

## **Efficacy of Rotary and Reciprocating Single-File Systems and Hand Files for Gutta-Percha Removal in Endodontic Retreatment with or without Solvent: An in-Vitro Study**

Monalisa Debbarma<sup>1</sup>, Harbinder Singh<sup>2</sup>

<sup>1</sup>Postgraduate Student, Department of Conservative Dentistry and Endodontics, Awadh Dental College and Hospital, Nh 33, Danga, Jamshedpur, Jharkhand.

<sup>2</sup>Professor & Hod, Department of Conservative Dentistry and Endodontics, Awadh Dental College and Hospital, Nh 33, Danga, Jamshedpur, Jharkhand.

---

Received: 16-04-2023 / Revised: 22-05-2023 / Accepted: 15-06-2023

Corresponding author: Dr. Monalisa Debbarma

Conflict of interest: Nil

---

### **Abstract:**

**Background:** In this study, we wanted to compare the effectiveness of single-file reciprocating systems and rotary systems in removing endotoxins and bacteria in endodontic retreatment, compare the efficacy of hand file, nickel titanium rotary instrument, and reciprocating instruments for removing filling material from extracted human teeth.

**Methods:** This was a hospital based study where 90 mandibular premolar teeth were collected from the Department of Oral and Maxillofacial Surgery from Awadh Dental College and Hospital, after obtaining clearance from the institutional ethics committee and written informed consent from the study participants.

**Results:** In comparison of coronal values between the groups using one-way ANOVA, it was found to be statistically significant. In pairwise comparison of coronal values between the groups using Tukey post-hoc analysis, statistically significant difference existed between the mean values of the group pairs: I vs V, III vs V and III vs VI. In comparison of middle values between the groups using one-way ANOVA, comparison of apical values between the groups using one-way ANOVA was found to be statistically significant. In pairwise comparison of apical values between the groups using Tukey Post Hoc analysis, statistically significant difference existed between the mean values of the group pairs: I vs III, II vs III, III vs IV, III vs V and III vs VI.

In comparison of the total values between the groups using One-Way ANOVA was found to be statistically significant. In pairwise comparison of the total values between the groups using Tukey Post Hoc analysis, statistically significant difference existed between the mean values of the group pairs: III vs V and III vs VI.

**Conclusion:** Wave One reciprocating file system used with ProTaper Universal retreatment system showed more efficacy in removing gutta-percha and sealer from the root canal walls when compared to Neoniti Rotary Files and H-files. The use of solvent, Endosolv R did not improve the removal of filling material from the root canals.

**Keywords:** Rotary, Reciprocating Single-File Systems, Hand Files, Gutta-Percha, Endodontic, Retreatment, Solvent

---

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>) and the Budapest Open Access Initiative (<http://www.budapestopenaccessinitiative.org/read>), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

---

## Introduction

The clinical success rate of endodontic treatment ranges between 50-90 %. [1] Although endodontic treatment is a predictable procedure with high success rates, failures can occur either through persistent infection or through recontamination of the root canal system at some time after endodontic intervention. [2] For symptoms such as fistulation, swelling, pain, percussion, tenderness, discomfort during chewing and in cases in which the apical lesion becomes larger or is not diminishing, retreatment is indicated. [3] According to the Glossary of Endodontics, retreatment is a procedure to remove root canal filling material from the tooth, followed by cleaning, shaping, and obturation of the canals. [4] In endodontic failures, we find between one and six species, where facultative anaerobes prevail, such as *Enterococcus faecalis* (EF), responsible for 80 to 90% of these failures. Endodontic failures must be evaluated so a decision can be made whether non-surgical retreatment, surgical retreatment, or extraction is required. The goal of non-surgical retreatment is to remove materials from the root canal space and repair any deficiencies or defects, if present. [5] Gutta-percha, in combination with a variety of sealers, is the most commonly used material for root canal obturation. [6] Various methods have been used to remove gutta-percha from root canal which include the use of K-type or H-type files along with solvents such as chloroform, xylene, eucalyptol, or orange solvents, Gates-Glidden drills and heated pluggers for removal of gutta percha from the coronal third, followed by hand instrumentation or ultrasonic technique. Numerous studies have proven the efficacy of solvents in softening gutta-percha, however these studies do not address the mechanical relationship between the efficacy of solvents to remove, dissolve, or dislodge these materials from the dentinal

