European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 07, Issue 07, 2020

Comparative evaluation of apical extrusion of debris and irrigating solution during hand, rotary and reciprocating instrumentations: an ex vivo study

Dr. Sachin Metkari[1], Dr. Dinesh Rao[2], Dr. Kulvinder Singh Banga[3]

[1]*Assistant Professor, Department of Conservative Dentistry and Endodontics, Nair Hospital Dental College, Dr.A.L.Nair Road, Opposite Maratha Mandir, Mumbai Central, Mumbai-400008, Maharashtra, India, Maharashtra University of Health Sciences, Nashik (M.U.H.S., Nashik), Research Scholar PAHER University Udaipur-313001, Rajasthan, India;*

[2]*Professor and Head of the Department, Department of Pediatric Dentistry, Pacific Dental College and Hospital, PAHER University Udaipur-313001, Rajasthan, India.*

[3]*Professor and Head of the Department, Conservative Dentistry and Endodontics, Nair Hospital Dental College, Dr.A.L.Nair Road, Opposite Maratha Mandir, Mumbai Central, Mumbai-400008, Maharashtra, India.*

Email: sachinsmetkari@gmail.com; pedodinesh2003@yahoo.co.in; ksbanga@gmail.com

ABSTRACT:

Background: Apical extrusion of debris, irrigating solution and microorganism are always being concern for operator as these may cause flare-ups during root canal therapy. These noxious insults can also cause cell-mediated or humoral immunological phenomenon causing severe distress to the patient. Aim of this ex vivo study was to evaluate the effect of different types of instrumentation in combination with different irrigation methods on apical expulsion of debris and irrigating solution.

Material and Methods: Four hundred and ten extracted human permanent teeth were selected for the study. Ten teeth were kept as control group which were neither instrumented nor irrigated. Manual file (MF), protaper universal rotary (PTU), waveOne reciprocating(WO) and flexiCON rotary systems (FC) were used for instrumentation of the canals using two different irrigation techniques: conventional needle irrigation and endoVac irrigation. A single experienced operator carried out all the endodontic procedures. Four hundred teeth were equally divided in four groups (n = 100), in which instrumentation was performed using a MF (group 1), PTU (group 2), WO (group 3) and FC (group 4). In each group, 50 samples were irrigated with conventional needle irrigation, and 50 samples were irrigated with the endoVac irrigation method. During instrumentation, apically extruded debris and irrigating solution were collected in preweighed Eppendorf tube. Weight of expelled debris and volume of expelled irrigating

solution were quantitatively measured individually. The data collected were statistically analysed.

Results: The group 1 showed highest extrusion of debris and irrigating solution while group 4 showed lowest. The order of sequence for debris expulsion from minimum to maximum is FlexiCON < waveOne < protaper < manual instrumentation. The order of sequence from minimum to maximum is FlexiCON < protaper < waveOne < manual instrumentation.

Conclusion: FlexiCON rotary instrumentation with the endoVac irrigation system produced significantly less debris and irrigating solution than the other techniques.

Clinical significance: This report highlights on how the apical extrusion of debris and irrigating solution can be minimised with altered instrumentation and irrigation technique for effective endodontic therapy.

Keywords: periapical extrusion, irrigation, flare-up.

1. INTRODUCTION:

One of the objectives of cleaning and shaping of root canal system is elimination of viable bacteria and bacterial toxins from the root canal system without expulsion in the periapex (1). Infected pulpal remnants, root canal debris and irrigating solution also cause noxious insult to the peri-radicular tissues when it extrudes beyond the periapex (2). Such periapical expulsion can cause cell-mediated or humoral immunological phenomena, causing pain, swelling or both, resulting in flare-ups (1-3). The incidence of flare-up during root canal treatment is about 1.4% to 16% (4). Apical extrusion of bacteria, debris and irrigating solution during chemo-mechanical debridement of root canal has been well documented (5-11).

The reciprocating system WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) based on reversed balanced force concept claimed to be better in periapical expulsion than other studies (12,13). FlexiCON rotaty system (US Endodontics, Johnson City, TN, USA) is annealed Fire-Wire, Ni-Ti rotary files system, recently introduced and manufactured by US Endodontics (Johnson City, Tennessee, USA). Manufacturer claims that these files have increased flexibility, resistance to cyclic fatigue, no shape memory and no canal transportation (14,15). Its cross section design is similar to K3XF rotary file, also has variable pitch and increased helical angle (16).

