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Research Article

Effect of M-pro Versus ProTaper Next Rotary Instrumentation Systems on Apically Extruded Debris in Single Canals (A Comparative *In Vitro* Study)

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Abstract

Aim: The purpose of this study aimed to evaluate the amount of apically extruded debris after canal preparation using M-Pro (CM) and ProTaper Next rotary system files.

Methodology: Forty extracted human, single-rooted mandibular premolars were divided into two groups (n=20) in each group. The root canal instrumented by G1 ProTaper Next (Dentsply Maillefer, Baillagues, Switzerland) and G2 M-Pro (CM) (Guangdong, shanghai, China) according to the manufactures' instructions. Distal water was used as the irrigant. The apically extruded debris was collected in preweighted glass vials. The vials were stored in an incubator for 5 days. The vials were weighed to obtain the final dry weight of the extruded debris. The amount of apically extruded debris was calculated from the difference between the weights of the glass vials with dried debris and prewighted of the empty glass vial. The data were statistically analyses.

Result: All specimens were associated with apical debris extrusion. No significant difference was noted among the PTN and M-Pro (CM) systems ($P > 0.05$).

Conclusion: All instrumentation systems extruded debris apically. However, M-pro (cm) NiTi rotary system had comparable value compared to the PTN regarding the debris apically extruded, but this was not statistically significant difference.

Keywords: Apical Extrusions; Rotary File System; ProTaprt Next; Controlled Memory; Root Canal Preparation; Mandibular Premolars Teeth

Introduction

One of the most important goals of endodontic procedures is to complete debridement of root canals using files and irrigation [1]. For successful treatment vital and necrotic tissue, microorganism and dentinal debris should be removed from the root canal system [2]. However, during root canal preparation, some of these dentin chips, pulp tissue remnants, and microorganism extruded into the periapical area thus, causing some clinical complication as pain, flare up or swelling leading to delayed periapical healing [1]. The incidence of these complications is reported to range between 1.4% and 16% [3].

This extrusion is an undesired result of the mechanical instrumentation of the root canal, and none of the obtainable instrumentation systems of the root canal can avoid apical debris extrusion [4]. All instrumentation systems tend to extrude debris beyond the foramen, the amount of debris extrusion into the periapical area depends on many factors as; influence of the preparation technique, the influence of the file system design [5], the coronal preflaring, the working length and disruption of apical diameter and the irrigation type and techniques.

Recently, several instruments and techniques for cleaning and shaping are available. Most of the recent techniques include nickel-titanium (NiTi) instruments. As nickel-titanium (NiTi) rotary instruments vary in their design, cross-section shapes, taper, cutting blade, alloy and methods of use, the amount of apically extruded debris also are different; the design of rotary files with the motion used tends to extrude the debris direct coronal toward the orifice [6].

ProTaper Next (PTN) rotary system (Dentsply Maillefer, Balaigues, Switzerland) this system is made with M-wire Nickel-titanium alloy. The features of this M-wire alloy are increased flexibility and greater resistance to cyclic fatigue of the instrument. The PTN files were designed with variable tapers and an off-centered rectangular cross-section, which create a swaggering effect. This design makes it possible to completely prepare root canals by fewer files [2]. The offset design maximizes the auguring of debris out of the canal compared with a centered mass and axis of rotation [7].

New endodontic system has been introduced to the market called M-Pro files (Guangdong, shanghai, China), multiple-file system, continuous taper, this alloy Controlled Memory (CM) wire thermo-mechanical surface treatment, that controls the materials memory. The unique design features of the CM instrument provide resistance to fatigue and superior flexibility compared to M-wire and conventional NiTi alloys. Furthermore, these files can be prebent similarly to stainless steel.

The current study compares the amount of apically extruded debris during preparation with ProTaper Next (Dentsply Maillefer, Balaigues, Switzerland) and M-Pro (Guangdong, shanghai, China). The null hypothesis was that there is no difference between ProTaper Next and M-Pro systems regarding apically extruded debris.

Materials and Methods

Sample size calculation

Based on a previous study by Yılmaz and Sa. (2014) [5]. The Sample size was calculated using the (G power software) t-test. As regarding the outcome (apical extruded debris), we found that selecting 20 extracted teeth per group was appropriate sample size for the study with a total sample size of 40 extracted teeth (2 groups).

Random allocation sequence generation will be done using computer random sequence generator and formulated into two columns to get the sequence.