wall of the root canal. [7] Diverse chemical solvents are available, and they dissolve root canal sealers at different intensities. Endosolv-R is an organic solvent, that has been shown to aid in fresh AH Plus removal after filling and dissolve set AH Plus *in vitro* better than orange oil and distilled water. [8] The conventional use of hand instruments for the removal of obturation material required more time and was tedious, whereas rotary systems were faster in removing the material from root canal system. Rotary retreatment file system plasticizes obturating materials by the heat produced by friction on rotation and the specific flute design tends to pull the gutta-percha into the file flute making the removal of obturating material more efficient. The ProTaper Universal retreatment system is designed to facilitate the removal of filling material. [9] It has three retreatment instruments, D1, D2 and D3. D1 has a cutting tip and designed for removing filling materials from the coronal section of the root canal, and D2, D3 used to remove filling material from the middle and apical portions of the canals respectively. [10] A new concept has been introduced for shaping the root canal from start to finish with one single file. A new file, Neoniti (Neolix, France), developed using wire cut electrical discharge machining (EDM) process, has been introduced in dentistry which can be used as a retreatment file. Using its exclusive EDM manufacturing process, NEOLIX has developed Neoniti A1 and Neoniti C1. The newly introduced WaveOne NiTi file (Dentsply Maillefer) is a single use, reciprocating, single file system, that can be used as a retreatment file. [11] WaveOne files have a reverse helix and non-cutting modified guiding tip (Burklein, 2012). Various techniques, such as, vertical sectioning of tooth, radiographs, use of dental operating microscopes, and scanning electron microscopy (SEM) can be used, to measure the amount of gutta percha

remaining in the root canals after retreatment. Taking into account that endodontic retreatments possess a high level of difficulty and are time consuming, use of single-file instruments - which may promote cleaning and shaping effects, and is less time consuming, this clinical study was conducted. [12]

### **Aims and Objectives**

To compare the efficacy of rotary and reciprocating single file systems and hand files for gutta-percha removal in endodontic retreatment with or without solvent.

To evaluate the percentage of the remaining filling material in coronal, middle and apical portions of root canal walls.

### **Methods**

This was a hospital based study where 90 mandibular premolar teeth were collected from the Department of Oral and Maxillofacial Surgery from Awadh Dental College and Hospital, after obtaining clearance from the institutional ethics committee and written informed consent from the study participants.

### **Inclusion Criteria**

Single rooted mandibular premolars, freshly extracted for orthodontic purposes, stored in saline and used within three months of extraction were selected.

### **Exclusion Criteria**

Fractured teeth, teeth having more than one root canal, resorption, open apices, caries, obturated teeth and curved rooted teeth were excluded.

### **Materials Used**

Saline-Vision Parenteral Pvt. Ltd., Uttar Pradesh, India, 3% NaOCl – Pyrax Polymars, Uttarakhand, India, 17% EDTA – Pyrax Polymars, Uttarakhand, India, Gutta Percha Size – 30, Taper – 4% - Dentsply Maillefer, AH Plus Root Canal Sealer – Dentsply Maillefer, Konstanz, Germany, Cavit – Xenon Biomed India,

Kolkata, India, Absorbent Paper Points – Siddgar, Navi Mumbai, Maharashtra, India, Gutta Percha Solvent – Endosolv R – Septodont Healthcare India Pvt. Ltd, 5 ml Disposable Syringes – One Touch Medical Products Ltd., Bihar, India.

### **Equipment/Instruments Used**

High Speed Airotor Hand Piece – Being Foshan Medical Equipment Co., Ltd, Endo Access Bur – Dentsply Maillefer, Switzerland, K-files – No. 10, 15 – Mani Dental. Inc., Japan, Endo-Bloc – Pivo International, Punjab, India, Spreaders 15, 20, 25 – Mani Dental. Inc., Japan, Double Sided Diamond Disc – AXIS, SybronEndo, H-files assorted pack – Mani Dental. Inc., Japan., Gates Glidden Drills – Ace Endodontics Instruments & Burs, Prime Dental Products Pvt. Ltd., Thane, Maharashtra, India, X-Smart Plus – Dentsply Maillefer, Switzerland, Protaper NiTi Rotary Instruments SX, S1, S2, F1, F2 – Dentsply Maillefer, Switzerland, ProTaper Universal Retreatment File – D1, D2, D3 - Dentsply Maillefer, Switzerland, Neoniti Rotary Files – Neolix, France, WaveOne Reciprocating File System – Dentsply Maillefer, Ballaigues, Switzerland, Incubator – Acme Instruments Co., Jaipur, Rajasthan, India.

