

## EFFICIENCY OF RECIPROCATING FILES IN REMOVAL OF GUTTACORE AND SINGLE-CONE FROM CURVED ROOT CANALS: A MICRO-CT ANALYSIS

REGIR RAMADHAN HASSAN and ABDULKAREEM RAMADHAN IBRAHIM

Dept. of Conservative Dentistry, College of Dentistry, University of Duhok, Kurdistan Region-Iraq

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### ABSTRACT

**Aims:** The purpose of this study was to assess and compare the retreatment ability of different reciprocating single file systems in curved canals obturated with GuttaCore and single-cone obturation techniques using microcomputed tomography. **Methods:** Sixty-four mandibular molar teeth with root canal systems that have two independent severely curved canals in the mesial root have been chosen for the current study. The root canals have been instrumented with WaveOne Gold primary file and obturated by two techniques: Group SC filled with Single-cone and group GC filled with GuttaCore obturation techniques, using AH Plus sealer in both methods. First micro-CT scan has been taken and the samples have been subdivided into 4 groups for each obturation technique (n16 canals each) according to the retreatment system: Group R: Reciproc (R25 file), group RB: Reciproc Blue (R25 file), group WO: WaveOne (Primary file 25) and group WOG: WaveOne Gold (Primary file 25). After the retreatment procedures, the second micro-CT scan has been taken and then the volume of residual obturation material was calculated. **Results:** The residual obturation material was spotted in all samples. The mean percentage of residual obturation material was significantly lower when canals retreated with the R25/ Reciproc Blue file, while no significant differences were observed among the other three systems. A significant difference was noticed between GuttaCore and single-cone remnants of obturation material. **Conclusion:** Under the circumstances of the current study, the use of the Reciproc Blue system is more effective in removing root canal obturation material filled either with GuttaCore or single-cone obturation techniques. R, WO, and WOG systems resembled in the removal of obturation material. The removal of obturation materials from severely curved root canals obturated with GuttaCore is more difficult than the single cone.

**KEYWORDS:** Reciproc, Reciproc Blue, WaveOne, WaveOne Gold, GuttaCore, Single-cone, severely curved root canal, Micro-CT

### INTRODUCTION

In spite of the favorable outcome of root canal treatment, failures occasionally happen and necessitate reintervention; in these cases, nonsurgical root canal retreatment is the primary treatment choice. Inadequate coronal restorations, unfilled or insufficiently filled root canals and poor root canal disinfection are the primary causes of failed endodontic therapy (Dioguardi et al., 2022). The removal of the old obturation material, establishing canal patency, thoroughly disinfecting and obturating the root canals are all necessary for the non-surgical root canal retreatment to be successful (Ng et al., 2011). However, previous research revealed the impossibility of completely removing the initial obturation material from root canal systems (Ajina et al., 2022).

Ultrasonic tips, hand files, heated instruments, continuous rotating and

reciprocating rotary files have all been suggested as retreatment techniques for removing the original root canal obturation and re-establishing access to the root canal system (Bodrumlu et al., 2008; Kfir et al., 2012; Rödig et al., 2014; Kasam et al., 2016).

To enhance gutta-percha removal, specific retreatment rotary files with continuous rotation, active tips, and more aggressive cutting have been developed. However, it was not demonstrated that their performance was superior to that of ordinary files. Moreover, using these instruments during endodontic retreatment can increase the likelihood of dentinal microcracks (Koçak et al., 2017; Jain et al., 2018), extending clinical time and expenses without providing any further benefits (Yilmaz et al., 2017; Bago et al., 2019).

The single file systems are the product of the latest revolution and development of endodontic instruments science concerning cross-sectional

design and alloy treatment. These files have shown to be more successful and efficient in root canal preparation than conventional multifile systems in addressing additional walls of the root canal systems. Their enhanced mechanical capabilities make them appropriate for the effective removal of gutta-percha (Altunbas et al., 2015; Azim et al., 2017).

The single-file systems with reciprocation motion ensure avoiding continuous rotational stress and the constant torque that is generated from traditional rotary-file systems on the inner surface of root canal walls (Franco et al., 2011).

