Journal of Clinical Cases and Reports

ISSN: 2582-0435 Clinical Research | Vol 3 Iss S3

# A Quantitative Assessment of Apically Extruded Debris Associated with Different Retreatment Systems with and without Solvent *in vitro* Study

**Mustafa A Aldajani[1] and Shibu Thomas Mathew[2*]**

[1]*Department of Endodontics, Dammam Medical Complex, MOH, Dammam, Saudi Arabia*

[2]*Department of Endodontics, Riyadh Elm University, Riyadh, Saudi Arabia*

Correspondence should be addressed to Shibu Thomas Mathew, shibust_mathew@rediffmail.com

Received: August 12, 2020; Accepted: August 25, 2020; Published: September 02, 2020

## ABSTRACT

### INTRODUCTION

Various kinds of rotary instrument and technique are used for mechanical preparation of canal during root canal treatment. These instrument techniques may produce and push debris out of the canal. The purpose of this study was to evaluate the amount of apically extruded debris during retreatment using deferent rotary system (PTG & Hyflex EDM) and also to assess the influence of solvent on apical extrusion.

### MATERIAL AND METHOD

60 freshly extracted human single root premolar were used in the study. All teeth were instrumented using PTN and obturated by AH plus with single matching GP cone. The samples were randomly divided into two groups for retreatment using Hyflex EDM, PTG with and without solvent. G1A (Hyflex EDM with solvent), G1B (PTG with solvent), G2A (Hyflex EDM without solvent) and G2B (PTG without solvent). Debris extruded from apical foramen was calculated into pre-post weight Eppendorf tube which were stored in dissector at 70° for each vail and mean value was calculated. the different between the weight of vail (pre-post weight) represent the weight of debris extruded from apical foramen.

### RESULT AND CONCLUSION

The data obtained were analyzed statistically using (ANOVA) and Tukey post HSD test. The result show that all groups induced extrusion of debris. Hyflex EDM (G2A) without solvent has statistically the lowest mean value of apically extrusion compared to all other groups, followed by PTG (G2B) without solvent, PTG (G1B) with solvent. Hyflex EDM (G1A) with solvent had the statistically highest mean value of apically extruded debris.

## KEYWORDS

Root canal; ANOVA; Apical extrusion

## INTRODUCTION

A growing interest in endodontic retreatment has been seen as a result of an increasing demand to preserve teeth. Whenever feasible, nonsurgical endodontic

**Citation:** Shibu Thomas Mathew, A Quantitative Assessment of Apically Extruded Debris Associated with Different Retreatment Systems with and without Solvent in vitro Study. J Clin Cases Rep 3(S3): 20-30.

retreatment should be preferred over endodontic surgery [1]. The main cause of endodontic failure making retreatment necessary, is the persistence of bacteria in the root canal system as a consequence of insufficient cleaning, inadequate obturation, or coronal leakage [2].

Nonsurgical endodontic retreatment is indicated as the primary choice to eliminate or substantially reduce the microbial content from endodontically failed teeth. Nevertheless, well-compacted root fillings offer resistance to the instruments used for retreatment, leaving root filling residues. This restricts access to the apical foramen and impairs root canal disinfection and complete reshaping [3].

Apically extruded debris contributes to the severity of periapical inflammation reaction. Tissue reactions following root canal instrumentation shorter than the apex are milder than those reactions that follow instrumentation beyond the apex. Therefore, minimizing the amount of apically extruded debris should minimize postoperative discomfort and pain [4].

Because flare-ups may arise with any irritation directed towards periapical tissues, an instrumentation or irrigation technique should minimize the risk of apical extrusion, even though it may not be prevented. There has been a rapid evolution of root canal instruments and irrigation systems through the last decade, and many have been assessed for their debris extrusion potential. However, up to date all systems extruded debris, regardless preparation technique [5].

Root canal treatment may fail due to microbial factors including intraradicular or extraradicular infections [6-10] or nonmicrobial factors such as foreign body materials and true cysts [11]. In these cases, root canal retreatment is often preferred over apical surgery or extraction of the tooth [12,13].

