A comparison of apically extruded debris and root canal preparation time of primary mandibular second molars using hand files, Mtwo, Reciproc, and Gentlefile rotary systems: An in-vitro study

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Abstract:

Apical extrusion of debris in root canal preparation leads to periapical inflammation and postoperative pain. The root canal preparation system affects the amount of extruded debris. On the other hand, reducing treatment time in pediatric dentistry is very important to improve behavior management. This study set out to compare the apical extrusion of debris and root canal preparation time of primary mandibular second molars using hand files, Mtwo, Reciproc, and Gentlefile rotary systems. In this experimental in-vitro study, 80 roots of primary mandibular second molars were randomly divided into four groups (n=20).The mesiobuccal canals were instrumented with hand files, Mtwo, Reciproc, and Gentlefile, and the preparation time was recorded. The extruded debris was collected in previously weighed Eppendorf tubes and desiccated in an incubator at 70°C for five days. The weight of the desiccated debris from each sample was calculated. Data were analysed using one-way ANOVA followed by the post-hoc Tukey's test for pairwise comparisons.Apical extrusion of debris and preparation time were significantly higher in the hand file group. Gentlefile caused minimal extrusion of debris with the shortest preparation

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Introduction:

Chemomechanical preparation is an inseparable part of root canal treatment.(Topcuoglu et al., 2016, Vyavahare et al., 2016) During root canal preparation, dentinal chips, pulp tissue residues, necrotic debris,

irrigation solution, and microorganisms enter the periapical tissues, leading to undesirable clinical consequences such as induction of inflammation, postoperative pain, and delayed periapical healing.(Topcuoglu et al., 2016, Gungor and Kustarci, 2016, Soi et al., 2015) As with permanent teeth, preventing or reducing apical extrusion of debris in deciduous teeth may increase treatment success rate. Due to the physiological root resorption in deciduous teeth and the widening of the apical foramen, intracanal debris, microorganisms, and irrigation solutions can more easily enter the periapical tissues.(Gungor and Kustarci, 2016) The extruded debris may damage the dental follicle of the underlying permanent tooth and the periapical tissue and cause hypoplasia, morphological changes of the dental crown, or cessation of root formation in the underlying permanent tooth bud.(Gungor and Kustarci, 2016, Kucukyilmaz et al., 2015, Thakur et al., 2017) Conventional endodontic treatment of deciduous teeth is performed with hand files. However, this treatment has shortcomings. For one thing, the preparation time is relatively too long, which requires more professional behavior management in pediatric patients.(Topcuoglu et al., 2016, Pinheiro SL, Barr et al., 2000) For another, root canal instrumentation with hand files results in greater extrusion of debris.(Topcuoglu et al., 2016) The extent of debris extrusion varies between different techniques and different file systems.(Topcuoglu et al., 2016, Gungor and Kustarci, 2016) In addition, several factors influence the extrusion of debris, such as instrumentation technique, size, and type of files.(Soi et al., 2015) To date, no technique has been able to completely prevent apical extrusion of debris.(Topcuoglu et al., 2016, Soi et al., 2015)

Rotary nickel-titanium (NiTi) files were first used for the endodontic treatment of deciduous teeth by Barr et al. in 2000.(Barr et al., 2000) Rotary files allow easy and fast cleaning and shaping of the root canal system. Moreover, due to their specific design, they reduce the risk of iatrogenic errors, especially in narrow and curved canals.(Pinheiro SL) The Mtwo rotary system includes NiTi rotary files with specific design and high flexibility. It preserves the root canal curvature and prepares the root canal efficiently and safely in a short time.(Topcuoglu et al., 2016)

Rotary systems often have multiple files for root canal shaping. Recently, single-file rotary systems have been introduced; however, their efficacy for deciduous teeth has not been well studied. The Reciproc system with reciprocal files is one of the single-file systems with higher flexibility and cyclic fatigue resistance than conventional NiTi alloy files.(Prabhakar et al., 2016) The reciprocal motion of Reciproc files allows their movement along the canal path with minimal resistance; therefore, they do not require a glide path.(Moreinos et al., 2016) This type of movement speeds up root canal preparation and reduces file engagement with the root canal wall. Consequently, procedural errors decrease, root canal shaping safety increases, and treatment time decreases.(Prabhakar et al., 2016)