Irrigation of root canal system has major impact on periapical expulsion of debris, irrigating solution and microorganism (17). There are several factors responsible for periapical expulsion like penetration depth of the irrigating needle, diameter of the root canal, the inner and outer diameter of the needle, irrigation pressure, viscosity of the irrigant, velocity of the irrigant at the needle tip, the type and orientation of the bevel of the needle (18).

Numerous reports on periapical expulsion are available in literature, but no studies comparing heat-treated flexiCON rotary instrumentation system with current instrumentation systems. It was hypothesized that no instrumentation shows apical expulsion during canal preparation.

The present study aimed to quantify apical extrusion of debris and irrigating solution with manual (hand filing), two rotary (protaper and flexiCON) instrumentation systems and one reciprocating system (WaveOne) with two different irrigation techniques (conventional and EndoVac).

2. MATERIAL METHOD:

Present study protocol was approved by institutional ethical committee (497/EC/2020 dated14/01/2020). Four hundred and ten extracted human permanent single-rooted teeth selected for the study. All teeth were kept in 0.5% sodium hypochlorite (Hypo, Kaushalya Health care PVT. LTD, Thane) for 24h for disinfection and then stored in the normal saline (0.9% NaCl, Rusoma laboratories private limited, Indore, India) until use. Standard endodontic access preparation was prepared with no. 2 carbide round bur (Dental carbide bur FG No.2 for high speed handpiece), pulp remnants were extirpated with barb broach (Dentsply Maillefer, Ballaigues, Switzerland) and canal patency was obtained with a no.#10 k-file (Dentsply Maillefer, Ballaigues, Switzerland). Mature permanent teeth with apical diameters that corresponded to an International Organisation of Standardization (ISO) size no.15 k-file were included in this study. If ISO size no.15 k-file extruded beyond the apex of root by gentle filing, then such samples were excluded from study. All teeth were observed under dental operating microscope (Karl Kaps, Germany) and the teeth with cracks, caries and crown/root resorption were excluded from the study. For the standardization purpose, the crown of all teeth were reduced and total length of all teeth were attained to 19 mm with preservation of coronal portion as a reservoir for irrigation purpose. Working length of all teeth were standardized to 18 mm by subtracting 1 mm as apical constriction from total length (19mm). Teeth with single canal and apical curvature <15˚ were selected for the study (19). Presence of single canal was confirmed with digital radiography (Clearray CMOS, Delhi, India). The outer surface of all the teeth were coated two to three times with nail varnish (LYN nail varnish, India) to prevent leakage of irrigant solution.

Manual hand file, protaper universal rotary, waveOne reciprocating and flexiCON rotary systems were included in the present ex-vivo study for instrumentation of the canals using two different irrigation techniques: conventional needle irrigation and endoVac irrigation. A single experienced operator carried out all the endodontic procedures.

Experimental model

In the present ex vivo study 2 ml eppendorf tubes were used for collection of debris, irrigating solution expelled apically during instrumentation. All the eppendorf were numbered and weight of all empty eppendorf measured and named as ‘pre-instrumental weight’. Teeth were held in the eppendorf tube with punched rubber dam sheet as per tooth’s diameter followed by cyanoacrylate gel was used to ensure fluid-tight seal.

Eppendorf tube was held in glass vial so as to stabilize in position during instrumentation. The rubber dam sheet was used to shield the Eppendorf tube to avoid bias for the operator during canal instrumentation. Using a hot instrument, the Eppendorf tube was placed in rubber stopper of the glass vial. To balance internal and external pressures, a 26-guage needle (Unolok Syringe, Lur lok, Vin Pharma Agency, Mumbai, India) was inserted along the side

of the mounted tooth into the Eppendorf tube through the rubber dam sheet, facilitating expulsion of apical debris and irrigating solution. (**Figure 1**).