It was demonstrated that significantly more debris was extruded in mandibular teeth than in maxillary teeth [14].

Gutta-percha removal can be achieved by several methods. One of these methods is the chemical technique, using different types of solvents, such as chloroform, eucalyptol, xylene, halothane, turpentine, or orange solvent [15-17].

Nevertheless, all studies agree that it is impossible to remove filling material from the root canal completely [18-20] and that all retreatment techniques cause various amounts of extruded irrigant and debris [21,22].

Resosolv (Pierre Rolland, Merignac, France) is a solvent specifically produced for solving resin-based sealers, such as AH Plus (Dentsply DeTrey, Konstanz, Germany). Resosolv contains 95% dimethylformamide and 1% - 2% Cinnamomum cassia.

The new Hyflex EDM (Coltene/Whaledent GmbH + Co. KG Germany) files constitute the 5$^{th}$ generation root canal files. HYFLEX EDM NiTi files have completely new properties due to their innovative manufacturing process using electric discharge machining.

The ProTaper Gold (PTG, Dentsply Maillefer, Ballaigues, Switzerland) system is a new type instrumentation system obtains a triangular cross section and a variable progressive taper. This progressively tapered design that serves to improve cutting efficiency and safety provides more durability for ProTaper Gold system.

Unfortunately, the information regarding the amount of extruded debris and data on the effectiveness of these instruments during retreatment procedure with and without solvent is limited.

Therefore, purpose of this study is to quantitively evaluate the amount of debris extruded during

retreatment using different rotary systems and its influence by the use of solvent.

The null hypotheses tested was that there are no significant differences on the amount of debris extruded among the two tested systems with or without the influence of solvent.

## 2. MATERIAL AND METHOD

The study was approved by Institutional Ethical Review Board of Ethical Committee of Riyadh Elm University with research registration number is FPGRP/43633004/181.

Sixty extracted human mandibular premolars with single root and canal confirmed radiographically were acquired. Soft tissue remnants and calculi on the external root surfaces were removed mechanically with ultrasonic scaler and radiographed buccolingually and mesiodistally to rule out any atypical canal morphology and to ensure that the teeth had single canals and one apical foramen.

Teeth was selected on the basis of the following inclusion criteria: Single root, single canal, absence of root canal fillings, mature centrally located apical foramen, For all roots, #20 K-file was inserted passively to full WL and couldn't pass beyond the WL through the apical foramen [23], patent apical foramen. For all roots, #10 K-file could pass through the apex without any resistance; while #15 K-file could pass through the apex with resistance and root devoid of any resorption, crack or fracture (Figure 1 and Figure 2).

***The Exclusion criteria***

Canals with dimension that exceeded size #15 K was excluded, more than one canal and Root canal treated canal.

**Figure 1:** Decoronated samples.

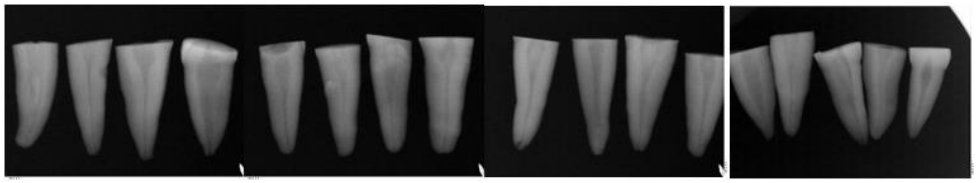


**Figure 2:** X-ray of decoronated samples.

***Sample Preparation***

The teeth were stored in 50% alcohol and 50% glycerin solution until proper experiment. For more uniform standardization, and to obtain a reference point the crowns were cut at the CEJ and flattened using steel discs, under copious water, and a final dimension of 15 mm root length was achieved for each tooth. Standard oval access was gained with access cavity burs (Endo Z Access Kit, Dentsply Tulsa, Oklahoma, USA), with a high-speed headpiece under water cooling. Then, all roots were measured using digital caliper.

***Pilot Study***

Before starting the main study, a pilot study was conducted using the same protocol in preparing and instrumentation of the root canal. Three roots were used using one preparation technique for every canal.