The Reciproc (VDW) and WaveOne (Dentsply Sirona) systems, which are utilized in reciprocation mode were developed utilizing M-Wire technology. Files manufactured from M-wire technology are enhanced by transforming a NiTi wire in the austenite phase into the R-phase, an intermediate phase formed during the transformation from martensite to austenite on heating, and reverse transformation on cooling. M-Wire files can be more safely used in curved canals as its more fatigue resistant than traditional nickel-titanium (NiTi) alloy files (AlRahabi and Atta, 2019).

The Reciproc (VDW) system files have a noncutting tip, S-shaped cross section. The WaveOne (Dentsply Sirona) system files have a reverse helix and 2 distinct cross-sections along the length of their active portions. From D1-D8, the WaveOne files have a modified convex triangular cross-section, whereas from D9-D16, these files have a convex triangular cross-section (Van der Vyver and Jonker, 2014).

The upgradation of Reciproc single-file system has generated Reciproc Blue file system (VDW). Similar in design to the Reciproc. It is made utilizing the "blue treatment," a brand-new heat treatment technique that was created to improve the flexibility of the file's structure (De-Deus et al. 2017; Topçuoğlu et al., 2018).

WaveOne Gold (Dentsply Sirona) is a reciprocating file system with a parallelogram cross-sectional design and two cutting edges. The file is created using a brand-new thermal treatment which is a post-manufacturing process that involves progressively cooling and heating the ground NiTi files resulting in enhanced features. While giving the file its unique gold finish, this procedure also significantly increases its strength and flexibility compared to its predecessor WaveOne file (Canali et al., 2019).

Carrier-based obturation systems have been developed to simplify root filling procedures. However, in retreatment cases, carrier-based systems removal may be more time-consuming and more difficult to be removed (Frajlich et al., 1998, Baratto et al., 2002). A new core-carrier system was introduced by the manufacturer of Thermafil (Dentsply Sirona) that consists of a cross-linked gutta-percha core (GuttaCore) instead of a plastic carrier. (Jorgensen et al., 2017).

In endodontics, it is quite uncommon to encounter a tooth with straight root canals because most teeth display some degree of curvature (Hargreaves et al., 2016). Teeth with curved roots make it extremely difficult to completely disinfect the canals and remove the obturation material (Alves et al., 2016).

Micro-computed tomographic (micro-CT) imaging provides a reliable, non-invasive method for evaluating root canals in three dimensions (3D). Comparing the effects of various files on the removal of different obturation materials in severely curved canals during non-surgical retreatment procedures using micro-computed tomographic imaging is limited in the literature (Aksoy et al., 2021)

Therefore, this study aimed to measure and compare the volume of remaining obturation materials (single-cone and GuttaCore) in the curved root canal systems retreated with Reciproc, Reciproc Blue, WaveOne, WaveOne Gold files using micro-computed tomographic imaging.

## MATERIAL AND METHODS

### Sample selection

Sixty-four extracted human lower (mandibular) molar teeth have been selected under the inclusion criteria and soaked in thymol 0.1% until use. The extracted teeth have been examined by CBCT for the following inclusion criteria: Mesial roots with type IV Vertucci's classification (Vertucci, 1984), with completely formed apex, no canal calcification; no previous root canal treatments and no external or internal resorption. After access cavity preparation, the radius and angle of curvature of the teeth have been examined using standardized periapical radiographs.

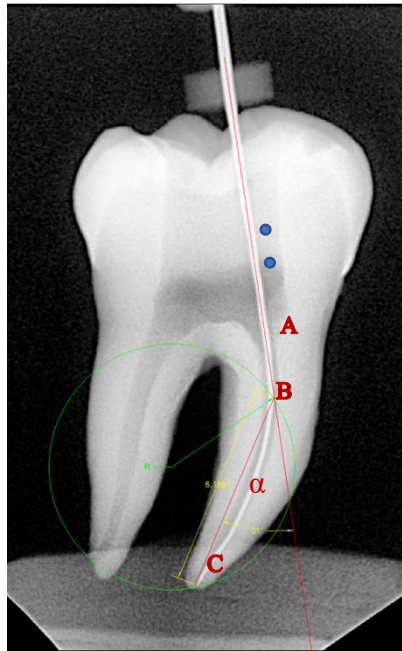
The root apex of each tooth has been embedded in wax and mounted for radiography in order to keep it in a constant and stable position. The dental sensor has been positioned in the paralleling device with the center of the X-

ray beam aligned perpendicular to the root canal and the long axis of the root canal being parallel and as close to the surface of the sensor as possible.