Teeth selection

Freshly extracted human lower premolars with completely formed apices and straight single canals with no previous root canal treatment, free of caries, fractures, external or internal root resorption and cracks, as verified by visual inspection using dental operating microscope. Teeth were scraped with curette to remove blood, residual tissue and calculus. Teeth were placed in 2.5% NaOCl for 30 min to disinfect the tooth surface then stored in distilled water.

Standardization for samples

Apical size standardization for debris extrusion assessment was obtained by inserting file size 25 in each canal to ensure that it did not by passing the foramen. Discarding samples will not follow these criteria and replaced with another specimen.

Preparation of samples

Pre-operative periapical radiographs of the teeth were taken in the buccolingual and mesiodistal directions for the presence of a single canal. All teeth were accessed using a diamond round bur and endo access bur in high-speed hand piece under water spray cooling. Decoronation was done to achieve a final length of 16 mm for each sample Apical patency was checked with a size 10 k-file until the tip will be just visible in the apical foramen. This length was noted and 1 mm was subtracted to calculate the working length (WL) of each tooth.

Grouping of samples

- **Group A**: Comparator group, n = (20) teeth were prepared With ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) up to X3 (30/0.06 Taper).
- **Group B**: Intervention Group, n = (20) teeth were prepared with M-Pro (Guangdong, shanghai, chain) up to # 35 files (0.04 Taper).

Root canal preparation

- **Group (A)** was instrumented by ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) rotary instruments following the manufacturer's instructions, including SX (Size 19/4% taper) was used to 2/3 of the working length at speed 300 rpm with a torque of 3-4 N/cm to shape the coronal portion of the root canal, followed by X1 (size 17/4% taper), X2 (25/6% taper) then X3 (30/7%) to the full working length. All the ProTper Next instruments were used at 300 rpm with a torque of 2-5.2 N/cm.
- **Group (B)** was instrumented by M-Pro (Guangdong, shanghai, chain) rotary instruments following the manufacturer's instructions including File (18/4% taper) was used to2/3 of the working length at speed 500 rpm with a torque 3N/cm followed by Files (20/4% taper), (25/6% taper) then (35/4% taper) to the full working length at speed 450 rpm with a torque of 1.5 N/cm.

All instruments were mounted on hand piece of X-SMART (Dentsply, Maillefer, Ballaigues, Switzerland) endodontic motor used with a gentle in-and-out motion until the instrument had reached into the full working length. Irrigation was performed using 1 ml distilled water after each instrument using 30-gauge double side-Vented needle. After instrumentation 1 ml, distilled water was used as a final rinse with a total of 5 ml for each sample. All irrigation solutions were delivered 2 mm short of the working length. The irrigation kinematics for all samples was static without any movements.

Evaluation of apically extruded debris

A similar method was used with previous studies Myers and Montgomery. (1991) [8], the cover was removed and the empty glass vials were weighed with an analytical balance three times and the average weight was calculated, then, using a hot instrument to create a hole in the center of the stopper (caps) of rubber stopper of glass vials. Two coats of nail varnish were applied to the external surface of all root specimens to prevent debris and irrigant extrusion through lateral canals or other discontinuities in the cementum except 1 mm around the apical foramen.

Each tooth was inserted into these holes under pressure up to the cement-enamel junction, then fixed with cyanoacrylate to prevent the leakage of irrigation solution through the hole and a 27-gauge needle was inserted through the stopper beside the tooth to equalize the air pressure, the whole apparatus was assembled into a glass vial holder and the vials were covered with aluminum foil, these tubes served as collectors for this debris produced during instrumentation.

After instrumentation and irrigation, separated stopper with the root was removed from the pre-weighed glass vials; the external root surface was flushed with 1ml distilled water to collect debris adhering to the surface.

The amount of apically extruded debris collected in pre-weighed glass vials were weighed again for each sample, these glass vials containing the extruded debris were stored in an incubator at 70^0C for 5 days to evaporate the moisture before weighing the dry debris.

The weights of the debris for each sample were calculated from the difference between weights of the glass vial with dried debris and pre-weighted of the empty glass vial three consecutive measurements were taken for each sample. All measurements were done using analytical balance (Satorius balance and scale, Poland); the analytical balance was calibrated before each weighing.

Statistical analysis

Numerical data were presented as mean and standard deviation values and were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Intergroup comparisons for parametric data were done utilizing independent t-test. The significance level was set at $p \le 0.05$ within all tests. Statistical analysis was performed using IBM® SPSS® Statistics Version 26 for Windows.

