance and the post hoc Tukey test.

Results: The WOG and HEDM file systems produced significantly more debris compared with SAF system \((P<0.05)\).

Conclusions: All instrumentation systems tested produced apical extrusion of debris. SAFs extruded significantly lesser amount of debris than WOG and HEDM.

Keywords: Apical extrusion, continuous rotation motion, endodontic instrumentation, Hyflex EDM, reciprocating motion, self-adjusting file, WaveOne Gold

INTRODUCTION

The possible consequences of cleaning and shaping are inflammation in periapical area resulting either from creation of wound due to pulp extirpations or from extrusion of debris into the periapical area.\(^1\)

It is accepted that contaminated as well as noncontaminated dentin and pulp tissue may have the potential to initiate an inflammatory reaction.\(^2\)

Initially, stainless steel hand files were extensively used for cleaning and shaping. Because of iatrogenic errors (ledging, zipping, canal transportation, apical extrusion, and blockage) caused by these files, attention has been directed toward the wide search for innovative materials, instruments, and techniques to obtain a clean disinfected debris-free canal and to minimize or prevent apical extrusion. Each system has its own advantages as well as disadvantages.

There are no data in the literature that shows comparative evaluation of WaveOne Gold (WOG), self-adjusting file (SAF),...
and Hyflex EDM (HEDM) on amount of debris extrusion in periapical tissues.

Hence, the purpose of this study was to quantitatively evaluate and compare the amount of apically extruded debris when these three file systems with different kinematics were used for the preparation of the root canal system.

**Aim and objectives**

The aim of the present study was to compare and quantitatively evaluate the apical extrusion of debris during biomechanical preparation using three different instrumentation systems.

1. WOG (Dentsply Sirona, Baillagues, Switzerland)
2. SAF (ReDent Nova, Ra’anana, Israel)
3. HEDM (Coltene/Whaledent, Altstätten, Switzerland).

**MATERIALS AND METHODS**

This *in vitro* study was conducted in the Department of Conservative Dentistry and Endodontics of A. M. C Dental College and Hospital, Khokhra, Ahmedabad, Gujarat, India, with an aim to compare and evaluate the apical extrusion of debris during biomechanical preparation using three different rotary instrumentation systems, namely, WOG, SAF and HEDM. Approval was taken from the Institutional Research Board of A. M. C Dental College and Hospital.

The mesiobuccal roots of 90 extracted human mandibular first molars with mature apices and root canals having curvature of 5°–20° according to Schneider’s method were selected for this investigation. Before experimentation, soft-tissue remnants, bone or tartars from the external root surfaces were removed with a periodontal curette. To create an easy reference point for the working length, the buccal cusp edge was flattened.

**Inclusion criteria**

- Mesiobuccal canals of permanent mandibular molars having canal curvature of 5°–20° according to Schneider’s method
- Noncarious tooth
- Tooth with completely formed apex.

**Exclusion criteria**

- Mutilated teeth
- Fractured teeth
- Teeth with root resorption
- Teeth with root caries
- Teeth with calcified canals and bifurcated/trifurcated root canals.

The teeth were opened for endodontic access with a round bur size 1/4 and access cavity preparation was refined with Endo-Z bur. Pulp tissues were removed with barbed broaches. A 10 No. K-file was passed 1.0 mm beyond the apical foramen to ensure the canal patency. Working length was established by subtracting 1.0 mm from this length. In addition, the root canal width near the apex was determined, and the specimen in which 15 No. K-file fits snugly at apex were selected.

Teeth were divided into three groups (*n* = 30)

1. Group 1 – BMP done with WOG file
2. Group 2 – BMP done with SAF
3. Group 3 – BMP done with HEDM file.

The present study used the experimental model described by Myers and Montgomery[3] for assessing the periapical extrusion of debris [Figure 1]. During the instrumentation process, the tooth and polyethylene tubes were shielded from the operator’s view by using a rubber dam.

**Instrumentation**

**Group-1, WaveOne Gold**

Thirty teeth were instrumented using single reciprocating file WOG (primary) in a pecking motion. The procedure included scouting the canal with 10 No. K file followed by irrigation. Then WOG Glider (Dentsply Sirona) was used, and the canal was again irrigated. WOG (primary) was then set to full working length. A preprogrammed reciprocating Endomotor (X-Smart Plus, Dentsply Maillefer) possessing the program for WOG (primary) file instrumentation was used. The flutes of the instrument were cleaned after three pecks. On meeting an obstruction, the file was removed, the canal was irrigated, recapitulated, and the file was re-introduced again into the canal. The instrumentation was continued till the WOG (primary) file reached the apex. Irrigation was done with 1.5 ml of bidistilled water between each instrument.