Figure 1

Sample allocation

Four hundred teeth were randomly divided into four groups (n = 100) and ten teeth were kept as control group. In control group, ten teeth were neither instrumented nor irrigated kept as control. All the instruments were used according to the manufacturer's instructions. The flutes of the files were cleaned after every three to four in-and-out movements.

In each group, the samples were again randomly divided into two subgroups (n = 50 in each) according to method of irrigation, either with conventional needle and endoVac irrigation method. Conventional irrigation was carried out using a 27-gauge double side-vented needle (RC Twents, prime dental products pvt. ltd, Maharashtra, India) by placing needle tip at the apical 3 mm level with pressure-less technique. EndoVac consists of microcannula which was placed at apical 3mm of root canal, creating apical negative pressure and macrocannula was placed in the pulpal chamber. EndoVac irrigation was carried out as per manufacturer's instruction. Frequent root canal irrigation was done using 10 ml of normal saline solution.

Instrumentation

Group 1: Manual hand instrumentation:

Each tooth in this group was instrumented with hand K and H-files. Instrumentation was carried out in the sequence of no. #15, #20, #25 K and H-files alternatively to the working length. Each file was used in the push-pull motion until it was loose in the canal before the next file was used. Final apical preparation was done till no.#25 file. Then progressive filing was done using three successive larger file, each at a length of 1mm shorter than previous file. Final step-back preparation was done till no. # 40 file.

Group 2: Protaper Universal rotary file instrumentation system

The protaper universal rotary instruments Sx, S1, S2, F1, F2 were used in a crown-down manner according to the manufacturer's instructions until a final apical size of 25.08. Torque-controlled electric motor (X-Smart; Dentsply Maillefer, Japan) and gear reduction handpiece was used for the canal prepartion until a final apical size of 25.08.

Group 3: WaveOne reciprocating file instrumentation system

WaveOne reciprocating single primary file system was used for this group. Instrumentation was carried out according to the manufacturer's instructions for the final apical size 25.08 at 150°ccw/30°cw reciprocation according to the manufacturer's instructions. WaveOne file instrumentation proceeded until no obstruction remained.

Group 4: FlexiCON file instrumentation system

All the teeth in this group were instrumented using the FlexiCON Ni-Ti X3 rotary instrumentation system, which includes negotiating files N1, N2, N3 and completing files C1, C2. Instrumentation was performed according to the sequence of the manufacturer's instructions, until a final apical size 25.06.

Evaluation of apically extruded debris

After instrumentation, weight of all Eppendorf tubes were measured as 'post-experimental weight' of debris and irrigating solution.

All Eppendorf tubes were kept in the incubator for 15days so as to evaporate the irrigating saline solution. Weight of eppendorf tubes containing dry extruded debris were measured and subtracted from 'post-experimental weight' to obtain weight of irrigating solution. Weight of irrigating solution was then converted to mili-litre (ml) of saline solution. Weight of saline to volume was converted using https://www.aqua-calc.com/calculate/weight-to-volume/substance/saline. Dry weight of extruded debris was then calculated by subtracting subsequent eppendorf tube's weight. Thus the amount of extruded debris weight and irrigating solution was recorded and subjected to statistical analysis.

Statistical analysis

The statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data. All the collected data were analysed as descriptive and inferential statistics. The level of significance was fixed at $p = 0.05$. Any value ≤ 0.05 was considered statistically significant.

The student's *t*-test (two tailed, unpaired) was applied to detect difference between two groups. An analysis of variance (ANOVA) was used to determine the significance of the study parameters in the different groups. Further post hoc analysis was carried out if the values of the ANOVA test were significant.

3. RESULTS:

All samples showed apical extrusion of debris and irrigating solution except control group.

A) Results for apical extrusion of debris

Among the instruments, manual instrumentation with conventional needle irrigation showed maximum (0.03170090 ± 0.015443941g) debris expulsion while FlexiCON with EndoVac irrigation showed minimum (0.00458040 ± 0.010529657g). (**Table no.1**)

FlexiCON instrumentation showed minimum debris expulsion while manual instrumentation showed maximum irrespective of the irrigation technique used. The order of sequence from minimum to maximum is FlexiCON < waveOne < protaper < manual instrumentation. EndoVac irrigation showed minimum debris expulsion than conventional needle irrigation irrespective of instrumentation used.