Recently, the Gentlefile system was introduced to the market, which consists of three layers of stainless steel wire wrapped around a central core. The apical end of these files consists of two layers of wire for greater flexibility in curved canals. The use of stainless steel alloy in these files lowers their cost compared to NiTi rotary files and reduces vertical stress, prevents procedural errors such as ledge formation, transportation, and strip perforation.(Moreinos et al., 2016)

Considering the importance of debris extrusion during root canal treatment and the need for systems with shorter chair time in pediatrics, this study aimed to compare the amount of apically extruded debris and root canal preparation time of root canal of primary mandibular second molars using hand files, Mtwo, Reciproc, and Gentlefile rotary systems.

Material and Methods:

1. Tooth selection

Primary mandibular second molars were extracted due to periapical pathologies or as part of an orthodontic treatment plan. They were extracted and immersed in 0.5% sodium hypochlorite solution for two days. A periodontal scaler was used to remove the pulpal residues and calculus from the outer root surface.(Labbaf et al., 2017) The teeth were then stored in saline solution until the experiment was conducted.(Soi et al., 2015) Mesiodistal and buccolingual radiographs were taken of the teeth, and those with 5-10° mesiobuccal root canal curvature, according to Schneider's method (Schneider, 1971), were

selected. Teeth with caries, cracks, or fractures in their mesial root were excluded.

After preparation of the access cavity, the patency of the mesiobuccal canal was ensured with a #10 K-file (Mani, Japan). A #10 K-file was inserted into the canal to determine the working length until its tip was visible at the apex. The working length was determined 1 mm below this length. Teeth with a canal working length < 8 mm or > 12 mm and internal root canal dimensions larger than a #25 K-file were excluded. Finally, 80 specimens were selected according to the eligibility criteria.

2. Specimen preparation

For standardization, the teeth were decoronated such that the occlusogingival height of the pulp chamber was approximately 3 mm from its floor.(Labbaf et al., 2017) The technique described by Myers and Montgomery was used to quantify the amount of debris extruded through the apex.(Myers and Montgomery, 1991) To this end, an Eppendorf microtube (Eppendorf India Limited, Chennai, India) was placed in a penicillin vial, a hole corresponding to the size of the root was created on each rubber stopper of the Eppendorf microtube, and the root was pushed into the level of the cementoenamel junction. The root was then fixed with cyanoacrylate adhesive. A 27-gauge needle was inserted into the rubber stopper to equalize the air pressure inside and outside the vial. To increase stability, each rubber stopper was attached to the vials with a silicone impression material (Coltene-Whaledent, Allstetten, Switzerland). The outer surface of the vials was wrapped with aluminum foil to mask the debris extruded through the apex during root canal preparation.(Topcuoglu et al., 2016) Before starting the root canal preparation, each empty microtube was rinsed, dried in an incubator, and weighed three times consecutively with a semi-microbalance (Sartorius AG, Göttingen, Germany) with an accuracy of 10-4 g. The mean value was calculated and considered as the weight of the microtube.(Labbaf et al., 2017) Then, the specimens were divided into four groups by block randomization.

3. Collection of extruded debris

Hand K-files Group: The root canals were prepared using hand K-files (Mani, Japan) in the order of 15/0.02, 20/0.02, 25/0.02, and 30/0.02 according to the standard technique. All files were used up to the working length. Before using each file, the root canal was rinsed with 0.6 ccs of distilled water. After each file was used to the working length, apical patency was ensured with a clean #10 K-file. Finally, the canal was rinsed with 0.6 ccs of distilled water.

Mtwo Group: The root canals were prepared with the Mtwo rotary system (VDW, Munich, Germany) in the order of 10/0.04, 15/0.05, 20/0.06, 25/0.06, and 30/0.05 using the Mtwo endomotor (X-Smart plus; Dentsply Maillefer) with a smooth up-and-down motion at 280 rpm according to the manufacturer's instructions. All files were used to the working length. Before using each file, the root canal was rinsed with 0.5 ccs of distilled water. After each file was used to the working length, apical patency was ensured with a clean #10 K-file. Finally, the canal was rinsed with 0.5 ccs of distilled water.

