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Deepthi Kosaraju
Department of Conservative Dentistry and Endodontics, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India

Nagesh Bolla
HOD and Professor, Department of Conservative Dentistry and Endodontics, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India

Roopa Devi Garlapati
Reader, Department of Conservative Dentistry and Endodontics, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India

Sudhir Surapaneni
Department of Oral and Maxillofacial Surgery, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India

Corresponding Author:
Nagesh Bolla
HOD and Professor, Department of Conservative Dentistry and Endodontics, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India

Effect of coronal flaring on apical extrusion of debris using rotary and reciprocating single file systems: An *in vitro* study

Deepthi Kosaraju, Nagesh Bolla, Roopa Devi Garlapati and Sudhir Surapaneni

Abstract

The purpose of this study is to evaluate the effect of coronal flaring on apical extrusion of debris using single file systems. Sixty freshly extracted human single-rooted mandibular incisor teeth were selected, and divided into four groups (n=15) as group 1- reciprocating system with coronal flaring (rewf), group 2- reciprocating system without flaring (rewof), group 3- rotary system with flaring (rwf), group 4- rotary system without flaring (rwof). Coronal flaring was performed in groups 1 and 3 with gates glidden drills (gg drills) (mani, japan) using sizes 1, 2, 3 upto a working length of 10mm. In rotary groups instrumentation was done using one shape files and in reciprocating groups wave one gold files are used. The experimental model described by myers and montgomery was used. Sixty eppendorf tubes were taken. The net weight of the dry debris per sample was calculated by subtracting the original weight of the empty eppendorf tube from the gross weight of the eppendorf tubes containing debris.

The results obtained showed that Rotary single file system extruded less amount of debris than Reciprocating single files and Coronal flaring reduced the debris extrusion in both groups.

Keywords: Coronal flaring, single file systems, apical debris extrusion, reciprocation

1. Introduction

Chemo-mechanical preparation is one of the major prerequisites of contemporary root canal treatment. During mechanical preparation, dentin chips, remnants of pulpal tissue, irrigating solutions, and microorganisms and their by-products are often transported through the apical foramen and introduced into the periapical tissues. The procedure encompasses not only canal shaping but also the usage of intracanal irrigants to provide optimal cleanliness and disinfection within the root canal system [1, 2]. Although various methodologies have been introduced, one inherent problem related with all root canal shaping and cleaning procedures is the extrusion of intracanal debris into the periradicular tissues. Ingle and Taintor refer to this debris as a "worm" of necrotic debris [3].

The most significant complications related with or that occurs as a consequence of apical extrusion during root canal procedures is inter-appointment flare-up and postoperative pain. Flare-up can be described as the development of pain, swelling, or the combination of both during root canal treatment resulting in unscheduled visits of the patients. This occurrence is also called inter appointment emergency. The incidence of flare-ups during root canal treatment is reported to be in the range of 1.4% and 16 % by seltzer and naidorf [4].

Balance exists between microbial aggression and host-defense in asymptomatic chronic periradicular lesions. When microorganisms are extruded apically during chemomechanical preparation, the balance will be disrupted with the periradicular tissues being challenged by more irritants and an acute reaction will occur to re-establish the balance [5].

Although the presence of virulent microorganisms is a critical causative factor in the occurrence of flare-ups, it is also accepted that contaminated as well as non-contaminated dentine and pulp tissue may have the potential to initiate an inflammatory reaction. Currently, all preparation techniques and file systems are associated with extrusion of debris, even when the instrumentation is done short of the apical terminus.

The reciprocating motion relieves stress on the files by special counter clockwise (cutting action) and clockwise (instrument release) movements [6].

Although these systems can cut significant amounts of dentin in short periods, previous studies have shown that reciprocating systems tend to push more debris and solutions through the apex and toward the periapical tissues than rotary systems.
The multi-file system is based on a sequence of files in different sizes. The main disadvantage with these systems is that it is time-consuming because they may require multiple exchanges of file sizes [7, 8].
This led to the evolution of single-file NiTi instrumentation systems, which has been adopted by Dr. Yared. The single file system has many advantages over the conventional multi-file NiTi systems: (i) reduced working time because it requires only a single file to prepare all the canals (ii) Lower cross-contamination (iii) faster preparation has added the advantage of reducing the instrument fatigue which minimizes separation within canal without compromising the cutting efficiency. The recently introduced single-file nickel-titanium systems Waveone gold (Dentsply Maillefer, Ballaigues, Switzerland) and One shape (OS; Micro-Mega) are claimed to be able to prepare root canals with only one instrument completely [9].
Coronal flaring of a root canal removes cervical interferences from the root canal orifice, which present an obstacle to free access of endodontic instruments to the apical portion of the root canals [10]. Coronal flaring also facilitates early access of irrigants and allows rotary instruments to subsequently prepare the apical portion with less wall contact, and hence less friction [10, 11].
So, the purpose of this study was to assess the effect of coronal flaring on the amount of debris extruded apically during root canal preparation using Waveone gold (reciprocating) and OneShape (rotary) single-file systems. The null hypothesis was that there would be no difference between the instrumentation techniques regarding the amount of apically extruded debris.