B) Results for apical extrusion of irrigating solution

Within the four instrumentation systems, manual instrumentation with conventional needle irrigation showed maximum extrusion of irrigating solution (0.02659932 ± 0.015404041ml) while FlexiCON with EndoVac irrigation showed minimum (0.00137922 ± 0.002841851 ml). FlexiCON instrumentation produced minimum irrigant expulsion while manual instrumentation showed maximum irrespective of the irrigation techniques used. The order of sequence from minimum to maximum is FlexiCON < protaper < waveOne < manual instrumentation. (**Table no.2**)

EndoVac irrigation showed minimum saline expulsion than conventional needle irrigation irrespective of instrumentation used.

Table 1: Comparison of the apical extrusion of debris in terms of {Mean (gram) (SD)} for different file systems with different irrigations using Mann Whitney U test

	Group	***N***	***Mean***	***Std. Deviation***	***Z value***	***P value***
Manual	***Conventional Irrigation***	50	0.03170090	0.015443941	**2.110**	**0.035***
	Endovac	50	0.02524664	0.014035576		
Protaper	***Conventional Irrigation***	50	0.02622020	0.011473340	**3.847**	**<0.001****
	Endovac	50	0.01754380	0.008636009		
Wave one	***Conventional Irrigation***	50	0.02436618	0.017646546	**6.453**	**<0.001****
	Endovac	50	0.00544780	0.008082230		
Flexicon	***Conventional Irrigation***	50	0.01197474	0.016869060	**3.412**	**<0.001****
	Endovac	50	0.00458040	0.010529657		

(p < 0.05 - Significant*, p < 0.001 - Highly significant)**

Table no.2: Comparison of the apical extrusion of irrigating solutions in terms of {Mean (millilitre) (SD)} for different file systems with different irrigations using Mann Whitney U test

	Group	***N***	***Mean***	***Std. Deviation***	***Z value***	***P value***
Manual	***Conventional Irrigation***	50	0.02659932	0.015404041	1.537	0.124
	Endovac	50	0.02147677	0.007863551		
Protaper	***Conventional Irrigation***	50	0.01108111	0.005751416	**3.764**	**<0.001****
	Endovac	50	0.01519676	0.005360228		
Wave one	***Conventional Irrigation***	50	0.01813069	0.011231370	**6.859**	**<0.001****
	Endovac	50	0.01032425	0.052066620		
Flexicon	***Conventional Irrigation***	50	0.00310470	0.004763120	**2.592**	**0.010***
	Endovac	50	0.00137922	0.002841851		

(p < 0.05 - Significant*, p < 0.001 - Highly significant)**

4. DISCUSSION:

All the instrumentation techniques showed apical extrusion of debris and irrigating solution. Hence null hypothesis was rejected.

For the standardization purpose, permanent mature teeth were selected for the study with all the samples were kept equal in length, straight canal or curvature less than 15° and apical diameter less than 0.15mm. This ensured that the amount of apical extrusion and irrigating solution produced by instrumentation only and not due other variables. All samples were painted with nail varnish except at the apical foramen so as to prevent leakage of irrigating solution and debris other than apical foramen.

The result of present study showed that apical extrusion of debris and irrigating solution more with step-back technique than engine driven instrumentation with either of the irrigation techniques (conventional needle and EndoVac devices). This observation is in agreement with numerous studies (5, 20-33). Rotary files tend to pack dentinal debris in the flutes and send it to cervical direction, that result in less compaction of debris in the root canal (34).

Current study showed more debris expulsion with protaper rotary instrumentation than other engine driven instrumentations. This finding is in agreement with other studies (35-37). Authors have concluded that protaper rotary system promoted greater dentin wear in shorter period of time because of greater cutting capacity and taper (35,36). But some research report concluded that protaper instrumentation showed less expulsion than waveone reciprocating instrumentation (38,39). In some studies where waveOne file worked in a 170° counter clockwise (large rotation angle in the cutting direction) and 50° clockwise reciprocating motion (smaller rotating angle in the disengaging direction) – this reciprocal motion, in and

out filing motion acts like a piston causes more debris extrusion apically (38,39).The file with aggressive cutting ability removes a substantial amount of radicular dentin in a relatively shorter period, but unable to displace debris coronally that enhanced the apical extrusion in combination with reciprocating motion (38,39).