All radiographs have been taken at the same source-to-sensor and object-to-sensor distances with the same exposure time. A computerized program for processing digital images (AutoCad 2021 v.24.1 program) was utilized to calculate

the canal curvature degree and radius. (Bürklein et al., 2019).

The angle and radius of the root canals curvature have been measured using Schneider's and Schafer's method. (Figure 1) (Schneider, 1971; Schäfer et al. 2002). Teeth with root canal curvatures 25-40 angle and radius curvatures of curvature less than 10 mm have been selected.



**Fig (1):** Measurement of radius and angle of curvature of tooth. Using Schneider's method: A is pointed at the canal orifice. B is pointed where the file begins to deviate the original path. C is pointed at the apical foramen.

Two straight lines are drawn, one on AB and the other one on BC. These lines are connected at a measured angle. Using Schafer's method: It is possible to calculate the radius according to the following formula:

$$R = BC \div 2 \sin \alpha$$

### Preparation and instrumentation of the samples

The teeth crowns have been flattened with a diamond disc to obtain an 18-mm tooth length, initially established with a digital caliper. K-file no.10 had been scouted into the canal to the level when it becomes visible in the apical foramen, then 0.5 mm have been subtracted, and the determined length have been the working length. The glide path has been created using a no. 15 K-file

Each tooth has been placed in polyvinylsiloxane impression material and stabilized on a vise to clinically simulate the alveolar position. All endodontic procedures were performed with the roots being in the

aforementioned stabilized position. (Prati et al., 2020)

The WaveOne Gold (Dentsply Sirona) primary file with the endomotor device (VDW Silver) have been used to instrument all canals. The WaveOne All mode has been chosen in the device. The file has been taken out, cleaned, and the canals have been irrigated with 2 ml 5.25% sodium hypochlorite (NaOCl) after each of three pecking movements instrumenting the canal. During the final irrigation, 1 ml 17% EDTA was applied for 1 minute, followed by 1 ml 5.25% NaOCl for 30 seconds, and finally 1 ml normal saline. With paper points, the root canals have been dried.

### **Root canal obturation**

The instrumented teeth have been divided into two obturation techniques (32 teeth: 64 canals each):

Group SC: Single-cone technique

Using single point gutta-percha and AH Plus (Dentsply Sirona) canal paste, each canal has been obturated.

Group GC: GuttaCore technique

Each canal was obturated using AH Plus (Dentsply Sirona) canal paste and a warmed gutta-percha carrier-based system (Dentsply Sirona) by heating a size 25 GuttaCore obturator in the ThermaPrep heater obturator oven (Dentsply Sirona) and subsequently introducing it into the root canal system at the working length. Following the manufacturer's instructions, the GuttaCore obturator was cut at the cement-enamel junction and compacted.

Following the root canal obturation, the access cavities have been sealed with temporary filling material (Cavit; 3 M ESPE, St Paul, MN). In an incubator with 37°C temperature and humidity of 100%, the teeth were stored for a week to allow the sealers to set.

Skyscan 1275 (Bruker microCT, Kontich, Belgium) micro-CT device was used to separately scan each sample. The parameters that to be used have been as follows: an isotropic voxel size of 18  $\mu\text{m}$  with a copper-aluminum filter, x-ray voltage of 80 kV and 125 mA, 360 rotations, and a 0.3 rotation step.

All the samples have been stored in an incubator at 37°C temperature and humidity of 100% for 1 month.

### **Removal of obturation material**

The samples have been randomly subdivided into 4 groups per each obturation technique (n16 canals each) according to the retreatment system to be used. Each instrument has been used in the removal of obturation materials from three canals in each group.