### **Study Procedure**

All endodontic procedures were performed by a single operator. In the selected samples, access opening was performed using endo-access bur size- 2. For uniform sampling, the crowns were flattened with a flat-end tapered diamond bur (coronally 1–2 mm) and a final working length of 19 mm was standardized for each sample. Each root canal was prepared by crown-down technique corresponding to Pro Taper size F2 (Dentsply Maillefer, Switzerland). During each shaping procedure the canals were irrigated with 3% NaOCl along with EDTA & saline. Paper points were used in drying the root canals and obturation was done upto 19 mm length with gutta percha of size 30 & 0.04 taper and AH Plus sealer.

After temporary filling, the samples were stored at 37 degrees Celsius in 100% humidity for 3 weeks. Radiographs of each sample were taken in buccal-lingual & mesial-distal direction to ensure the adequacy of the root filling.

For retreatment, tooth samples were divided in 6 groups, each containing 15 samples:

#### **Group I (15 samples)**

Retreatment with ProTaper Universal Retreatment files (Dentsply Maillefer, Switzerland), followed by re-shaping with Neoniti file system. In all specimens, the bulk of gutta percha was removed using the ProTaper Universal Retreatment files at preset lengths: D1 (size 30, taper 0.09) for coronal one-third, D2 (size 25, taper 0.08) for middle one-third and D3 (size 20, taper 0.07) for apical one third. Further re-shaping of teeth was done with Neoniti C1 (size 25, taper 0.12) and A1 (size 25, taper 0.06) upto the working length.

#### **Group II (15 samples)**

Endosolv R (2-4 drops) was used before re-treatment and re-shaping procedure same as in Group I.

#### **Group III (15 samples)**

Retreatment with ProTaper Universal Retreatment files followed by reshaping with WaveOne file. In all specimens, the bulk of gutta percha was removed with ProTaper Universal Retreatment files, as done in the previous groups. Further re-shaping of teeth was done with Wave One primary file (size 25, taper 0.08), upto the working length.

#### **Group IV (15 samples)**

Endosolv R (2-3 drops) was used before retreatment and re-shaping procedure same as in Group III.

#### **Group V (15 samples)**

Retreatment with GG drills (size 3 & 2) & H-files up to size 40. In all the specimens, the gutta percha from the coronal third of the canal was removed with GG drills and the bulk of gutta percha from the middle and apical third was removed with H-files (size 30, 25 and 20). Apical enlargement was performed using H-file size 40, up to the working length.

#### **Group VI (15 samples)**

Endosolv R (2-3 drops) was used before insertion of GG drills and H-files same as in Group V. Re-treatment was considered complete when - no remaining was found on the surface of the files.

Tooth samples were then vertically sectioned in buccal-lingual direction; using a double-sided diamond disc under continuous irrigation. Specimens were then photographed at 1:1 aspect ratio (square image). Using Adobe Photoshop CC (2014), the total area of canal of each tooth specimen was measured, & the remaining gutta percha in coronal, middle & apical 3rd was measured in millimeter square.

#### **Evaluation of Percentage of Residual Filling Material**

The area of the canal and of the residual filling material was recorded, and the percentage of remaining filling material on canal walls was calculated with the following equation:

$$\text{Percentage of area of remaining filling material} = \frac{\text{Area of remaining filling material}}{\text{Area of the canal wall}} \times 100$$

#### **Statistical Methods**

SPSS software version 20.0 was used for statistical analysis. One-Way ANOVA and Tukey Post Hoc analysis were done for the comparison. A p value < 0.05 was considered as statistically significant.

#### **Results**

**Table 1: Comparison of coronal values between the groups using One-Way ANOVA**

Groups	Mean	SD	F value	p value	Significance
I	14.522	12.819	4.649	0.001	Statistically significant
II	23.557	18.123			
III	7.599	3.855			
IV	18.046	12.467			
V	33.880	16.218			
VI	29.229	29.914			

Statistically significant difference exists between the mean values of the groups ( $p < 0.05$ ).