The pulpal tissue was removed by using barbed broach. The exact location of apical foramen and the patency of the canals were verified by insertion of #15 K file

(Dentsply Maillefer, Ballaigues, Switzerland) into the canal and advancing until it was visualized at the apical foramen. The WL was obtained by subtracting 1mm from the length of the root.

***Treatment Group***

All instrumentations were done by single operator [24]. In this group the root canals prepared with the ProTaper next system (Dentsply Maillefer, Ballaigues, Switzerland) in a crown-down manner using an endodontic motor (X Smart, Dentsply Maillefer, Ballaigues, Switzerland) at a rotational speed of 300 rpm and 2 NCm torque as per the manufacturer's instructions. X1 (size 17/0.04 taper) and X2 (size 25/0.06 taper) files were used to prepare the coronal and middle thirds of the roots. Apical enlargement performed using the X3 (size 30/0.07 taper) file. A gentle in-out brushing motion was used, in each sample the root canals were irrigated by 2 ml of 2.5% NaOCl between each instrument. The smear layer removed by irrigation with 10 ml of 2.5% NaOCl, 10 ml of 17% ethylenediaminetetraacetic acid, and 10 ml of 2.5% NaOCl, respectively, followed by a final rinse with 10 ml of distilled water.

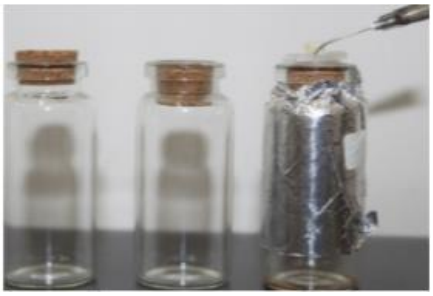


**Figure 3:** Vials.

The root canals were dried with sterile paper points and obturated using GP and epoxy resin-based sealer (AH Plus, Dentsply DeTrey GmbH, Konstanz, Germany) by Single Matching gutta percha (X3 GP cone). All specimens were stored in 100% humidity at 37°C for 1 month. At the end of the storage period, the teeth attached to Eppendorf tubes (Figure 3).

***Instrument and Debris Collection***

The stoppers were separated from the Eppendorf tubes. An analytical balance (ANDW-GR-120 microbalance, ANDW-GR-120 Instrument, Japan) used to measure the initial weights of the tubes. Eppendorf tube were weight to 4-10 using electronic balance, three consecutive weights obtained for each tube, and the mean were recorded. 60 teeth were numbered and randomly assigned into 4 groups of 15 specimens each. A hole created on each stopper. Each tooth inserted up to the cementoenamel junction, and a 27-gauge needle placed alongside the stopper for used as a drainage cannula to balance the air pressure inside and outside the tubes. Then, each stopper with the tooth and the needle attached to its Eppendorf tube, and the tubes fitted into the vials. Experimental model described by Myers and Montgomery 1991 was used, a hole was created in the cap of Eppendorf tube and tooth was inserted to its CEJ, 27-gauge needle alongside the cap as a derange canula and to parlance the Air pressure inside and outside the tube, stoppers were then attached to their Eppendorf tube, and the tube were fitted into vials. The assembly was secured to prevent any movement that disrupt standardization of the instrumentation procedure.

***Retreatment Protocol Performed***

All retreatment procedures completed by a single operator to avoid variation and eliminate biases. The operator shielded from seeing the root apex during instrumentation by an aluminum foil that covered the Eppendorf tube. The retreatment procedure was considered finish when the working length was reached, no more GP and sealer could be seen on the surface at last used instrument, and farther radiographic examination revealed no radiographic material. if the canal was judged un clean the final rotary file was again inserted several times. In addition, the time required for complete removal of the root filling were recorded in seconds by the aid of a stop watch. Time needed for file

change, file cleaning and irrigation was excluded (Figure 4).