Results

The results of this study are statistically presented as mean and standard deviation (SD) values for extruded debris apically shown in table 1 and figure 2.

Descriptive statistics

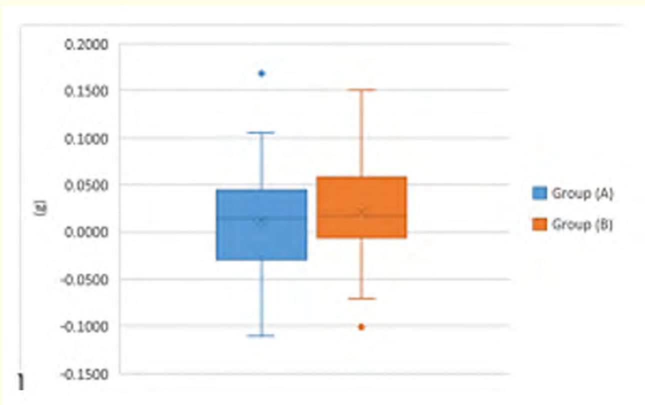

Figure 1: Box plot showing values apically extruded debris (g) for different groups.

Group A (ProTaper Next): The maximum weight of debris in grams (0.168) while the median weight (0.014) and the minimum weight (-0.111).

Group B (M-Pro): The maximum weight of debris in grams (0.151) while the median weight (0.018) and the minimum weight (-0.101).

Intergroup comparison

Mean and standard deviation (SD) values of apically extruded debris (g) for different groups are presented in table 1 and figure 2.

Independent t-test results showed that there was no significant difference between the amount of apically extruded debris in group (A) (PTN) (0.012 ± 0.068) (g) and group (B) (M-Pro) (0.022 ± 0.059) (g) (p = 0.631).

Apically extruded debris (mean ± SD)		p-value
Group (A) PTN	Group (B) M-Pro	
0.012 ± 0.068	0.022 ± 0.059	**0.631ns**

Table 1: Mean ± standard deviation (SD) of apically extruded debris (g) for different materials.
ns; non-significant (p > 0.05).

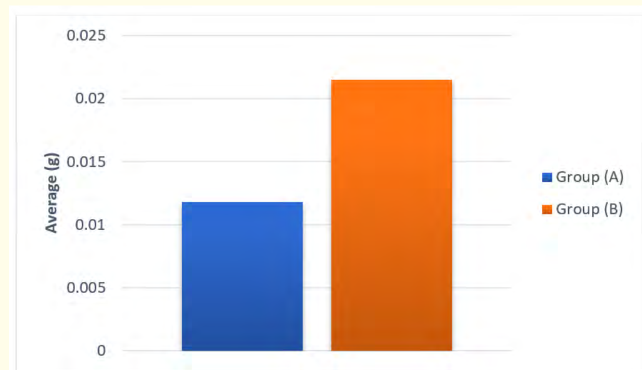

Figure 2: Bar chart showing the mean apically extruded debris (g) for different groups.

Discussion

This study was performed to compare and evaluate the amount of extrusion of debris created after cleaning and shaping by new NiTi rotary instruments (ProTaper Next and M-Pro) in permanent mandibular premolars teeth.

Post operative pain and mid treatment flare up are common problems that occur during root canal treatment. A major cause for such problems is the extrusion of debris apically through the apical foramen during root canal instrumentation into the periapical tissues, resulting in persistent periapical inflammation [9].

There are two types of factors that affect the extrusion debris apically; natural physical factors, such as the anatomy of apical constriction [10], and mechanical factors such as the selection of the final apical size of instruments, technique and the design of the instruments and irrigation solution [11].

The instruments used in this study were engine driven as this technique extruded a smaller amount of debris and irrigant due to rotary motions, which tend to direct debris toward the orifice avoiding its complication in the root canal [6]. Most rotary instrument systems compared to hand stainless steel K-files lead to less apical extrusion and postoperative pain due to their rotary action [12].

Nickel-Titanium engine driven instruments for the crown-down technique extruded less debris and irrigant as early flaring of the coronal part of the preparation improving instrument control during the preparation of the apical third [13].