**Table 2: Pairwise comparison of coronal values between the groups using Tukey Post Hoc analysis**

Pair of groups	Mean difference	p value	Significance
I vs II	9.035	0.715	Not statistically significant
I vs III	6.922	0.885	Not statistically significant
I vs IV	3.523	0.994	Not statistically significant
I vs V	19.358	0.036	Statistically significant
I vs VI	14.707	0.201	Not statistically significant
II vs III	15.958	0.133	Not statistically significant
II vs IV	5.511	0.953	Not statistically significant
II vs V	10.322	0.586	Not statistically significant
II vs VI	5.671	0.948	Not statistically significant
III vs IV	10.446	0.573	Not statistically significant
III vs V	26.281	0.001	Statistically significant
III vs VI	21.630	0.013	Statistically significant
IV vs V	15.834	0.139	Not statistically significant
IV vs VI	11.183	0.498	Not statistically significant
V vs VI	4.651	0.978	Not statistically significant

Statistically significant difference exists between the mean values of the group pairs: I vs V, III vs V and III vs VI ( $p < 0.05$ ).

**Table 3: Comparison of apical values between the groups using One-Way ANOVA**

Groups	Mean	SD	F value	p value	Significance
I	15.387	10.147	2.308	0.05	Statistically significant
II	12.404	9.089			
III	9.901	5.555			
IV	16.371	9.645			
V	17.013	8.939			
VI	19.692	9.178			

*Comparison of middle values between the groups using One-Way ANOVA*

Groups	Mean	SD	F value	p value	Significance
I	5.823	6.172	6.031	0.000	Statistically significant
II	5.315	1.868			
III	12.922	4.490			
IV	6.260	5.334			
V	6.657	4.009			
VI	6.918	3.343			

Statistically significant difference exists between the mean values of the groups ( $p < 0.05$ ). Statistically significant difference exists between the mean values of the groups ( $p < 0.05$ ).

**Table 4: Pairwise comparison of apical values between the groups using Tukey Post Hoc analysis**

Pair of groups	Mean difference	p value	Significance
I vs II	0.507	0.954	Not statistically significant
I vs III	7.098	0.000	Statistically significant
I vs IV	0.437	0.966	Not statistically significant
I vs V	0.834	0.995	Not statistically significant
I vs VI	1.094	0.984	Not statistically significant
II vs III	7.606	0.000	Statistically significant
II vs IV	0.945	0.992	Not statistically significant
II vs V	1.342	0.961	Not statistically significant
II vs VI	1.602	0.919	Not statistically significant
III vs IV	6.661	0.001	Statistically significant
III vs V	6.264	0.003	Statistically significant
III vs VI	6.003	0.005	Statistically significant
IV vs V	0.397	0.997	Not statistically significant
IV vs VI	0.657	0.999	Not statistically significant
V vs VI	0.260	0.931	Not statistically significant

Statistically significant difference exists between the mean values of the group pairs: I vs III, II vs III, III vs IV, III vs V and III vs VI ( $p < 0.05$ ).

**Table 5: Pairwise comparison of the total values between the groups using Tukey Post Hoc analysis**

Groups	Mean	SD	F value	p value	Significance
I	11.911	10.782	3.266	0.007	Statistically significant
II	13.759	13.768			
III	10.141	5.081			
IV	13.559	10.762			
V	19.184	15.587			
VI	18.613	20.013			
<i>Comparison of the total values between the groups using One-Way ANOVA</i>					
Pair of groups	Mean difference	p value	Significance		
I vs II	1.848	0.987	Not statistically significant		
I vs III	1.770	0.989	Not statistically significant		
I vs IV	1.648	0.992	Not statistically significant		
I vs V	7.272	0.111	Not statistically significant		
I vs VI	6.702	0.175	Not statistically significant		
II vs III	3.618	0.800	Not statistically significant		
II vs IV	0.200	0.934	Not statistically significant		
II vs V	5.424	0.399	Not statistically significant		
II vs VI	4.853	0.528	Not statistically significant		
III vs IV	3.418	0.835	Not statistically significant		
III vs V	9.042	0.020	Statistically significant		
III vs VI	8.472	0.037	Statistically significant		
IV vs V	5.624	0.357	Not statistically significant		
IV vs VI	5.053	0.482	Not statistically significant		
V vs VI	0.570	0.918	Not statistically significant		

Statistically significant difference exists between the mean values of the groups ( $p < 0.05$ )  
Statistically significant difference exists between the mean values of the group pairs: III vs V  
and III vs VI ( $p < 0.05$ ).