Newly introduced FlexiCON rotary heat-treated Ni-Ti instrumentation system showed minimum expulsion of debris and irrigating solution irrespective of irrigation method used. This finding is supported by Kumar et al (16). Heated Ni-Ti files has superior flexibility and resistance to cyclic fatigue showed less aggressive cutting tendency (40). Newer file has variable pitch and increased helical angle that supports the removal of debris in coronal direction (16). This could have result in less apical extrusion of debris and irrigating solution. No contrary studies found in the literature showing less expulsion than flexiCON system till date.

Root canal irrigation has a very vital role in chemo-mechanical preparation of endodontic therapy as root canal system has complex and highly variable structure were instrument cannot reach (41,42). There are two types of irrigation pressure positive and negative, both were compared in current study. Positive pressure irrigation was done with conventional side-vented needle while negative pressure irrigation with EndoVac irrigation system. EndoVac has macro cannula which was placed in the pulp chamber space to pour fresh irrigating solution while micro cannula was placed in the apical third of root canal to suck the irrigation solution and debris by preventing extrusion beyond the apex. Thus, EndoVac irrigation showed less apical extrusion of debris and irrigating solution than conventional needle irrigation.

Many studies had supported the result of the present study that endoVac irrigation showed less expulsion than conventional needle irrigation (43-49).

5. CONCLUSION:

FlexiCON rotary instrumentation reported significantly less apical extrusion of debris and irrigating solution than WaveOne reciprocating and protaper rotary instrumentation. EndoVac irrigation system showed less apical expulsion than conventional needle irrigation. Manual instrumentation exhibited maximum expulsion than engine-driven instrumentation.

Acknowledgement: We were very grateful for help and support of Proff. A.B. Pandit VC , ICT Mumbai., Dr. Milind Ubale, Proff and Head, Dept.,of Microbiology and Mr.Sandeep Gungambhire for the study.

6. REFERENCES:

[1] Spangberg L, Engström B, Langeland K. Biologic effects of dental materials. 3. Toxicity and antimicrobial effect of endodontic antiseptics in vitro. Oral Surg Oral Med Oral Pathol 1973; 36:856-871.
[2] Serper A, Ozbek M, Calt S. Accidental sodium hypochlorite induced skin injury during endodontic treatment. J Endod 2004; 30:180-181.
[3] Siqueira JF Jr. Microbial causes of endodontic flare‐ups. Int Endod J 2003; 36:453-63.