2. Materials and Methodology

2.1 Sample preparation

Sixty freshly extracted human single-rooted mandibular incisor teeth were selected.
Inclusion criteria are:

- Single root canal
- No visible root caries, cracks, or fractures
- Teeth without internal or external resorption or calcification,
- A completely formed apex
- Root curvature < 5° according to Schneider's technique (1971).

Pre-operative mesio distal and bucco lingual radiographs of each tooth were taken to verify the presence of a single canal. To ensure standardization and obtain a reference point, the incisal edge of each tooth was flattened using a high-speed bur. The corono apical length of all teeth was standardized to 19 mm. Access cavities were prepared using diamond burs (Endo access bur #1 Dentsply, USA) with a high-speed handpiece under water cooling. After creating an access cavity, apical patency of the root canal was established with a size 10 K-file (Mani, Japan). The size of minor foramen was controlled by advancing a size 15 k-file to the working length, and those teeth with the tip of the file extruding beyond the apical foramen were excluded to standardize apical diameter. The working length was established 0.5 mm short of root apex. Initial root canal preparation of all the teeth was done using k- files (Mani, Japan) of sizes 15, 20, 25 to 0.5mm short of working length for creating a glide path and to ensure the same apical diameter of size 25 for all teeth in all groups.
Sixty teeth were then divided into four groups (n=15)
Group 1- Reciprocating system with coronal flaring (REWF)
Group 2- Reciprocating system without flaring (REWOF)
Group 3- Rotary system with flaring (RWF)
Group 4- Rotary system without flaring (RWOF)
Coronal flaring was performed in Groups 1 and 3 with Gates Glidden drills (GG drills) (Mani, Japan) using sizes 1, 2, 3 up to a working length of 10mm in both groups. The samples in both groups were then irrigated with distilled water.

2.2 Debris collection

The experimental model described by Myers and Montgomery was used. Sixty Eppendorf tubes were taken. Two caps were selected for each tube. A hole was created on one cap, and the other cap was left intact. Then all the empty Eppendorf tubes with intact cap were weighed to 10^{-6} precision using a Microbalance (Mettler Toledo).
Each tube was weighed three times, and the average mean was calculated. Teeth were inserted up to the cementoenamel junction in the cap with a hole and fixed with cyanoacrylate. A 27-Gauge needle was placed alongside the cap to equalize air pressure inside and outside the Eppendorf tubes. Then, each cap with the tooth and the needle was attached to its Eppendorf tube, and the Eppendorf tubes were fitted into glass vials. The entire apparatus was handled only by the vial and was not touched by fingers.

2.3 Root canal preparation

The teeth in the groups three and four were instrumented using Oneshape rotary files (Micro mega) (size 25.06 taper) with X-smart plus endo motor at a rotational speed of 400rpm and $4N/cm^2$ torque following manufacturer's instructions. Root canals were instrumented with Oneshape in a pecking motion, as recommended by the manufacturer and the instrument was cleaned after every three movements.
The teeth in groups one and two were instrumented using Waveone gold file (Dentsply mallifer) (size 25, 0.06 taper) with gentle inward pecking motion, and short amplitude strokes, to passively advance the file without pressure at a rotational speed of 400 rpm and 2 N/cm torque at the working length. The instrument was cleaned after every three movements. The canal of each tooth in all groups was irrigated with a total of 10ml distilled water during instrumentation.
Each instrument was used to prepare only one canal. The root canal instrumentation was completed when the file reached the working length. A single operator completed all procedures.
On completion of the canal preparation, the Eppendorf tubes were removed from the vials. The debris attached to the external surface of the apex of the tooth was collected by rinsing the root with 1 mL of distilled water in the tube. Then the tubes are replaced with intact caps. The tubes were then stored in an incubator at 60°C for three days to facilitate evaporation of distilled water as suggested by Kocak *et al*. (2013) [13]. Three consecutive weights were obtained for each tube, using microbalance with a precision of 10^{-6} and the mean value was calculated.
The net weight of the dry debris per sample was calculated by subtracting the original weight of the empty Eppendorf tube from the gross weight of the Eppendorf tubes containing debris.