## Discussion

Endodontic retreatment is a procedure performed on a tooth that had previously undergone root canal treatment resulting in a condition requiring further endodontic treatment to achieve a successful outcome. [13] The main success of endodontic retreatment relies on the complete removal of root canal filling material to regain access to the apical foramen to facilitate sufficient cleaning and shaping of the entire root canal system. In failed endodontic cases, obturating material harbours necrotic tissue and bacteria which are responsible for periapical inflammation. Hence, complete removal of the obturating material is necessary to reduce the microbial burden within the canal. [14] In this study, the teeth were standardized to a working length of 19 mm, and hence these varying lengths could not exert an influence on the results.

In recent years, the use of nickel-titanium (NiTi) rotary files and automated root canal devices has been increasing in endodontic treatments. The advantages of rotary NiTi instruments over hand instruments include facilitating canal preparation, preserving the shape of curved canals and producing smooth surfaces in lesser time than with manual instruments. The use of single endodontic instruments was recently recommended to decrease instrument fatigue and possible cross-contamination. This study analysed and compared three non-surgical endodontic retreatment techniques: endodontic rotary instruments, endodontic reciprocating instruments, and combined root canal retreatment technique with Gates-Glidden drills and Hedstrom files. Various studies have reported that endodontic rotary or reciprocating instruments remove the root canal filling material more effectively, whereas other studies have reported that hand files are

more efficient. [15] The ProTaper Universal retreatment system was used for retreatment in this study. This system can remove large amounts of gutta-percha through spirals running around the instruments, which produce both cutting and softening actions. Moreover, the specific flute design and rotary motion of ProTaper Universal retreatment instruments tend to pull the gutta-percha into the file flutes and direct it towards the orifice. [16]

Furthermore, the tip of the D1 file is active which helps in penetrating the filling material as compared to the original ProTaper shaping files. However, the tips of D2 and D3 are non-active which helps in preventing ledges and perforations during retreatment. [17] Wave One and Neoniti file systems were used for further gutta-percha removal as well as for reshaping in respective groups. Reciprocating systems such as Wave One produce a broader motion in the counter-clockwise direction yet shorter in the clockwise direction, keeping the file more centred in the canal. This factor, together with the marked taper of the Wave One files, creates a greater contact area between the instrument and gutta-percha, allowing the removal of obturating material as effective as that produced with continuous rotation. Reciprocating systems were not originally designed for use in retreatment procedures; nevertheless, they have been found to be effective in removing the filling material from the root canals. Neoniti files have been used for root canal treatment as well as for retreatment cases. The Neoniti rotary system has a non-homogeneous rectangular cross-section and multiple taper in a single instrument. None of the above mentioned instruments (ProTaper Universal Retreatment System, Neoniti Rotary System, Wave One Reciprocating File and

H-Files) completely removed the obturating material from the root canals of mandibular premolars. These findings are in agreement with several studies that evaluated different instruments and systems for this purpose. Solvents have been used to soften and dissolve gutta-percha in the root canal to facilitate its penetration and removal. Whether solvents are helpful during gutta-percha removal or not, is inconclusive.

In the present study, root canals were evaluated in three sections of coronal third, middle third and apical third. The result of this study showed maximum amount of remaining filling material in the coronal third and the middle third of the root canals and least in the apical third of the root canal in most of the groups. This might be explained due to more amount of gutta-percha in the coronal third.

The middle third has greater compaction of obturating material and sealer. Moreover, greater sealer penetration into dentinal tubules at the middle third could be the reason for greater amount of remaining debris in the middle third. Clinical factors that may negatively impact the outcome of endodontic retreatment are iatrogenic errors such as ledges, perforations, or instrument separation. [18] In this study, there were no perforations, instrument separation or ledges observed in any of the samples from all the groups. Another limitation of this study, was the technique that was used to determine the amount of remaining filling material. Taking digital images after splitting teeth longitudinally provided direct visualization of the filling material. Several studies have reported that the use of vertical split roots is an adequate technique, and is more accurate than radiographic examinations, which produce only two-dimensional images of the samples. [19]

### Conclusion

None of the evaluated instruments (ProTaper Universal Retreatment System,

Neoniti Rotary Files, Wave One Reciprocating File and H-Files) completely removed the obturating material from the root canals. WaveOne reciprocating file system used with ProTaper Universal retreatment system showed more efficacy in removing gutta-percha and sealer from the root canal walls when compared to Neoniti Rotary Files and H-files. The use of solvent, Endosolv R did not improve the removal of filling material from the root canals.