Group R: Reciproc system

The VDW endomotor was utilized with the Reciproc R25 file (tip size 25; variable taper 0.08) in reciprocation Reciproc All mode. According to the manufacturer's instructions, the file was advanced apically using an in-and-out pecking motion with an extent of around 3 mm; light apical pressure was applied with a brushing motion on the lateral walls. The file is taken out of the canal after three pecks, cleaned with sterile gauze, and then 5.25% NaOCl is used to irrigate the canal. Up till the instrument reached the WL, this technique was repeated.

Group RB: Reciproc Blue system

The removal of obturation material has been performed with the Reciproc Blue (RB) R25 file (tip size 25; variable taper 0.08) using the same retreatment technique described for Group R.

Group WO: Wave One system

WaveOne (WO) 25.08 Primary file have been used with the VDW motor set at reciprocation Wave One All mode. The retreatment technique is the same as used in the previous groups.

Group WOG: Wave One Gold system

The WaveOne Gold (WOG) primary file (tip size 25; variable taper 0.07; Dentsply Sirona Endodontics) have been used with the VDW motor set at reciprocation WaveOne All mode. The retreatment technique is the same as used in the previous groups.

Prior to each file reinsertion, around 2 ml of 5.25% NaOCl was used to irrigate the canal, and an overall of 20 ml have been used for each canal. Following the retreatment procedures. 3 ml of 17% EDTA have been used in order to remove the smear layer followed by the final rinsing protocol: rinsing with 3 ml of 5.25% NaOCl for 30 s then 1 ml of saline solution for 30s.

Retreatment is considered complete when each instrument reached the WL for five consecutive times and when there is no remaining filling material visible on the file. The canals have been dried with paper points.

After removal of obturation materials, the samples have been scanned individually employing the same micro-CT device with the same parameters used for the first scan.

### **Measurement of remaining root canal obturation material**

The CTAn v.1.18.1 program was used in order to determine the volume of obturation material in the root canal. The percentage of remaining obturation material in the mesial canals had been calculated as follows:

$$F/I \times 100 = \text{Volume (\%)} \text{ of remaining obturation material}$$

Where F represents final volume of obturation material in  $\text{mm}^3$ , I, Initial volume of obturation material in  $\text{mm}^3$ .

### **Statistical analysis**

For the evaluation of normality of data, the Kolmogorov-Smirnov test was used. One-way analysis of variance, Post hoc Duncan, and the independent t test were used for comparison of percentage volume the residual obturation materials of experimental groups. all the results

were analyzed utilizing IBM SPSS Statistic software (v.25.0; IBM Corp).

**RESULTS**

No sample showed complete removal of the root canal obturation material (Figure 5). The result of present study concerning the volume reduction of obturation material between the experimental groups are presented in table 1, 2 and 3.

**1. Volume of the remaining obturation material according to the file systems irrespective to the obturation techniques used**

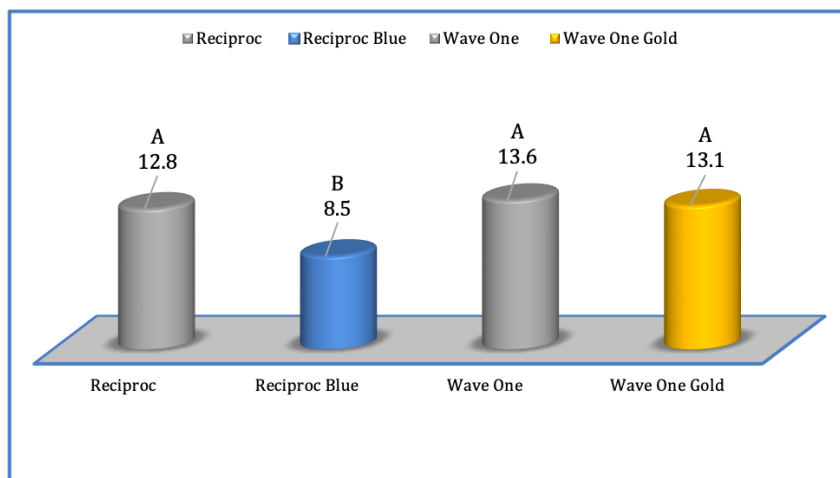
The lowest mean volume of the remaining obturation material were found in group RB ( $8.5 \pm 3.7$ ) followed by group R ( $12.8 \pm 6.3$ ), WOG ( $13.1 \pm 6.5$ ) and WO ( $13.6 \pm 6$ ) respectively (Figure 2).