As well Nickel-Titanium (NiTi) instruments differ in their design, cross section, taper and application methods, resulting in varying amounts of debris extrusion apically into the periapical region, which leads to a different level of postoperative pain. ProTaper Next rotary file system was selected as compotator due to its off-centered rectangular cross-section lead to the removal of more debris in the coronal direction and result in less debris extrusion [2]. The asymmetric design reduces the stress on the instruments during canal instrumentation so minimizing the engagement between the files and dentin, and increase the available volume for upward debris removal [7]. The M-wire technology of PTN enhances file flexibility and cutting efficiency [14]. It has been successfully used over years, and can be present as a reference for comparison [15].

On the other hand the selection of M-Pro NiTi rotary system was due to introduced to the market as a new rotary system consisting of three shaping files, which have been heat-treated representing the CM (Control Memory) wire technology, which increases the efficiency and flexibility of the files. Extracted human mandibular premolars were used in this study rather than stimulated canals in resin blocks to provide real life conditions. Where, simulated artificial canals have different micro-hardness and surface texture compared to root dentin [16,17]. The major drawbacks of using rotary instruments in resin blocks are the heat generated which soften the resin material and leads to binding of cutting blades and separation of the instrument [18].

The technique described by Myers and Montgomery for evaluation of apically extruded debris was used with some modification on it [8-19].

Many studies show that the minimal amount of extrusion of debris through the apical foramen is reached using crown-down technique with engine-driven NiTi systems. This technique was used in this study, it allow the instruments to enlarge the coronal third of the root canal, which reduces the apical extrusion of debris [20].

Regarding the coronal preflaring with NiTi rotary files was used in this study because it was reported that canal preparation with coronal flaring reduced the amount of apically extruded debris [21-22]. Coronal flaring facilitates early access of irrigants and allows rotary instruments to reach the apical portion with less wall contact and less friction [23,24].

In this study, the foramen size preparation was not taken into consideration, although Mckendery. (1990) [25] and AL-omari., *et al*. (1995) [26] found no significant correlation between the apical size and the amount of debris extrusion. The amount of extruded debris was not affected by the canal length, curvature of the foramen size [27].

All rotary files were used with in and out motion following the manufactures instruction, as it decreases the binding of instruments and torque-generated cyclic fatigue [28,29].

All samples were flattened to a length of 16 mm for standardization [30,31]. The working length in this study was confined to 1 mm short of the apical foramen; Myers and Montgomery. (1991) [8] reported that there was a great amount of debris extrusion when the canals were instrumented to a length beyond the apical foramen compared to 1 mm short of the foramen. Silva., *et al*. (2016) [32] showed that the working length and the apical preparation size did not have a significant effect on debris extrusion.

The irrigant used during chemo-mechanical preparation was distilled water in all experimental groups it has no solvent effect thus extrusion of debris depends only on mechanical preparation. Although NaOCl is most irrigant used during endodontic treatment due to the antimicrobial effect and tissue dissolving ability, NaOCl leads to formation of sodium crystallization phenomenon, which can affect the results of this study so distilled water used to avoid any possible weight increase due to NaOCl crystal formation [33].

A 30-gauge needle tip was used for irrigation; the needle penetration was done (1-2 mm) shorter than the working length (passive injection) to avoid the production of high apical pressure increasing the risk of apical debris extrusion [34]. The irrigation needles may be safely used during endodontic therapy [32]. Conventional syringe with side vented needle group extruded significantly less debris than PUI and XP-endo finisher files [35].

The debris apically extruded in this study was collected in vials and then heated until the distilled water was completely evaporated and the debris dried the collected debris must be due to mechanical preparation of root canals. The weight of debris for each sample will be calculated as the difference between the glass vial empty and from dried debris [5-19].

Concerning the results of the apically extruded debris in this study after weighting the debris extrusion between the two groups, there was no statistically significant difference between the PTN and M-Pro systems in agreement with Tanalp., *et al*. (2006)[33], Topcuoglu., *et al*. (2016) [21], Verma., *et al*. (2017) [36]. However, the PTN showed less debris extrusion apically. These results were in agreement with other studies by Caper., *et al*. (2014) [37], Sen., *et al*. (2008) [38]. Some authors justify that the design of the ProTaper Next promotes better bacterial removal than other automated systems. This design seems to promote the removal of dentin in the coronary direction [39,40].

Alternatively, Control Memory (CM) wire produced less debris extrusion as, unwinding the spirals of rotary system occurs during the preparation of the canal, this phenomenon may lead to decrease the cutting ability and cleaning efficiency for the files resulted in the production of dentinal chips and debris were decreased and the less debris extrusion apically happened [41].