Net weight = weight of Eppendorf tube with debris - weight of empty Eppendorf tube

3. Results

3.1 Statistical Analysis

The results were analyzed using SPSS version 20.0 (Statistical Package for Social science, IBM Corporation) Software. All the groups were analyzed for overall significance values using one way ANOVA (Analysis of Variance) test whereas, comparison within the group and other intergroup comparisons were done utilizing Post-hoc Tukey's tests with a level of significance set at $p<0.05$.

3.2 Results

Under the experimental conditions of the current *in vitro* study, the results obtained show that both instrumentations, i.e., rotary and reciprocating file systems caused apical extrusion of debris. However, the highest amount of debris was extruded in Reciprocating group without flaring (GROUP2-REWOF) and least amount of debris was observed in the Rotary group with flaring (GROUP3-RWF).

The amount of apically extruded debris was measured in micrograms (µg) and was derived by subtracting the pre-instrumentation weights from post-instrumentation weights.

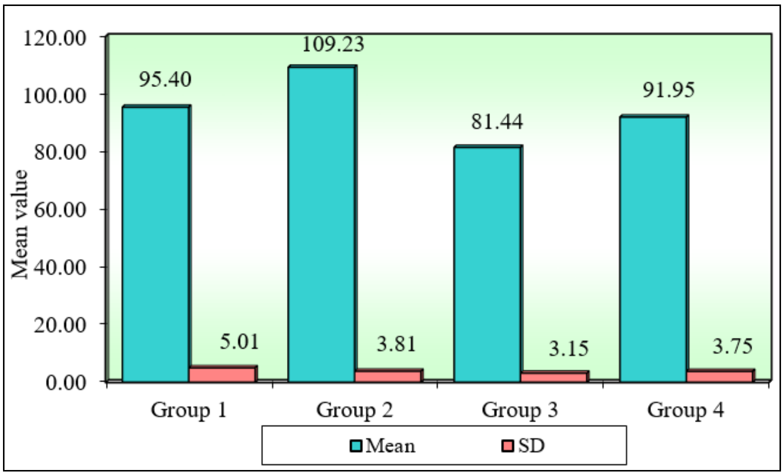
Table 1: Comparison of four study groups (1, 2, 3, 4) with respect to pre instrumentation weights in micrograms (µg) by one way ANOVA.

Variable	Sources of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	p-value
Pre-instrumentation	Between groups	3	496866261	165622087	0.6106	0.6109
	Within groups	56	15188580809	271224657		
	Total	59	15685447070			

Table-1 represents comparison between the groups and within the groups with respect to pre- instrumentation weights in micrograms (µg) by one way ANOVA. This comparison revealed that there was no statistical significance with a p-value of 0.6109 within the pre instrumentation group. This shows that no significant differences were found between groups in the pre-instrumentation weights ensuring standardization.

Table 2: Mean, SD and SE of gain from pre to post in weight of apically extruded debris in micrograms (µg) in four study groups (1, 2, 3, 4).

Groups	Mean	SD	SE
Group 1	95.40	5.01	1.29
Group 2	109.23	3.81	0.98
Group 3	81.44	3.15	0.81
Group 4	91.95	3.75	0.97



Graph 1: Comparison of four study groups (1, 2, 3, 4) with respect to gain from pre to post in weight of apically extruded debris in micrograms (µg).

Table2 & Graph1 represents the mean weight of the amount of apically extruded debris in micrograms (µg) in four study groups (1, 2, 3, 4). The mean values of apical debris extrusion for different groups were determined, and the highest amount of debris was seen in group 2 followed by group 1 and group 4, and lowest amount of debris was seen in group 3.

Group – 1 (REWF): Demonstrated a mean apical extrusion of 95.40 µg with a standard deviation of + 5.01.

Group – 2 (REWOF): Demonstrated a mean apical extrusion of 109.23 µg with a standard deviation of + 3.81.

Group – 3 (RWF): Demonstrated a mean apical extrusion of 81.44 µg with a standard deviation of + 3.15.

Group – 4 (RWOF): Demonstrated a mean apical extrusion of 91.95 µg with a standard deviation of + 3.75.