**Figure 4:** Aluminum foil that covered the Eppendorf tube.

***Sample Grouping***

The specimens were randomly divided into two equal groups according to the retreatment systems as follows:

- Group 1A (with solvent) (n = 15): The filling material were removed using HYFLEX EDM.
- Group 1B (with solvent) (n = 15): The filling material were removed using ProTaper Gold files.
- Group 2A (without solvent) (n =15): The filling material were removed using HYFLEX EDM.
- Group 2B (without solvent) (n = 15): The filling material were removed using ProTaper Gold.

***Method of Sample Fixation and Debris Collection***

After the retreatment procedure were completed, the stopper, needle, and tooth separated from the bottle, and the debris adhering to the root surface collected by washing the root with 1 ml distilled water in the tube, before weighing the dry debris. The tubes stored in a desiccator at 70ºC for 5 days to evaporate the distilled water before weight (Figure 5).

Weight calculations was performed by a second examiner who was blinded to the group assignment. Three consecutive weight are obtained for each tube and the mean value was calculated. The vials weighed using the same method to obtained their final weight including the extruded debris. The vials weighed 3 times, and the mean value calculated.

**Figure 5:** Eppendorf tube stabilizer.

***Final Debris Collection***

The dry weight of the extruded debris was calculated by subtracting the weight of the empty vial from that of the vial containing debris [23-25].

***Statistical Analysis***

Statistical analysis was performed using SPSS version 21.0 software. Data was prescribed as mean and standard deviation values. The data was analyzed using one-way analysis of variance (ANOVA), the Kruskal-Wallis test ($p > 0.001$). P-values equal to or more than 0.05 ($P \geq 0.05$) were considered as statistically non-significant (NS), and P-values less than 0.05 ($P < 0.05$) were considered as statistically significant (*), whereas P-values equal to or less than 0.01 ($P \leq 0.01$) were considered as statistically highly significant (**), and P-values less than 0.001 ($P \leq 0.001$) were considered as statistically very highly significant (***).

## 3. RESULTS

Data that represent the amount of AED values for all groups were displayed in the appendices (I, II, III, IV).

| Group number | Operation time |
|---|---|
| G1A(HYFLEX) | 3 Minutes |
| G1B(PTG) | 3 Minutes |
| G2A(HYFLEX) | 4 Minutes |
| G2B(PTG) | 4 Minutes |

**Table 1:** The operating standard time for retreatment procedure.

The operating time are shown in Table 1. Statistical significant difference was not seen in between the groups before retreatment (Figure 6).

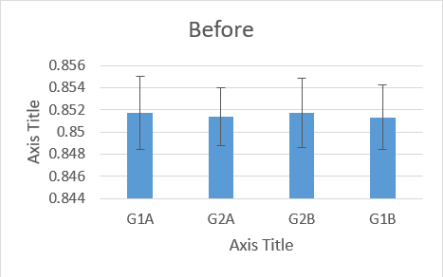



**Figure 6:** The Weight of Eppendorf tubes before retreatment.

According to the results of this study, all groups induced extrusion of debris with different values.

All retreatment techniques caused extrusion of apical debris. The mean standard deviation minimum and maximum weight debris extruded apically in each group are summarized in Table 2.

| | | N | N | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| **Before** | G1A | 15 | .851727 | .0032775 | .0008463 | .849912 | .853542 | .8462 | .8556 |
| | G2A | 15 | .851340 | .0026095 | .0006738 | .849895 | .852785 | .8431 | .8526 |
| | G2B | 15 | .851680 | .0031237 | .0008065 | .849950 | .853410 | .8462 | .8572 |
| | G1B | 15 | .851313 | .0029221 | .0007545 | .849695 | .852932 | .8465 | .8575 |
| | Total | 60 | .851515 | .0029228 | .0003773 | .850760 | .852270 | .8431 | .8575 |
| **After** | G1A | 15 | .860467 | .0036829 | .0009509 | .858427 | .862506 | .8535 | .8675 |
| | G2A | 15 | .853193 | .0014069 | .0003632 | .852414 | .853972 | .8526 | .8580 |
| | G2B | 15 | .858700 | .0038916 | .0010048 | .856545 | .860855 | .8510 | .8638 |
| | G1B | 15 | .859433 | .0113502 | .0029306 | .853148 | .865719 | .8496 | .8978 |
| | Total | 60 | | | | | | | |