Reciproc Group: The root canals were prepared using the Reciproc rotary system (VDW, Munich, Germany). The R25 file (25/0.08) with a Silver Reciproc Endo motor (VDW, Munich, Germany) was used for this purpose. Before each use of the R25 file, the root canal was rinsed with 1 cc of distilled water. The file was inserted into the canal in two steps, with the rubber stop set to two-thirds of the length the first time and the entire working length the second time. The range of the pecking motion did not exceed 3-4 mm. After the file reached two-thirds of the working length, apical patency was ensured with a clean #10 K-file. The flutes of the R25 file were also cleaned with gauze soaked in alcohol. Finally, the root canal was rinsed with 1 cc of distilled water.

Gentlefile Group: The root canals were prepared with the Gentlefile rotary system (MedicNRG, Kibbutz Afikim, Israel), so the GF1 file (22/0.04) and the corresponding handpiece were used at 6500 rpm. Each root canal was rinsed with 1 cc of distilled water before using the GF1 file. The file was inserted into the canal in two steps, with the rubber stop set to two-thirds of the length the first time and the entire working length the second time. The file was inserted for five seconds with gentle pecking motion and light pressure. After reaching two-thirds of the working length, apical patency was ensured with a clean #10 K-file. The flutes of the GF1 file were also cleaned with gauze

soaked in alcohol. Finally, the root canal was rinsed with 1 cc of distilled water.

For all specimens, 3 ccs of distilled water delivered via a 30 G side-opening endodontic irrigation needle for root canal irrigation, which was passively inserted in the first 2 mm of the working length. A single operator prepared all root canals. The total preparation time, including file activation, file change, flute cleaning, and root canal irrigation, was measured with a digital chronometer with an accuracy of 0.01s.(Kucukyilmaz et al., 2015)

After root canal preparation was completed, the outer surface of the root end was rinsed with 1 mm of distilled water to loosen and collect the debris adhering to the apex. The surface of the microtubes was cleaned with alcohol to remove impurities. The microtubes were then placed in an incubator at 70 °C for five days to evaporate moisture before the debris was weighed.(Labbaf et al., 2017) The microtubes were weighed three times consecutively using a semi-microbalance (Sartorius AG, Göttingen, Germany). The mean of the measurements was calculated and subtracted from the weight of each dry microtube (measured at the baseline) to calculate the weight of the desiccated debris extruded through the root apex.(Labbaf et al., 2017)

4. Statistical analysis used:

The four groups were compared using one-way ANOVA. Pairwise comparisons were performed using the post-hoc Tukey's test. All statistical analyses were performed using SPSS version 20 at $P<0.05$ level of significance.

Results:

Table 1 shows the mean amount of extruded debris and the mean root canal preparation time in the four groups. One-way ANOVA revealed significant differences in the amount of extruded debris and preparation time among the four groups ($P< 0.01$).

Pairwise comparisons using the Tukey's test (table 2) showed that the amount of extruded debris and preparation time in the hand file group was significantly higher than the corresponding values in the other groups ($P = 0.000$). In addition, the amount of extruded debris and the preparation time in the Gentlefile group were significantly lower than the corresponding values in all the other groups ($P = 0.000$). The amount of extruded debris was not significantly different between the Mtwo and Reciproc groups ($P = 0.95$). However, the preparation time was significantly longer in the Mtwo group than in the Reciproc group ($P = 0.001$).