[4] Siqueira JF, Rocas IN, Favieri A, Machado AG, Gahyva SM, Oliveira JCM. Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy. J Endod 2002; 28:457–60.
[5] Kustarchi A, Akpinar KE, Kursat Er. Apical extrusion of intracanal debris and irrigant following use of various instrumentation techniques. Oral Pathol Oral Radiol Endod J 2008;105;257-262.
[6] Logani A and Shah N. Apically extruded debris with three contemporary Ni-Ti instrumentation system: an ex vivo comparative study. Indian J Dent Res. 2008;19(3):182-185.
[7] Kocak MM, Cicek E, Kocak S, Saglam BC and Yilmaz N. Apical extrusion of debris using protaper universal and protaper next rotary systems. Int Endod J 2015;48(3): 283-286.
[8] Topçuoğlu, H.S., Aktı, A., Tuncay, Ö., Dinçer, A.N., Düzgün, S. and Topçuoğlu, G., 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. J Endod, 2014;40(12):.2066-2069.
[9] Fairboum DR, McWalter GM, Montgomery S. The effect of four preparation techniques on the amount of apically extruded debris. J Endod 1987;13: 102-8.
[10] Ruiz-Hubard EL, Gutmann JL, Wagner MJ. A quantitative assessment of canal debris forced periapically during root canal instrumentation using two different techniques. J Endod 1987;12;554-8.
[11] Ferraz CCR, Gomes NV, Gomes BPFA, Zaia AA, Teixeira FB and Souza-Filho FJ. Apical extrusion of debris and irrigants using two hand and three engine-driven instrumentation techniques. Int Endod J 2001;34(5):354-358.
[12] Silva, E.J.N.L., Sá, L., Belladonna, F.G., Neves, A.A., Accorsi-Mendonça, T., Vieira, V.T., De-Deus, G. and Moreira, E.J., Reciprocating versus rotary systems for root filling removal: assessment of the apically extruded material. J Endod, 2014;40(12): 2077-2080.
[13] Ustun Y, Canakci BC, Dincer AN, Er O and Duzgun S. Evualation of apically extruded debris associated with several Ni-Ti system. Int Endod J 2015;48(7):701-704.
[14] http://www.flexicon.in/pdf/X7-Hyflex-K3-AND-M2-Series.pdf dated 1/03/2019.
[15] https://www.dentbay.com/flexicon-x5-niti-rotary-files.html dated 1/03/2019.
[16] Kumar GP, Godavarthy DS, Yarlagadda M, Beesetty N, Killi N. Apical extrusion of debris in mesiobuccal root of maxillary molars with five rotary file systems. J Clin and Diagno Res. 2018:05 ZC05 - ZC09.
[17] Vande Visse JE, Brilliant JD. Effect of irrigation on the production of extruded material at the root apex during instrumentation. J Endod 1975; 1:243-6.
[18] Peters OA, Koka RS. Preparation of coronal and radicular spaces. In: Ingle JL, Bakland LK, Baumgartner JC, eds. Ingle's endodontics. 6th ed. Hamilton, Ontario: BC Decker Inc; 2008:968.
[19] Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Path Oral Rad and Endod 1971;2: 271–5.
[20] Al-Omari MAO, Dummer PMH. Canal blockage and debris extrusion with eight preparation techniques. J Endod 1995;21(3):154-158.

[21] Vansan, L.P., Pécora, J.D., da COSTA, W.F., Silva, R.G. and Savioli, R.N. Comparative in vitro study of apically extruded material after four different root canal instrumentation techniques. Braz Dent J 1997;8(2):79-83.
[22] Beeson TJ, Hartwell GR, Thornton JD and Gunsolley JC. Comparison of debris extruded in straight canal: conventional filing versus profile .04 taper series 29. J Endod 1998;24(1):18-22.
[23] Reddy SA, Hicks ML. Apical extrusion of debris using two hand and two rotary instrumentation techniques. J Endod 1998;24: 180-183.
[24] Kustarci A, Akdemier N, Siso SH, Altunbas D. Apical extrusion of intracanal debris using two engine driven and step-back instrumentation technique: an in vitro study. Eur J Dent 2008;2;233-239.
[25] Ruiz-Hubard EE, Gutmann JL, Wagner MJ. A quantitative assessment of canal debris forced periapically during root canal instrumentation using two different techniques. J Endod 1987;13(12):554-8.
[26] Mckendry DJ. Comparison of balance forces, endosonic and step-back filing instrumentation techniques: quantification of extruded apical debris. J Endod 1990;16(1):24-27.
[27] Bidar M, Rastegar AF, Ghaziyani P and Namazikhah MS. Evaluation of apically extruded debris in conventional and rotary instrumentation techniques. J Calif Dent Assoc 2004;32(9): 665-671.
[28] Zarrabi MH, Bidar M and Jafarzadeh H. An in vitro comparative study of apically extruded debris resulting from conventional and three rotary (profile, RaCe and Flexmaster) instrumentation system. J Oral sci 2006;48(2):85-88.
[29] Adl A, Sahebi, S, Moazami F and Niknam M. Comparison of apical debris extrusion using a conventional and two rotary techniques. Iran Endod J. 2009;4(4):135-138.
[30] Madhusudhana K, Mathew VB, Reddy NM. Apical extrusion of debris and irrgants using hand and three rotary instrumentations systems- an in vitro study. Contemp Clin Dent 2010;1(4):234-236.
[31] Ghivari SB, Kubsad GC, Chandak MG and Akarte NR. Apical extrusion of debris and irrigant using hand and rotary systems: a comparative study. J Conserve Dent 2011;14(2):187-190.
[32] Reyhani MF and Ghasemi N Apically extruded debris: Mtwo vs BioRaCe and K-file. Eur int j of sci and tech 2016;5(2):54-59.
[33] Mangalam S, Rao CVN, Laxminarayanan L. Evaluation of apical extrusion and irrigant using three instrumentation techniques. Endodontology 2002; 14:19-23.
[34] Borges AH, Pereira AM, Porto AN, Estrela CRDA, Pedro FLM, Aranha AMF and Guedes OA) The influence of cervical preflaring on the amount of apically extruded debris after root canal preparation using different instrumentation systems. J Endod 2016; 42(3):465-469.
[35] Lu Y., Wang R., Zhang L., Li, H.L., Zheng, Q.H., Zhou, X.D. and Huang, D.M., Apically extruded debris and irrigant with two Ni-Ti systems and hand files when removing root fillings: a laboratory study. Int Endod J, 2013;46(12):1125-1130.