**Table 2:** Comparison of weight of the tube before and after instrumentation for all groups.

The weight obtained after the use of each systems where subtracted from the pre-instrumentation weight, giving the result of actual amount of debris extruded by rotary files used for retreatment (Table 3) (Figure 7).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Difference** | G1A | 15 | .008760 | .0050279 | .0012982 | .005976 | .011544 | .0020 | .0212 |
| | G2A | 15 | .001853 | .0026808 | .0006922 | .000369 | .003338 | .0001 | .0095 |
| | G2B | 15 | .007013 | .0044993 | .0011617 | .004522 | .009505 | .0000 | .0133 |
| | G1B | 15 | .008127 | .0112005 | .0028920 | .001924 | .014329 | .0003 | .0468 |
| | Total | 60 | | | | | | | |

**Table 3:** Difference between pre and post-weight tube.

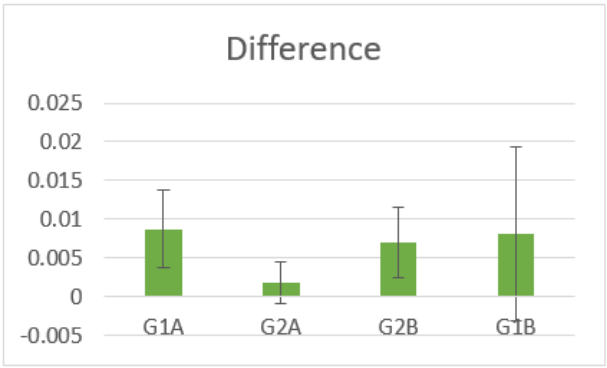



**Figure 7:** Bar chart graph for the difference between pre-weight and post-weight.

According to the statistical analysis there was a significant difference among the groups as shown on (Table 5) analyzed suing (ANOVA) (P = 0.026) (Figure 8).

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| | | Sum of Squares | Df | Mean Square | F | Sig. |
| **Before** | Between Groups | .000 | 3 | .000 | .080 | .971 |
| | Within Groups | .001 | 56 | .000 | | |
| | Total | .001 | 59 | | | |
| **After** | Between Groups | .000 | 3 | .000 | 3.977 | .012 |
| | Within Groups | .002 | 56 | .000 | | |
| | Total | .003 | 59 | | | |
| **Difference** | Between Groups | .000 | 3 | .000 | 3.322 | .026 |
| | Within Groups | .002 | 56 | .000 | | |
| | Total | .003 | 59 | | | |

**Table 5:** Statistical analysis of one way (ANOVA).

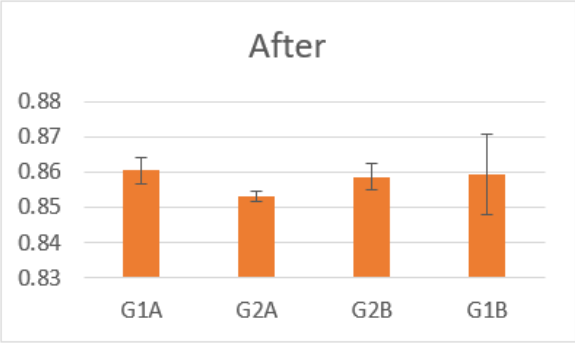


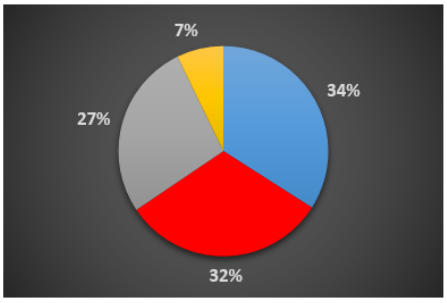

**Figure 8:** Bar chart graph for AED weight after retreatment.

Tukey HSD (honest significant difference) test was performed to know where the statistical significant is by pairwise compensation.