Also these results showed disagreements with many studies comparing the amount of apically extruded debris Ustun., *et al*. (2015) [42], Dincer., *et al*. (2017) [43].

However, the systems that we compared in this study are different from those mentioned in the clinical study. Thus, assessment of the clinical performance of these systems is necessary to make further comments. There are no many published data on the extrusion of apical debris with ProTaper Next and M-Pro systems.

Conclusion

Within the limitations of this study it was concluded that all systems were associated with extrusion of debris. M-pro (CM) NiTi rotary system had comparable value compared to the PTN regarding the debris apically extruded (No statistically significant difference).

Conflict of interest

The authors deny any conflicts of interest in this study.

Bibliography

1. Seltzer S and Naidorf I J. "Flare-ups in Endodontics :I. Etiological Factors Manifestaciones Agudas en Endodoncia : I . Factores Etiologicos". *Journal of Endodontics* 11.11 (1985): 472-478.
2. Ozsu D., *et al*. "Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems". *European Journal of Dentistry* 8.4 (2014): 504-508.
3. Siqueira JF Jr., *et al*. "Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy". *Journal of Endodontics* 28 (2002): 457-460.
4. Nevares G., *et al*. "Apical extrusion of debris produced during continuous rotating and reciprocating motion". *The Scientific World Journal* (2015): 5 .
5. Yılmaz N and Sa B C. "Apical extrusion of debris using ProTaper Universal and ProTaper Next rotary systems". *International Endodontic Journal* (2014): 1-4.
6. Beeson T., *et al*. "Comparison of debris extruded apically in straight canals: conventional filing versus profile. 04 Taper series 29". *Journal of Endodontics* 24.1 (1998): 18-22.
7. Ruddle, C. J., *et al*. "The shaping movement: Fifth-generation technology". *Dentistry Today* 32.4 (2013): 22-28.
8. Myers G and Montgomery S. "A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques". *Journal of Endodontics* 17 (1991): 275-279.
9. Logani A and Shah N. "Apically extruded debris with three contemporary Ni-Ti instrumentation systems: An ex vivo comparative study". *Indian Journal Dental Research* 19 (2008): 182-185.
10. Tinaz A., *et al*. "The effect of disruption of apical constriction on periapical extrusion". *Journal of Endodontics* 31.7 (2005): 533-535.
11. Elmsallati EA., *et al*. "Debris retention and wear in three different nickel-titanium rotary instruments". *Australian Endodontic Journal* 32 (2006): 107-111.

12. Mittal R., *et al*. "A Comparison of Apical Bacterial Extrusion in Manual, ProTaper Rotary, and One Shape Rotary Instrumentation Techniques". *Journal of Endodontics* 41.12 (2015): 2040-2044.

13. Kustarci A., *et al*. "Apical extrusion of intracanal debris using two engine driven and step-back instrumentation techniques: an in-vitro study". *European Journal of Dentistry* 2.4 (2008): 233-239.

14. Liu M., *et al*. "Less extrusion debris during the retreatment of curved canals using twisted files with higher rotational speeds: an ex vivo study". *BMC Oral Health* 17 (2017): 45.

15. Uzunoğlu-Özyürek., *et al*. "Effects of Different Rotary Files Combined with Different Irrigation Needles on Apically Extruded Debris". *Brazilian Dental Journal* 26 (2015): 347-50.

16. Schafer E and Vlassis M. "Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 1. Shaping ability in simulated curved canals". *International Endodontic Journal* 37 (2004): 229-238.

17. Dummer PMH. "Comparison of undergraduate endodontic teaching programmes in the United Kingdom and in some schools in Europe and the United States". *International Endodontic Journal* 24 (1991): 169- 177.

18. KUM K., *et al*. "Shaping Ability of Three ProFile Rotary Instrumentation Techniques in Simulated Resin Root Canals". *Journal of Endodontics* 26.12 (2000): 719-723.

19. Brown DC., *et al*. "An in vitro study of apical extrusion of sodium hypochlorite during endodontic canal preparation". *Journal of Endodontics* 21.12 (1995): 587-591.

20. Vaudt J., *et al*. "Ex vivo study on root canal instrumentation of two rotary nickeltitanium systems in comparison to stainless steel hand instruments". *International Journal of Endodontics* 42 (2009): 22-33.