[36] Karataş E, Ersoy İ, Gündüz HA, Uygun AD, Kol E, Çakıcı F. Influence of instruments used in root canal preparation on amount of apically extruded debris. Artif Organs 2016; 40:774-7.

[37] Ehsani M, Farhang R, Harandi A, Tavanafar S, Raoof M, Galledar S. Comparison of apical extrusion of debris by using single-file, full-sequence rotary and reciprocating systems. J Dent (Tehran) 2016; 13:394-9.

[38] Vivekanandhan P, Subbiya A, Mitthra S, Karthick A. Comparison of apical debris extrusion of two rotary systems and one reciprocating system. J Conserv Dent 2016; 19:245-9.

[39] Nayak, G., Singh, I., Shetty, S. and Dahiya, S. Evaluation of apical extrusion of debris and irrigant using two new reciprocating and one continuous rotation single file systems. J Dent (Tehran, Iran), 2014;11(3):302-309.

[40] Chi CW, Lai EHH, Liu CY, Lin CP, Shin CS. Influence of heat treatment on cyclic fatigue and cutting efficiency of ProTaper Universal F2 instruments. J Dent Sci 2017;12: 21-6.

[41] Walton R, Torabinejad M. Endodontics: principles and practice. 4th ed. St. Louis, MO: Saunders/Elsevier; 2009.

[42] Ash M, Nelson S. Wheeler's Dental Anatomy, Physiology and Occlusion. 8th ed. Philadelphia: Saunders; 2003.

[43] Mitchell RP, Yang SE, Baumgarter JC. Comparison of apical extrusion of NaOCl using the EndoVac or needle irrigation of root canal. J Endod 2010;36(2):338-341.

[44] Tambe, V.H., Nagmode, P.S., Vishwas, J.R., Saujanya, K.P., Angadi, P. and Ali, F.M., Evaluation of the amount of debris extruded apically by using conventional syringe, Endovac and ultrasonic irrigation technique: An in vitro study. J Int Oral Health, 2013;5(3):.63-66.

[45] Karatas E, Ozsu D, Arslan H and Erdogan AS. Comparison of the effect of nonactivated self-adjusting file system, Vibringe, EndoVac ultrasonic and needle irrigation of apical extrusion of debris. Int Endod J 2015; 48(4):317-322.

[46] İriboz, E., Bayraktar, K., Türkaydın, D. and Tarçın, B., Comparison of apical extrusion of sodium hypochlorite using 4 different root canal irrigation techniques. J Endod 2015;*41*(3):380-384.

[47] Yost, R.A., Bergeron, B.E., Kirkpatrick, T.C., Roberts, M.D., Roberts, H.W., Himel, V.T. and Sabey, K.A., Evaluation of 4 different irrigating systems for apical extrusion of sodium hypochlorite. J Endod 2015;41(9):.1530-1534.

[48] Barbosa-Ribeiro M, Arruda-Vasconcelos R, Fabretti FL, Silva EJNL, De-Deus G, Gomes BPFA. Evaluation of Apically Extruded Debris Using Positive and Negative Pressure Irrigation Systems in Association with Different Irrigants. Braz Dent J 2018;29(2): 184-188.

[49] Azim AA, Aksel H, Margaret Jefferson M, Huang GT. Comparison of sodium hypochlorite extrusion by five irrigation systems using an artificial root socket model and a quantitative chemical method. Clin Oral Investig. 2018;22(2):1055-1061.