It was found that the statistical significant was found only between G1A (HYFLEX EDM with solvent) and G2A (HYFLEX EDM without solvent), (P = 0.031).

Tuckey HSD post hoc test showed that G1A caused significantly more debris extrusion compared to G2A (P >0.05).

There was no significant difference between G1A and G2B (P < 0.05), G1A and G1B (P< 0.05), and G2B and G2A (P <0.05), G1B and G2A (P <0.05), and G1B and G2A (P <0.05).




| | | | |
|---|---|---|---|
| G1A | 0.00876 | | 34% |
| G1B | 0.008127 | | 32% |
| G2B | 0.007013 | | 27% |
| G2A | 0.001853 | | 7% |

**Figure 9:** Bar graph showing the significant differences between groups.

According to the data, in an increasing order, the amount of debris extruded from the apex was, G2A (Hyflex EDM without solvent) (0.008153) followed by G2B (ProTaper Gold without solvent) (0.007013), followed by G1B (ProTaper Gold with solvent) (0.00127), with G1A (Hyflex EDM with solvent) (0.008760), having the highest amount of debris extrusion respectively.

A significant difference was observed between groups G1A and G2A (P >0.05). As shown in (Figure 9).

## DISCUSSION

Root canal instrumentation requires technical knowledge to be applied to the biological area, so as to obtain a well instrumented and disinfected canal without damage to its biological structure. Since the root canal includes the

space that contains the pulpal organ, one of its ends is in the pulp chamber and the other(s) corresponds to the apical foramina. Thus, instrumentation of root canals can cause extrusion of material through the foramen by virtue of the anatomy of the canal itself [26].

In root canal retreatment, complete removal of preexisting obturation material is an important factor because it allows reinstrumentation and re-disinfection of the root canal system. An appropriate retreatment technique should be selected to completely remove the preexisting filling material as fast as possible, while reducing the amount of apical extrusion, to prevent pain and inflammation.

Apical extrusion of debris during primary root canal treatment has been reported for all canal preparation techniques [27]. The extrusion of infectious tissue and irrigants into the periapical space has been considered as one of the reasons for poorer outcomes of root canal treatment [9,10,21,28]. The leading reason for failure after retreatment is debris extruded from the apex during the retreatment procedure [9]. However, furthermore to the above factors, extrusion of root filling materials such as sealer and gutta-percha from the root canal system must be considered for retreatment cases [10,21]. To date, only few studies have assessed debris extrusion during retreatment procedures in straight root canals [21,22,29,30].

The main objective of this study was to compare the amount of AED by different rotary systems (with and without solvent).

Moreover, no study has quantitatively evaluated the amount of debris extruded apically when using the Hyflex EDM and ProTaper Gold rotary NiTi retreatment systems. Therefore, this study aimed to evaluate the debris extruded apically during the removal of root canal filling material with the Hyflex EDM and ProTaper Gold systems.

It has been stated that the in vitro setup suspended the apex in air, whereas in vivo the apex would be surrounded by granulomatous or periradicular tissues, which could help restrict apical extrusion to some extent [21,24].

Vande Visse and Brilliant [31] showed that instrumentation with irrigation produced significantly more extruded debris than did instrumentation without irrigation. In the current study, distilled water was used as an irrigation solution to avoid any possible crystallization of NaOCl [21].

A review of the literature revealed that only a few studies evaluated the amount of debris extruded from the apex during retreatment [21,29,32,33]. Thus, the present study compared the amount of debris extruded from the apex during retreatment procedures with and without solvent using Hyflex EDM and ProTaper Gold file systems, which have different designs and working principles.

The potential effect of gravity on debris extrusion has been previously mentioned [34-36] and it has been suggested that gravity may play a role both in access of the irrigants to the apical foramen and their extrusion beyond the canal terminus [37].

There is an absence of physical back-pressure provided by the periapical tissues in in vitro studies. Therefore, the clinical relevance of the results of the present study should be interpreted with caution. Myers and Montgomery have discussed such shortcomings of in vitro studies.