**Group-2, self-adjusting file**

Thirty teeth were prepared with the SAF system. Glide path was confirmed and 20 No. K-file was inserted up to the WL. The samples were prepared with this hand file. Then, the SAF (1.5-mm diameter and 25-mm length) was used in the canal using an RDT3 NX handpiece head (Re-Dent Nova) with an Endo-Mate (NSK) endodontic motor that produced 5000 vibrations per minute with the amplitude of 0.4 mm. The SAF was used for 4 min with distilled water irrigation at a flow rate of 1 mL/min.

**Group-3, Hyflex EDM**

Thirty teeth were instrumented by HEDM according to the manufacturer’s instructions, using gentle apical strokes and pecking movements with torque-controlled endodontic motor X-Smart (Dentsply) having a continuous rotation at 500 rpm.
These data were then analyzed using one-way analysis of variance (ANOVA) test and the difference between the groups were found using post hoc Tukey test.

The mean extrusion, median values, and range of extrusion (minimum and maximum values) were calculated. The P values were obtained after the comparison of groups.

Table 1 shows a comparison of mean and standard deviation values of apically extruded debris after the use of different systems. The highest amount of debris extruded by HEDM method (0.00311 ± 0.01206 mg), followed by WOG (0.00235 ± 0.001389 mg) and SAF (0.00189 ± 0.001047 mg).

The results of ANOVA (one-way ANOVA) test [Table 2] show statistical significance at the level of 95% (<0.05). \( F = 7.760 \). It means that amount of apically extruded debris with WOG-SAF-HEDM varies significantly.

Results of Tukey test [Table 3] showed that there was a significant difference in the apical extrusion of debris between Group I and Group II and Group II and Group III. There was no statistically significant difference among the Group I and Group III.

Graphical representation of mean and standard deviation values of different groups in terms of debris extrusion.

DISCUSSION
Following an endodontic intervention, an inter-appointment flare-up is a true complication characterized by the development of pain, swelling, or both.\(^4,5\)

During the process of elimination of microbes from the root canal system, in spite of strict control of the root canal length, there is a chance of extruding intracanal debris into the periapical tissues mainly consisting of dentinal filings, pulp tissue fragments, microorganisms, and intracanal irrigants. The apical extrusion of infected debris may have the potential to disrupt the balance between microbial aggression and host defense, resulting in episodes of acute exacerbations and flare ups.\(^4,5\)

The amount of debris extruded differs according to the preparation techniques because of the various designs of the file systems and irrigation devices. All instrumentation techniques used for biomechanical preparation result in apical extrusion of debris, even after the root canal preparation is maintained short of the apical terminus.\(^6\)
variance) between three groups WaveOne Gold-self-adjusting file; HEDM: Hyflex EDM

Table 2: Analysis of variance test using (one-way analysis of variance) between three groups WaveOne Gold-self-adjusting file-Hyflex EDM shows statistical significance at level of 95% (<0.05)

| Difference       | Sum of square | F     | Significance |
|------------------|---------------|-------|--------------|
| Between group    | 0.00          | 7.760 | <0.05        |
| Within group     | 0.00          |       |              |
| Total            | 0.00          |       |              |

WOG: WaveOne Gold; SAF: Self-adjusting file; HEDM: Hyflex EDM

Table 3: Post hoc test (Tukey test)

| (I) | (J) | Mean difference (I−J) | Significance |
|-----|-----|-----------------------|--------------|
| WOG | SAF | 0.000460              | >0.05        |
|     | HEDM| −0.000763             | <0.05        |
| SAF | WOG | −0.000460             | >0.05        |
|     | HEDM| −0.001223             | <0.05        |
| HEDM| WOG | 0.000763              | <0.05        |
|     | SAF | 0.001223              | <0.05        |

The mean difference is significant at the 0.05 level. WOG: WaveOne Gold; SAF: Self-adjusting file; HEDM: Hyflex EDM

Various methodologies and experimental designs have been used for the assessment of apically extruded debris.

In this study, Myers and Montgomery[31] experimental model was used. This system consists of a rubber stopper through which the instrumented root is forced and secured, a glass vial where the extruded debris or irrigants are collected and a flask made of glass into which the vial is placed. Periapical tissues are not present in this model to act as a natural barrier against apical extrusion, so the current result cannot be directly extrapolated to the clinical situation.