21. Topçuoğlu H., *et al*. "Apically extruded debris during root canal preparation using Vortex Blue, K3XF, ProTaper Next and Reciproc instruments". *International Endodontic Journal* 49.12 (2016): 1183-1187.

22. Borges ÁH., *et al*. "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 (2016): 465-469.

23. Leeb J. "Canal orifice enlargement as related to biomechanical preparation". *Journal of Endodontics* 9 (1983): 463-470.

24. Peters OA and Paque F. "Current developments in rotary root canal instrument technology and clinical use: a review". *Quintessence International* 41 (2010): 479-488.

25. McKendry D. "Comparison of balanced forces, endosonic, and stepback filing instrumentation techniques: quantification of extruded apical debris". *Journal of Endodontics* 16.1 (1990): 24-27.

26. Al-Omari M. and Dummer P. "Canal blockage and debris extrusion with eight preparation techniques". *Journal of Endodontics* 21.3 (1995): 154-158.

27. Hinrichs RE., *et al*. "A comparison of amounts of apically extruded debris using handpiece-driven nickel-titanium instrument systems". *Journal of Endodontics* 24.2 (1998): 102-106.

28. Sattapan B., *et al*. "Defects in Rotary Nickel-Titanium Files After Clinical Use". *Journal of Endodontics* 26 (2000): 161-165.

29. Li UM., *et al*. "Cyclic fatigue of endodontic nickel-titanium rotary instruments: static and dynamic tests". *Journal of Endodontics* 28 (2002): 448-445.

30. Rödig T., *et al*. "Comparison of root canal preparation with two rotary Ni-Ti instruments: ProFile.04 and GT rotary". *International Endodontics* 40 (2007): 553-562.

31. Fayyad DM., *et al*. "Computed tomographic evaluation of the apical shaping ability of Hero Shaper and REVO-S". *ENDO Endodontic Practice Today* 6 (2012): 119-124.

32. Silva E., *et al*. "Influence of Apical Preparation Size and Working Length on Debris Extrusion". *Brazilian Dental Journal* 27.1 (2016): 28-31.

33. Tanalp J., *et al*. "Quantative evaluation of the amount of apically extruded debris using 3 different rotary instrumentation systems". *Oral Surgery* 101 (2006): 250-257.

34. Mittal R., *et al*. "A Comparison of Apical Bacterial Extrusion in Manual, ProTaper Rotary, and One Shape Rotary Instrumentation Techniques". *Journal of Endodontics* 41.12 (2015): 2040-2044.
35. Gawdat Shaimaa and Elkhodary Sherif. "Efficacy of XP-Endo finisher file compared to passive ultrasonic irrigation and conventional syringe irrigation on removal of triple antibiotic paste and calcium hydroxide". *Endodontic Practice* (2017): 11.
36. Verma M., *et al*. "Comparison of apical debris extrusion during root canal preparation using instrumentation techniques with two operating principles: An in vitro study". *Journal of Conservative Dentistry* 20.2 (2017): 96.
37. Capar ID., *et al*. "Comparative study of different novel nickel-titanium rotary systems for root canal preparation in severely curved root canals". *Journal of Endodontic* 40 (2014): 852-856.
38. Sen OG., *et al*. "Evaluation of Apically Extruded Debris Using Continuous Rotation, Reciprocation, or Adaptive Motion". *Brazilian Dental Journal* 29 (2018): 245-248.
39. Machado M E de L., *et al*. "Instrument Design May Influence Bacterial Reduction During Root Canal Preparation". *Brazilian Dental Journal* 28.5 (2017): 587-591.
40. Siddique R., *et al*. "Comparison of antibacterial effectiveness of three rotary file system with different geometry in infected root canals before and after instrumentation-a double-blinded randomized controlled clinical trial". *Brazilian Dental Journal* 6.1 (2020).
41. Labbaf H., *et al*. "An In vitro Comparison of Apically Extruded Debris Using Reciproc, ProTaper Universal, Neolix and Hyflex in Curved Canals". *Iranian Endodontic Journal* 12.3 (2017): 307-311.
42. Üstün Y., *et al*. "Evaluation of apically extruded debris associated with several Ni-Ti systems". *International Endodontic Journal* 48.7 (2015): 701-704.
43. Dincer A., *et al*. "Apical extrusion of debris during root canal preparation using a novel nickel-titanium file system: Wave One gold". *Journal of Conservative Dentistry* 20.5 (2017): 322.