Table 1. Amount of extruded debris (g] and root canal preparation time(s] in the four groups

Group(n=20)		Mean ± SD	Minimum	Maximum
Hand files	Debris	0.051305 ± 0.0206189	0.0216	0.0962
	Preparation time	330.55 ± 49.661	250	450
Mtwo	Debris	0.022050 ± 0.0085227	0.0038	0.0442
	Preparation time	223.05 ± 45.352	128	299
Reciproc	Debris	0.019685 ± 0.0033311	0.0141	0.0281
	Preparation time	166.80 ± 29.040	97	207
Gentlefile	Debris	0.015490 ± 0.0025563	0.0200	0.0110
	Preparation time	106.80 ± 18.872	79	143

Table 2. Pairwise comparison of the extruded debris weight and root canal preparation time between groups

Group(n=20)			Significance	95% confidence interval	
				Lower bound	Upper bound
Hand files	Debris	Mtwo	0.000	0.013963	0.044547
		Reciproc	0.000	0.016939	0.046301
		Gentlefile	0.000	0.021174	0.050456
	Preparation time	Mtwo	0.000	62.79	152.21
		Reciproc	0.000	124.96	202.54
		Gentlefile	0.000	187.21	260.29
Mtwo	Debris	Hand files	0.000	-0.044547	-0.013963
		Reciproc	0.950	-0.003922	0.008652
		Gentlefile	0.032	0.000386	0.012734
	Preparation time	Hand files	0.000	-152.21	-62.79
		Reciproc	0.001	20.08	92.42
		Gentlefile	0.000	82.59	149.91
Reciproc	Debris	Hand files	0.000	-0.046301	-0.016939
		Mtwo	0.950	-0.008652	0.003922
		Gentlefile	0.001	0.001394	0.006996
	Preparation time	Hand files	0.000	-202.54	-124.96
		Mtwo	0.001	-92.42	-20.08
		Gentlefile	0.000	36.75	83.25
Gentlefile	Debris	Hand files	0.000	-0.050456	-0.021174
		Mtwo	0.032	-0.012734	-0.000386
		Reciproc	0.001	-0.006996	-0.001394
	Preparation time	Hand files	0.000	-260.29	-187.21
		Mtwo	0.000	-149.91	-82.59
		Reciproc	0.000	-83.25	-36.75

Discussion:

Flare-up or postoperative pains and inflammation are common problems after endodontic treatments (Kalra et al., 2017), mainly due to the extrusion of bacteria, debris, irrigation solutions, and intracanal medications into the

periapical area. The severity of the reactions depends not only on the amount of extruded debris but also on the virulence of the bacteria.(Soi et al., 2015) Thus, even the extrusion of a small amount of debris causes pain and inflammation.(Ehsani et al., 2016) Therefore, it is important to find a root canal instrumentation system with minimal extrusion of debris.(Kalra et al., 2017)

In this study, apical extrusion of debris was compared using hand files, Mtwo, Reciproc, and Gentlefile rotary systems. The results showed extrusion of debris in all groups; however, extruded debris was significantly higher in the hand file group than in all the other groups (P = 0.000). Several factors such as the instrumentation technique, depth of flutes, degree of taper, and cross-sectional area of the file influence the apical extrusion of debris. (Soi et al., 2015), (Neelakantan et al., 2018, Wycoff and Berzins, 2012) When hand files are used, the filing motion in the standard technique simulates the effect of a piston on the apical portion of the root and results in greater extrusion of debris through the apex compared to coronal extrusion of debris.(Kalra et al., 2017, Ebrahimzadeh et al., 2020) The Mtwo files with an S-shaped cross-section, positive cutting angle, and a non-cutting tip, cut through the dentinal walls.(Azar et al., 2012) The presence of a space between the blades in this particular type of file increases the transport of debris towards the coronal region.(Burklein and Schafer, 2012)

Moreover, the gradual increase in such spaces from the tip to the shaft prevents the interlocking of the file in the root canal walls during file rotation and reduces the apical extrusion of debris.(Topcuoglu et al., 2016) The cross-section of the Reciproc file is also S-shaped, and the canals were shaped with only one file. These files are made of M-wire alloy produced by heat treatment of the conventional NiTi.(Barr et al., 2000) It is proved that the M-wire alloy has higher flexibility and cyclic fatigue resistance than the conventional NiTi alloy.(Prabhakar et al., 2016) The counterclockwise (150°) motion of the file cuts through the dentinal wall, while its clockwise (30°) rotation at 300 rpm (10 cycles of reciprocating motion) loosens the flutes from the root canal wall. This type of movement accelerates root canal preparation and reduces file engagement with the root canal wall; consequently, this results in less apical extrusion of debris.(Barr et al., 2000)