Various factors that affect apical extrusion are patency, apical diameter, canal curvature, working length, instrument design, technique of instrumentation, irrigation needle type, needle insertion depth, and irrigation methodologies or devices.

In our study, apical patency of selected samples was confirmed by the introduction of a 10 No. K-file. The patency file was not used during instrumentation as the file system we used was a single file system. The study by Lambrianidis et al.[71] evaluated the extrusion concept in terms of the maintenance of apical patency during instrumentation. They described a greater amount of extrusion occurred when the apical constriction remained intact.

In the present study, standardization of the size of apical foramen has been taken into consideration to ensure even distribution between the experimental groups. Tinaz et al.[80] suggested that more debris was extruded with an increase in apical diameter. However al-Omari and Dummer[11] reported no correlation between weight of debris extruded and parameters of canal shape, one of which was apical diameter.

Hinrichs et al.[9] concluded that factors such as canal length, curvature, and foramen size had no influence on the amount of debris extruded. Leonardi et al.[10] focused on roots with greater curvatures and determined no significant differences between slight and moderate curvatures. Martin and Cunningham,[11] Myers and Montgomery,[3] Beeson et al.[12] stated that filing up to the foramen resulted in more debris extrusion than compared to filing 1 mm shorter than the foramen.

The irrigation system also has a great impact on debris extrusion. Side-vented irrigation needles produce lesser debris extrusion apically.[13] Because of this reason we used side-vented needles in our study.

The result of our study shows a significant difference in the apical extrusion of debris between WOG and SAF, and SAF and HEDM. There was no statistically significant difference among the WOG and HEDM; however, WOG resulted in less amount of apical extrusion.

The less amount of apical extrusion by SAF (ReDent Nova, Ra'anana, Israel) can be explain by its innovative kinematics for cleaning and shaping that uses vibratory motion and circumferentially removes dentin from the walls of the canal, simultaneously enlarging and irrigating while maintaining the original canal configuration with less debris extrusion.[14]

The results of our study are similar to the study by Ozsu et al.[15] who compared SAFs with Protaper Universal, Protaper Next, and WaveOne and reported less amount of periapical debris extrusion with SAF. Dietrich et al.[16] Pawar et al.[17] Vyavahare et al.[18] have also stated that SAF system extruded less amount of periapical debris as compared to another rotary files system.

The study by Koçak et al. (2013)[19] stated that reciproc produced less debris than SAF. Contradicting in results of this study may be due to variations in the sample in that they used mandibular premolar with straight canal.
In our study, WOG showed less amount of debris extrusion than HEDM. WOG has a unique design features having a parallelogram-shaped off-centered cross-section with 85° cutting edges in contact with the canals with a variable and reducing taper. There is no study that compared WOG with HEDM in literature. However, studies in literature described the comparison of WOG with other rotary files system in terms of apical debris extrusion. In that Dincer et al. stated that there was less amount of periapical debris extrusion with WOG and Twisted File Adaptive System when compared with Protaper NEXT. Tomar et al. compared WOG with One Shape, F360, and Reciproc and reported less amount of periapical debris extrusion with WOG.

The findings of our study are not consistent with the findings of Uslu et al. who showed less amount of debris extrusion by Continuous Rotation Motion (HEDM) as compared to Reciprocation Motion (Reciproc Blue). The contradicting results of this study may be because of differences in methodology, experimental model, and file design (Reciproc Blue) used. The literature presents controversial results, especially when comparing reciprocating single file and continuous rotation multifile systems in terms of apical extrusion. With regard to movement kinematics, some authors have stated that reciprocal motion may act as a mechanical piston that appears to increase the transportation of debris toward the apex, while continuous rotation provides the coronal transportation of dentin. However, other authors have suggested that reciprocating motion actually imitates the balanced force technique that causes less debris extrusion.

There is a need of further studies to assess the extrusion of solid debris along with intracanal irrigants. Further in vivo studies are also required to evaluate post instrumentation pain with these instrumentation systems.

**CONCLUSIONS**

Under the conditions of this in vitro study, the following conclusion may be drawn:

- All the techniques tested caused apical debris extrusion to some degree
- There was a significant difference in the apical extrusion of debris between WOG and SAF, and SAF and HEDM
- There was no statistically significant difference among the WOG and HEDM.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

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