Table 3: Comparison of four study groups (1, 2, 3, 4) with respect to gain from pre to post in weight of apically extruded debris in micrograms (µg) by one way ANOVA.

Sources of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	p-value
Between groups	3	5924.46	1974.82	124.3245	0.0001*
Within groups	56	889.53	15.88		
Total	59	6813.99			

*$p<0.05$

Table-4 represents the comparison of weights of apically extruded debris within the groups and in between the groups using one-way ANOVA analysis. This comparison revealed that there was a highly statistically significant difference in the amount of debris extruded between experimental groups (p-value = 0.0001*).

Table 4: Pair wise comparisons of four study groups (1, 2, 3, 4) with respect to gain from pre to post in weight of apically extruded debris in micrograms (µg) by Tukey's multiple posthoc procedures.

Groups	Group 1	Group 2	Group 3	Group 4
Mean	95.40	109.23	81.44	91.95
SD	5.01	3.81	3.15	3.75
Group 1	-			
Group 2	p=0.0002*	-		
Group 3	p=0.0002*	p=0.0002*	-	
Group 4	p=0.0943	p=0.0002*	p=0.0002*	-

*$p<0.05$

Table-5 represents pair wise comparisons of four study groups (1, 2, 3, 4) with respect to the weight of apically extruded debris in micrograms (µg) by Tukey's multiple posthoc procedures. The comparisons were done between Group 1 & Group 2, Group1 & Group3, Group 1 & Group 4, Group 2 & Group3, Group 2 & Group 4, Group 3 & Group 4. This Intergroup comparison for experimental groups utilizing Post-hoc Tukey’s test revealed a statistically significant difference (**p=0.0002***) in extrusion between all Groups except between Group-1 and Group-4.

3.4 Inference

- The amount of apically extruded debris was analyzed statistically using one way ANOVA of variance followed by the Tukey post-hoc test.
- It was found that all techniques resulted in a measurable amount of debris extrusion during instrumentation.
- There is a significant difference between the rotary and reciprocating systems in the amount of apically extruded debris with less apical extrusion of debris seen in rotary systems.
- Subgroup analysis was done to check the differences between files used with flaring and without flaring within both rotary and reciprocating systems. Of all the groups Group-2 (reciprocating group without flaring REWOF) showed highest debris extrusion (mean difference = 109.23µg), and least was observed in case of Group-3 (rotary with flaring RWF) (mean difference = -81.44µg)
- A significant difference was not seen only between Group 1-reciprocating files with flaring (95.40 µg) and Group 4-rotary files with flaring (91.95 µg). All other pair-wise comparisons demonstrated statistical significance.

4. Discussion

Endodontic treatment is fairly foreseeable with reported success rates up to 86-98% [4]. Traditionally, success has been determined by lack of any symptoms and a normal radiological presentation. Likewise “failure” has variable definitions. It has been defined as a recurrence of clinical symptoms along with the presence of a periapical radiolucency [4]. A myriad of factors limit the success of a root canal therapy, and apical extrusion of debris is one of them. Extrusion of intracanal irrigants or debris is of frequent occurrence during cleaning and shaping procedures, and every instrumentation system or technique is associated with it. The apically extruded material in any form such as filling materials, medications, instrument fragments, irrigants, debris or necrotic pulp tissue may result in an endodontic flare-up or even treatment failure because of foreign body reaction [4, 5].

There are various techniques for root canal instrumentation including manual preparation, sonic and ultrasonic preparation, use of laser systems, and nickel-titanium instruments. Apical extrusion is common to all preparation techniques, but the difference in quantities depends on the method used. Martin and Cunningham (1982) [12] noted that endosonic preparation extruded less apical debris than hand instrumentation. Dr. Fairbourn *et al*. (1987) conducted a study to evaluate the effect of four preparation techniques on the amount of debris extruded. These techniques include conventional filing, sonic preparation, cervical flaring, and ultrasound preparation. The results showed that the sonic and cervical flaring method resulted in less amount of debris than other groups.

Recent advances in endodontics, regarding canal preparation, focused on the concept of "less is more," which in clinical practice results in a drastic reduction in the number of instruments needed for treatment, and in parallel at a reduction of potential errors. The dream of a canal preparation obtained with a single instrument, pursued by endodontists over fifty years, is slowly taking shape, opening the door to more and more promising prospects and results. These recently introduced Single file NiTi systems such as Waveone gold and Oneshape claim to be able to prepare and clean root canals with only one instrument completely. Use of single file rotary systems, are cost-effective, time-saving, reduce instrument fatigue and possible cross-contamination [13].