The present study compared the amount of debris extruded from the apex during retreatment procedures using PTG, Hyflex EDM file systems, which have different designs and working principles. According to the results of the present study, the Hyflex EDM (without solvent) group extruded significantly least debris than the

Hyflex EDM (with solvent) group. Thus, the null hypothesis of the present study was rejected.

## CONCLUSION

Within limitation of the present study, following conclusion can be driven:

- Apical extrusion was seen in all groups.
- Under the experimental condition of the present study it can be possible to conclude that Hyflex EDM file system with solvent (G1A) led to higher level of apical extrusion. The least apical extrusion was recorded using Hyflex EDM system without solvent (G2A). Furthermore, there was statistical significant found between G1A and G2A ($P = 0.031$).

## LIMITATION OF THE STUDY

1. Absence of physical back pressure provided by periapical tissue, apical extrusion was not limited.
2. Zero back pressure used in this study design, gravity may have carried the irrigant out of the canal.

## RECOMMENDATIONS

1. Evaluate the effect of instruments on the amount of apically extruded debris with and without apical patency.
2. Evaluate the effect of instruments on the amount of apically extruded debris with curved roots.
3. Evaluate the amount of apical extrusion debris using other instrumentation technique.
4. Study the effect of various irrigating solution techniques and concentrations on the amount of apical extrusion of debris.
5. Evaluate the periapical responses using different instrumentation systems: An in vivo study.

## REFERENCES

1. Paik S, Sechrist C, Torabinejad M (2004) Levels of evidence for the outcome of endodontic retreatment. Journal of Endodontics 30(11): 745-750.
2. Giuliani V, Cocchetti R, Pagavino G (2008) Efficacy of ProTaper universal retreatment files in removing filling materials during root canal retreatment. Journal of Endodontics 34(11): 1381-1384.
3. Só MVR, Saran C, Magro ML, et al. (2008) Efficacy of ProTaper retreatment system in root canals filled with gutta-percha and two endodontic sealers. Journal of Endodontics 34(10): 1223-1225.
4. Hinrichs RE, Walker III WA, Schindler WG (1998) A comparison of amounts of apically extruded debris using handpiece-driven nickel-titanium instrument systems. Journal of Endodontics 24(2): 102-106.
5. Borges ÁH, Pereira TM, Porto AN, et al. (2016) The influence of cervical preflaring on the amount of apically extruded debris after root canal preparation using different instrumentation systems. Journal of Endodontics 42(3): 465-469.
6. Sjögren U, Figdor D, Persson S, et al. (1997) Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. International Endodontic Journal 30(5): 297-306.
7. Sundqvist G, Figdor D, Persson S, et al. (1998) Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 85(1): 86-93.
8. Sunde PT, Olsen I, Lind PO, et al. (2000) Extraradicular infection: A methodological study. Dental Traumatology 16(2): 84-90.
9. Siqueira Jr JF (2003) Microbial causes of endodontic flare-ups. International Endodontic Journal 36(7): 453-463.
10. Nair PNR (2006) On the causes of persistent apical periodontitis: A review. International Endodontic Journal 39(4): 249-281.