Like the study by Uzun et al. (Uzun et al., 2016), the present study showed higher apical extrusion of debris in the Mtwo group than Reciproc; however, this difference was not statistically significant (P = 0.95). It appears that the use of fewer files and the high cutting efficiency of the blades in the Reciproc system results in root canal preparation with less force and thus less apical extrusion of debris.(Topcuoglu et al., 2016, Wycoff and Berzins, 2012)

The amount of extruded debris in the Gentlefile group was significantly lower than in all the other groups (P < 0.05). To date, no study has investigated the apical extrusion of debris when using the Gentlefile system. A significant difference between the Gentlefile and the other rotary systems is that it has a non-cutting file tip and an abrasive surface, which resulted in the wear of the root dentin rather than cutting it.(Neelakantan et al., 2018) However, the S-shaped cross-section and sharp cutting blades of the Mtwo and Reciproc files resulted in the invasive removal of root dentin.(Nayak et al., 2014, Nevares et al., 2015) Thus, it appears that the abrasive nature of the file and the low apical preparation responsible for the lower apical debris extrusion were responsible for the lower apical extrusion of debris in this group.

In the literature, the mean amount of debris extruded through the apex of permanent teeth after root canal preparation with hand files, Mtwo, and Reciproc was much lower than that in deciduous teeth.(Labbaf et al., 2017, Uzun et al., 2016) This finding may be due to the lower stiffness and hardness of primary dentin compared to permanent dentin.(Govindaraju et al., 2017)

In the present study, the root canal preparation time was also compared in the four groups of hand files, Mtwo, Reciproc, and Gentlefile. The preparation time with hand files and the Gentlefile was significantly longest and shortest, respectively. In addition, instrumentation time with Mtwo was significantly longer than that with Reciproc (P = 0.001). These results were consistent with previous findings on deciduous teeth.(Ramezanali et al., 2015, Ramazani et al., 2016)

An influential factor in reducing root canal preparation time is the number of files used. It seems that the use of only one file in the Reciproc

group is responsible for a significantly shorter preparation time in this group compared to the Mtwo group (P = 0.001). In addition, it has been discussed that a high frequency of the rotation of a particular system may increase the speed of cutting through the dentin and decrease the root canal preparation time.(Mehlawat et al., 2019) Thus, the working speed of the Gentlefile, i.e., 6500 rpm compared to that of Reciproc, i.e., 300 rpm, may also be responsible for the significant reduction in root canal preparation time by the Gentlefile.

A strength of this study was quantifying the amount of debris extruded through the apex of the mesiobuccal canal of primary mandibular second molars with 5-10° curvature and 8-12 mm length, as variations in canal length, diameter, and curvature affect the extrusion of debris.(Soi et al., 2015, Lu et al., 2015) Extensive irrigation of the root canal during instrumentation is very important due to the presence of accessory canals that are not accessible to the instruments.(Ramezanali et al., 2015) The size and depth of insertion of the irrigation syringe into the canal have been shown to influence the extent of the apical extrusion of debris.(Nevares et al., 2015) Therefore, in this study, an insulin syringe was used for irrigation in all specimens, which was passively inserted into the upper 2 mm of the canal. Furthermore, since sodium crystals may remain after the evaporation of sodium hypochlorite (Ramazani et al., 2016) and affect the results, distilled water was used instead of sodium hypochlorite for root canal irrigation in the present study. The current results may not be fully generalizable to the clinical setting due to the lack of periapical tissue around the root apex, which would serve as a natural barrier to the extrusion of debris; this can be considered a limitation of this study.(Gungor and Kustarci, 2016) Some previous studies used floral foam or agar gel to simulate the natural barrier function of periapical tissue.(Nevares et al., 2015, Nayak et al., 2014) However, floral foam can absorb the extruded root canal irrigation solution and debris (Burklein and Schafer, 2012), and the density of agar gel is different from that of the periapical tissue.(Mitchell et al., 2010) Therefore, these materials cannot optimally simulate the periapical tissue and were therefore not used in this study

Conclusions:

In this study, it was found that all root canal preparation systems caused apical extrusion of debris. However, the Gentlefile group caused minimal extrusion of debris with the shortest preparation time.