Tanalp *et al.* [14] also stated that increasing number of instruments might increase the amount of apical debris extrusion, showing the advantage of single file systems over multiple file systems. Oneshape is a new concept of single file instrumentation which uses a single instrument in a full clockwise rotation. Micro Mega (Besancon, France) developed this system. The Oneshape rotary system consists of only one single instrument made of a conventional austenite 55-NiTi alloy.

The Oneshape file system has a tip size of 25 and a constant taper of 0.06. The unique design of the Oneshape file system incorporates a variety of different cross-sections along the active length of the file, which ensures an optimal and improved cutting action in three areas of the root canal. At the apical part of the file, there are three symmetrical cutting edges. In the middle, there are two cutting edges. In the coronal part, there are two S-shaped cutting edges. The Oneshape file has a non-cutting safety tip. Its non-working (safety) tip ensures an effective apical progression avoiding obstructions which are often preceded by instrument separation [15]. Waveonegold instruments are manufactured utilizing a unique DENTSPLY proprietary thermal process, producing a super-elastic NiTi file. The gold process is a post-manufacturing procedure wherein the NiTi files are heat-treated and slowly cooled. The primary 25/0.07 file is used in the present study. The files have a parallelogram-shaped off-centered cross-section with 85° cutting edges in contact with the canal with a variable and reducing taper. Waveone gold has active cutting lengths of 16mm; shortened 11mm handles for improved posterior access and the same expanding ISO colour-coded ABS ring as Waveone. The tip of Waveone gold is ogival, roundly tapered and semi-active, modified to reduce the mass of the center of the tip and improve its penetration into any secured canal with a confirmed, smooth and reproducible glide path [16].

Standardization of the methodology used is essential for the minimization or elimination of procedural errors during evaluation of apical debris extrusion. In the present study, Standardization was achieved by selection of a narrow root, the inclusion of samples with similar initial apical diameter, canal curvature in the range of 10° to 20°, for all samples and a common irrigation system. The angle of curvature was measured using Schneider technique [17]. In the present study, single operator prepared all the canals to eliminate the inter-operator variable, and a standardized protocol was followed to decrease the number of variables and to increase the probability. Single-rooted mandibular anterior teeth were selected as most of the working part of the file is in contact with their narrow canal walls, which may not be possible in teeth with wider apical diameters and canal geometry as previously reported by Kirchhoff *et al.* [18] Single and straight roots also help in eliminating loss of working length and non standardized preparation and irrigation protocols. Single-rooted teeth with single and straight canals and low curvatures also help in reducing the complications that arise in instrumentation of curved canals.

Teeth with mature root apices were only selected, because the results may completely change with teeth in which apical closure has not occurred. Mc Kendry *et al.* [8] also made the same observations. The author explained that the reason why some patients experience more pain and flare-up might be due to the substantially high amount of debris extruded in cases with large apical foramen.

It can also be considered that even the microhardness of dentin tissue inside the root canal may influence the amount of apical extrusion since a softer dentin tissue would be more susceptible to being removed, and hence will be extruded more readily than one having a higher microhardness value. But it was impossible to make a standardization regarding root dentin hardness, so this factor is not considered in the present study.

Decoronation was performed to ensure standardization of the length of the specimens. Teeth were decoronated to obtain standardized working length. Moreover, it was found that the length of the canal was directly proportional to the amount of debris extruded. Although decoronation does not mimic the clinical situation and may improve the outcome of treatment by facilitating root canal access, it allows specimen standardization by eliminating some variables, such as crown anatomy and root canal length, thus providing a more reliable comparison of the proposed treatment techniques (AkanshaGarg, Ajay Nagpal, 2015). The single instrument was used for each tooth to ensure that wear of instruments did not influence the debris extrusion.

Early flaring, regardless of the method used widens the space and reduces file contact, which allows the file to progress more easily towards the apex. One of the most commonly used rotary instruments for early coronal flaring is a Gates-Glidden (GG) drill [19]. GG instruments are inexpensive, safe and clinically beneficial tools. In the present study, Gates-Glidden drills were used for coronal flaring because the single-file systems tested do not have a coronal flaring instrument.

Different methods for measuring debris extruded include Myers & Montgomery (1991) method using a precise microbalance, Lyophilization (dry freezing) (Tanalp *et al.* 2006), Filter column suction system (Ruiz-Hubard *et al.* 1987). The system that has gained the most attention and has been adopted by most studies about debris extrusion is the one proposed by Myers & Montgomery (1991).