11. Nair PR (2004) Pathogenesis of apical periodontitis and the causes of endodontic failures. Critical Reviews in Oral Biology & Medicine 15(6): 348-381.
12. Bergenholtz G, Lekholm U, Milthon R, et al. (1979) Retreatment of endodontic fillings. European Journal of Oral Sciences 87(3): 217-224.
13. Çalışkan MK (2005) Nonsurgical retreatment of teeth with periapical lesions previously managed by either endodontic or surgical intervention. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 100(2): 242-248.
14. Uzunoglu E, Görduysus M (2014) Apical extrusion of debris and irrigant using novel preparation systems. The Journal of Contemporary Dental Practice 15(4): 423-427.
15. Farzaneh M, Abitbol S, Friedman S (2004) Treatment outcome in endodontics: The Toronto study. Phases I and II: Orthograde retreatment. Journal of Endodontics 30(9): 627-633.
16. Tamse A, Unger U, Metzger Z, et al. (1986) Gutta-percha solvents - a comparative study. Journal of Endodontics 12(8): 337-339.
17. Wong R (2004) Conventional endodontic failure and retreatment. Dental Clinics of North America 48(1): 265-289.
18. Wilcox LR, Krell KV, Madison S, et al. (1987) Endodontic retreatment: Evaluation of gutta-percha and sealer removal and canal reinstrumentation. Journal of Endodontics 13(9): 453-457.
19. Hülsmann M, Drebenstedt S, Holscher C (2008) Shaping and filling root canals during root canal re-treatment. Endodontic Topics 19(1): 74-124.
20. Rödig T, Reicherts P, Konietschke F, et al. (2014) Efficacy of reciprocating and rotary NiTi instruments for retreatment of curved root canals assessed by micro-CT. International Endodontic Journal 47(10): 942-948.
21. Huang X, Ling J, Wei X, et al. (2007) Quantitative evaluation of debris extruded apically by using ProTaper Universal Tulsa rotary system in endodontic retreatment. Journal of Endodontics 33(9): 1102-1105.
22. Topçuoğlu HS, Aktı A, Tuncay Ö, et al. (2014) Evaluation of debris extruded apically during the removal of root canal filling material using ProTaper, D-RaCe, and R-Endo rotary nickel-titanium retreatment instruments and hand files. Journal of Endodontics 40(12): 2066-2069.
23. Bürklein S, Schäfer E (2012) Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. Journal of Endodontics 38(6): 850-852.
24. Myers GL, Montgomery S (1991) A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. Journal of Endodontics 17(6): 275-279.
25. Kustarci A, Altunbas D, Akpinar KE (2012) Comparative study of apically extruded debris using one manual and two rotary instrumentation techniques for endodontic retreatment. Journal of Dental Sciences 7(1): 1-6.
26. Vansan LP, Pécora JD, da COSTA WF, et al. (1997) Comparative in vitro study of apically extruded material after four different root canal instrumentation techniques. Brazilian Dental Journal 8(2): 79-83.
27. Tanalp J, Güngör T (2014) Apical extrusion of debris: A literature review of an inherent occurrence during root canal treatment. International Endodontic Journal 47(3): 211-221.
28. Seltzer S, Naidorf IJ (1985) Flare-ups in endodontics: I. Etiological factors. Journal of Endodontics 11(11): 472-478.
29. Dincer AN, Er O, Canakci BC (2015) Evaluation of apically extruded debris during root canal retreatment with several NiTi systems. International Endodontic Journal 48(12): 1194-1198.

30. Silva EJNL, Sá L, Belladonna FG, et al. (2014) Reciprocating versus rotary systems for root filling removal: Assessment of the apically extruded material. Journal of Endodontics 40(12): 2077-2080.
31. VandeVisse JE, Brilliant JD (1975) Effect of irrigation on the production of extruded material at the root apex during instrumentation. Journal of Endodontics 1(7): 243-246.
32. Lu Y, Wang R, Zhang L, et al. (2013) Apically extruded debris and irrigant with two N i-T i systems and hand files when removing root fillings: A laboratory study. International Endodontic Journal 46(12): 1125-1130.
33. Çanakçi BC, Ustun Y, Er O, et al. (2016) Evaluation of apically extruded debris from curved root canal filling removal using 5 nickel-titanium systems. Journal of Endodontics 42(7): 1101-1104.
34. Leonardi LE, Atlas DM, Raiden G (2007) Apical extrusion of debris by manual and mechanical instrumentation. Brazilian Dental Journal 18(1): 16-19.
35. Elmsallati EA, Wadachi R, Suda H (2009) Extrusion of debris after use of rotary nickel-titanium files with different pitch: A pilot study. Australian Endodontic Journal 35(2): 65-69.
36. Bürklein S, Benten S, Schäfer E (2014) Quantitative evaluation of apically extruded debris with different single-file systems: R eciproc, F 360 and O ne S hape versus M two. International Endodontic Journal 47(5): 405-409.
37. Uzunoglu E, Görduysus M (2014) Apical extrusion of debris and irrigant using novel preparation systems. The Journal of Contemporary Dental Practice 15(4): 423-427.