### References

1. Pirani C, Pelliccioni GA, Marchionni S, Montebugnoli L, Piana G, Prati C. Effectiveness of three different retreatment techniques in canals filled with compacted gutta-percha or Thermafil: a scanning electron microscope study. *Journal of Endodontics* 2009;35(10):1433-40.
2. Santos-Junior AO, Pinto LD, Mateo-Castillo JF, Pinheiro CR. Success or failure of endodontic treatments: A retrospective study. *Journal of conservative dentistry: JCD* 2019;22(2):129.
3. Chaurasiya S, Yadav G, Tripathi AM, Dhinsa K. Endodontic failures and its management: a review. *Int J Oral Health Med Res* 2016;2(5):144-8.
4. Moushmi C. Bhagavaldas, A. Diwan. Efficacy of two rotary retreatment systems in removing gutta-percha and sealer during endodontic retreatment with or without solvent. *Journal of Conservative Dentistry* 2017;20(1):12-6.
5. Ruddle CJ. Nonsurgical endodontic retreatment. *CDA Journal* 2004;32(6): 474-84.
6. Zarei M, Shahrami F, Vatanpour M. Comparison between gutta-percha and Resilon retreatment. *Journal of Oral Science* 2009;51(2):181-5.
7. Hwang JI, Chuang AH, Sidow SJ, McNally K, Goodin JL, McPherson JC. The effectiveness of endodontic solvents to remove endodontic sealers.



- Military medicine. 2015;180(Suppl 3): 92-5.
8. Müller GG, Schönhofen ÂP, Mora PM, Grecca FS, So MV, Bodanezi A. Efficacy of an organic solvent and ultrasound for filling material removal. *Brazilian Dental Journal* 2013;24:585-90.
  9. Giuliani V, Cocchetti R, Pagavino G. Efficacy of ProTaper universal retreatment files in removing filling materials during root canal retreatment. *Journal of Endodontics* 2008;34 (11) :1381-4.
  10. Shojaee NS, Vakilinezhad E, Shokouhi MM. In vitro comparison of efficacy of neolix and protaper universal retreatment rotary systems in removal of gutta-percha combined with two different sealers. *Journal of Dentistry* 2019;20(4):285.
  11. Bhondwe S, Mahajan V, Dhoot R, Bhamare R, Bhandari S. Single file NiTi rotary systems: Simple approach to root canal. *Int J Curren Res* 2016; 8(11):41165-68.
  12. Martinho FC, Freitas LF, Nascimento GG, Fernandes AM, Leite FR, Gomes AP, Camões IC. Endodontic retreatment: clinical comparison of reciprocating systems versus rotary system in disinfecting root canals. *Clinical oral investigations* 2015:1411-7.
  13. Kumari A, Gupta R, Tomer AK. A comparative evaluation of Gutta-percha removal by various rotary files: an in vitro study. *J Dent Med Sci* 2016 ;15:99-101.
  14. Fatima K, Nair R, Khasnis S, Vallabhaneni S, Patil JD. Efficacy of rotary and reciprocating single-file systems on different access outlines for gutta-percha removal in retreatment: An in vitro study. *Journal of Conservative Dentistry: JCD* 2018;21(4):354-8.
  15. Alakabani TF, Faus-Llácer V, Faus-Matoses I, Ruiz-Sánchez C, Zubizarreta-Macho Á, Sauro S, et al. The efficacy of rotary, reciprocating, and combined non-surgical endodontic retreatment techniques in removing a carrier-based root canal filling material from straight root canal systems: a micro-computed tomography analysis. *Journal of Clinical Medicine* 2020; 9(6):1989.
  16. Malhotra K, Taneja S, Kumar P. Comparison of efficacy of hand and rotary instrumentation for removing a resin-based obturating material (EndoRez) in curved root canals during retreatment: an: in vitro: study. *Endodontology* 2017;29(1):60-4.
  17. Keshav V, Passi S, Monga P, Mahajan P. Effectiveness of hand and rotary instruments in retreatment of teeth filled with resin-based filling material: an in vitro study. *Endodontology* 2016;28(2):132-6.
  18. Azim AA, Wang HH, Tarrosh M, Azim KA, Piasecki L. Comparison between single-file rotary systems: Part 1- Efficiency, effectiveness, and adverse effects in endodontic retreatment. *Journal of Endodontics* 2018;44(11):1720-4.
  19. Cordeiro KF, Silva Filho DF, IDJ CF. Current protocols for endodontic retreatment: a review. *J Odontol* 2018; 2(3):111-6.