Periapical tissues, which act as a natural barrier against debris extrusion, are mimicked in some laboratory models. Many proposals have been made for the simulation of the periodontal ligament to represent clinical conditions better. Hachmeister *et al.* (2002) proposed the use of floral foam to replicate the resistance of the periapical tissues to pressure exerted from within the root canal. But Altundasar *et al.* (2011) stated that foam might absorb irrigants and debris when used as a barrier, thus altering the results. So, no attempt has been made to simulate periapical tissues in the current study.

In the current study, distilled water was used as an irrigant to avoid possible crystallization of sodium hypochlorite (Huang *et al.* 2007) because sodium crystals that remain after the evaporation of the irrigation solution cannot be separated from the debris (Tanalp & Gungor 2014). These residues may cause considerable alteration of the results.

Quantitatively, evaluation of apically extruded debris has been done in either wet debris combined with irrigation (Huang, Ling, 2007) or dry debris with no irrigation (Huang X, J. Ling, 2007 Myers G.L, 1991) was done. To reduce the discrepancy between measurements due to the presence of irrigant which may be extruded in a high or low measurable amount from the apical foramen, quantitative evaluation for the amount of dry apically extruded debris was done in the present study. Moreover, in in-vitro studies, the apex of the teeth hang in the air, unlike the in-vivo situation in which teeth are surrounded by per apical tissues which could help to restrict apical extrusion of the irrigant.

Various studies used different methods for evaporation of water and to obtain dry debris. Fairbourn *et al.* used an incubator at 90ºC and a desiccator at room temperature for the drying procedure. In the present study, to obtain dry debris, the samples were placed in an incubator at 60º for five days that allow the distilled water to evaporate leaving behind dry debris.

Several methods, such as the scoring system and weighing the material using a microbalance, have been proposed to evaluate the amount of debris extruded apically. The scoring system evaluates the extruded debris in a semi-quantitative form and would not be sufficiently sensitive to detect tiny differences among the various canal preparation techniques. However, weighing with a microbalance may provide more accurate measurements because its precision is to ten-thousandths of a gram. The method chosen in the present study was to weigh the debris with a microbalance (Mettler-toledo) with a precision of 10^{-6}.

The results of the present study show that coronal flaring resulted in less amount of apical extrusion of debris with both file systems, and the least amount of apically extruded debris was observed in Group-3 (RWF) rotary (Oneshape) group with coronal flaring, whereas the highest amount of debris was associated with Group-4 (REWOF) reciprocating (Waveone gold) group without coronal flaring. The results obtained in the present study are in agreement with a study done by Thiago Machado Pereira *et al.* (2016) to determine the effect of cervical preflaring on the amount of apically extruded debris after root canal preparation using different instrumentation systems. These observations are also in agreement with previous findings by Topcuoglu *et al.* (2016) [20] whose study showed Reciproc and Waveone file (reciprocating) resulted in the greater amount of debris extrusion than Oneshape files (rotary). The authors also reported that coronal flaring reduced the amount of debris extruded in both rotary and reciprocating groups.

Every effort should be made to limit the periapical extrusion of intracanal material during treatment that has the potential to bring about serious systemic diseases such as endocarditis and septicemia, particularly in compromised patients. Further *in vivo* research in this direction could provide more insight into the biologic factors associated with correlations and consequences of apically extruded debris. Results of this study can be extrapolated to clinical conditions, but with caution because the presence of periapical and pulpal tissue may show resistance to apical extrusion of debris in clinical conditions.

Fig 1: Collected Sample

Fig 2: Eppendorf tubes

Fig 3: Weighing of eppendorf tubes using microbalance

Fig 4: Collection assembly for apiclly extruded debris

Fig 5: Grouping of samples

Fig 6: Eppendorf tube showing extruded dry debris

Fig 7: Incubator with eppendorf tubes

5. Conclusion
Within the limitations of the present study, the following conclusions can be drawn

- Both the instrumentation systems used in the present study produced a considerable amount of apical extrusion of intracanal debris.
- Rotary instrumentation produced less debris than reciprocating instrumentation.
- Coronal flaring significantly reduced the amount of debris extruded in both the groups with the least amount of debris in the rotary group with flaring (RWF-Group-3).
- Reciprocating instruments when used without coronal flaring resulted in the highest amount of debris extrusion.

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