References:

1. AZAR, M. R., SAFI, L. & NIKAEIN, A. 2012. Comparison of the cleaning capacity of Mtwo and Pro Taper rotary systems and manual instruments in primary teeth. *Dent Res J (Isfahan),* 9**,** 146-51.
2. BARR, E. S., KLEIER, D. J. & BARR, N. V. 2000. Use of nickel-titanium rotary files for root canal preparation in primary teeth. *Pediatr Dent,* 22**,** 77-8.
3. BURKLEIN, S. & SCHAFER, E. 2012. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. *J Endod,* 38**,** 850-2.
4. EBRAHIMZADEH, E., TAVASSOLI-HOJJATI, S. & AGHAEI, S. 2020. Comparison of apically extruded debris and instrumentation time using rotary, endodontic handpiece and hand files in primary molar teeth: (In-vitro). *journal of research in dental sciences,* 17**,** 327-334.
5. EHSANI, M., FARHANG, R., HARANDI, A., TAVANAFAR, S., RAOOF, M. & GALLEDAR, S. 2016. Comparison of Apical Extrusion of Debris by Using Single-File, Full-Sequence Rotary and Reciprocating Systems. *J Dent (Tehran),* 13**,** 394-399.
6. GOVINDARAJU, L., JEEVANANDAN, G. & SUBRAMANIAN, E. M. G. 2017. Comparison of quality of obturation and instrumentation time using hand files and two rotary file systems in primary molars: A single-blinded randomized controlled trial. *Eur J Dent,* 11**,** 376-379.
7. GUNGOR, O. E. & KUSTARCI, A. 2016. Evaluation of Apically Extruded Debris using Two Niti Systems Associated with Two Irrigation Techniques in Primary Teeth. *J Clin Pediatr Dent,* 40**,** 490-495.
8. KALRA, P., RAO, A., SUMAN, E., SHENOY, R. & SUPRABHA, B. S. 2017. Evaluation of conventional, protaper hand and protaper rotary instrumentation system for apical extrusion of debris, irrigants and bacteria- An

in vitro randomized trial. *J Clin Exp Dent,* 9**,** e254-e258.
9. KUCUKYILMAZ, E., SAVAS, S., SAYGILI, G. & UYSAL, B. 2015. Evaluation of Apically Extruded Debris and Irrigant Produced by Different Nickel-Titanium Instrument Systems in Primary Teeth. *J Contemp Dent Pract,* 16**,** 864-8.
10. LABBAF, H., NAZARI MOGHADAM, K., SHAHAB, S., MOHAMMADI BASSIR, M. & FAHIMI, M. A. 2017. An In vitro Comparison of Apically Extruded Debris Using Reciproc, ProTaper Universal, Neolix and Hyflex in Curved Canals. *Iran Endod J,* 12**,** 307-311.
11. LU, Y., CHEN, M., QIAO, F. & WU, L. 2015. Comparison of apical and coronal extrusions using reciprocating and rotary instrumentation systems. *BMC Oral Health,* 15**,** 92.
12. MEHLAWAT, R., KAPOOR, R., GANDHI, K., KUMAR, D., MALHOTRA, R. & AHUJA, S. 2019. Comparative evaluation of instrumentation timing and cleaning efficacy in extracted primary molars using manual and NiTi rotary technique - Invitro study. *J Oral Biol Craniofac Res,* 9**,** 151-155.
13. MITCHELL, R. P., YANG, S. E. & BAUMGARTNER, J. C. 2010. Comparison of apical extrusion of NaOCl using the EndoVac or needle irrigation of root canals. *J Endod,* 36**,** 338-41.
14. MOREINOS, D., DAKAR, A., STONE, N. J. & MOSHONOV, J. 2016. Evaluation of Time to Fracture and Vertical Forces Applied by a Novel Gentlefile System for Root Canal Preparation in Simulated Root Canals. *J Endod,* 42**,** 505-8.
15. MYERS, G. L. & MONTGOMERY, S. 1991. A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. *J Endod,* 17**,** 275-9.
16. NAYAK, G., SINGH, I., SHETTY, S. & DAHIYA, S. 2014. Evaluation of apical extrusion of debris and irrigant using two new reciprocating and one continuous rotation single file systems. *J Dent (Tehran),* 11**,** 302-9.
17. NEELAKANTAN, P., KHAN, K., LI, K. Y., SHETTY, H. & XI, W. 2018. Effectiveness of supplementary irrigant agitation with the Finisher GF Brush on the debridement of oval root canals instrumented with the Gentlefile or nickel titanium rotary instruments. *Int Endod J,* 51**,** 800-807.
18. NEVARES, G., XAVIER, F., GOMINHO, L., CAVALCANTI, F., CASSIMIRO, M., ROMEIRO, K., ALVARES, P., QUEIROZ, G., SOBRAL, A. P., GERBI, M., SILVEIRA, M. & ALBUQUERQUE, D. 2015. Apical Extrusion of Debris Produced during Continuous Rotating and Reciprocating Motion. *ScientificWorldJournal,* 2015**,** 267264.
19. PINHEIRO SL, N. L., IMPARATO JCP, DUARTE DA, DA SILVEIRA BUENO CE, CUNHA RS Analysis of the instrumentation time and cleaning between manual and rotary techniques in deciduous molars. . *RSBO,* 9**,** 238–44.
20. PRABHAKAR, A. R., YAVAGAL, C., DIXIT, K. & NAIK, S. V. 2016. Reciprocating vs Rotary Instrumentation in Pediatric Endodontics: Cone Beam Computed Tomographic Analysis of Deciduous Root Canals using Two Single-file Systems. *Int J Clin Pediatr Dent,* 9**,** 45-9.
21. RAMAZANI, N., MOHAMMADI, A., AMIRABADI, F., RAMAZANI, M. & EHSANI, F. 2016. In vitro investigation of the cleaning efficacy, shaping ability, preparation time and file deformation of continuous rotary, reciprocating rotary and manual instrumentations in primary molars. *J Dent Res Dent Clin Dent Prospects,* 10**,** 49-56.
22. RAMEZANALI, F., AFKHAMI, F., SOLEIMANI, A., KHARRAZIFARD, M. J. & RAFIEE, F. 2015. Comparison of Cleaning Efficacy and Instrumentation Time in Primary Molars: Mtwo Rotary Instruments vs. Hand K-Files. *Iran Endod J,* 10**,** 240-3.
23. SCHNEIDER, S. W. 1971. A comparison of canal preparations in straight and curved root canals. *Oral Surg Oral Med Oral Pathol,* 32**,** 271-5.
24. SOI, S., YADAV, S., SHARMA, S. & SHARMA, M. 2015. In Vitro Comparison of Apically Extruded Debris during Root Canal Preparation of Mandibular Premolars with Manual and Rotary Instruments. *J Dent Res Dent Clin Dent Prospects,* 9**,** 131-7.
25. THAKUR, B., PAWAR, A. M., KFIR, A. & NEELAKANTAN, P. 2017. Extrusion of Debris from Primary Molar Root Canals following Instrumentation with Traditional and New File

Systems. *J Contemp Dent Pract,* 18**,** 1040-1044.
26. TOPCUOGLU, G., TOPCUOGLU, H. S. & AKPEK, F. 2016. Evaluation of apically extruded debris during root canal preparation in primary molar teeth using three different rotary systems and hand files. *Int J Paediatr Dent,* 26**,** 357-63.
27. UZUN, I., GULER, B., OZYUREK, T. & TUNC, T. 2016. Apical extrusion of debris using reciprocating files and rotary instrumentation systems. *Niger J Clin Pract,* 19**,** 71-5.
28. VYAVAHARE, N. K., RAGHAVENDRA, S. S. & DESAI, N. N. 2016. Comparative evaluation of apically extruded debris with V-Taper, ProTaper Next, and the Self-adjusting File systems. *J Conserv Dent,* 19**,** 235-8.
29. WYCOFF, R. C. & BERZINS, D. W. 2012. An in vitro comparison of torsional stress properties of three different rotary nickel-titanium files with a similar cross-sectional design. *J Endod,* 38**,** 1118-20.