ANOVA and Duncan test revealed significant difference between the groups in which Recipro blue file was significantly different from the other files (Table 1).

**Table (1):** Descriptive and statistical analysis (ANOVA, Duncan) of residual root canal obturation according to the file systems used

Experimental groups	N	Mean $\pm$ SD	p-value	Duncan
R	32	12.8 $\pm$ 6.3	0.002*	B
RB	32	8.5 $\pm$ 3.7		A
WO	32	13.6 $\pm$ 6		B
WOG	32	13.1 $\pm$ 6.5		B

R: Recipro, RB: Recipro Blue, W: WaveOne, WOG: WaveOne Gold. SD; Standard deviation  
Different uppercase letters in the vertical direction: statistically significant differences.



**Fig. (2):** Percentage volume of the reaming obturation material according to the file systems used

**2. Volume of the remaining obturation material according to the file systems and obturation techniques used**

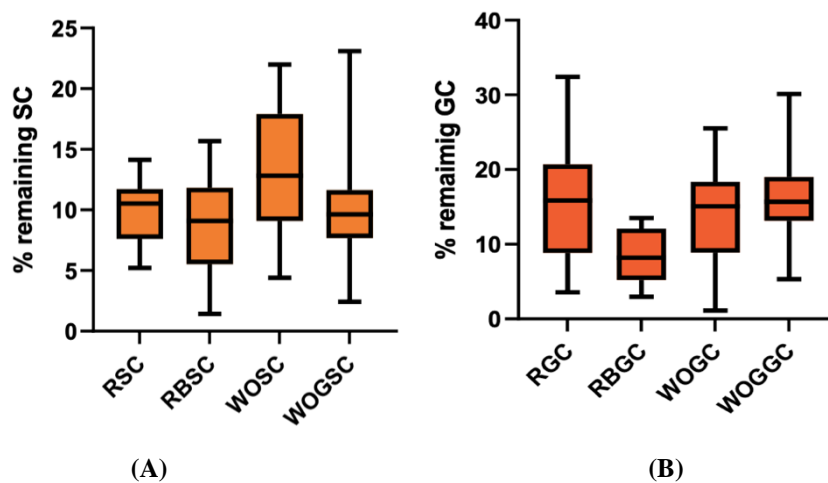
Figure 3 shows the percentage of the remaining obturation material according to the file systems and obturation techniques used. It is evident from table 2 that lowest mean volume of remaining obturation material was in group RBSC ( $8.57 \pm 4.12$ ) and RBGC ( $8.46 \pm 3.47$ ), followed by group WOGSC ( $9.74 \pm 4.84$ ) and RSC ( $9.99 \pm 2.88$ ) while, the highest mean volume of remaining obturation material can be

found in group WOGGC ( $16.53 \pm 6.20$ ), RGC ( $15.53 \pm 7.59$ ).

Duncan's test result showed a significant difference in RBSC, RBGC from RGC, WOSC, WOGC and WOGGC, while it did not show a significant difference from RSC and WOGSC. Also, WOGSC showed significant difference of from WOGC, RGC and WOGGC and no significant difference from RSC and WOSC. On the other hand, WOGGC and RGC were significantly different from all other group except WOSC and WOGC

**Table (2):** Descriptive and statistical analysis (ANOVA, Duncan) of residual root canal filling according to the file systems and obturation techniques used

Experimental Groups	N	Mean (%)	SD (%)	P value	Duncan
RSC	16	9.99	2.88	< 0.001*	ABC
RBSC	16	8.57	4.12		A
WOSC	16	13.36	5.07		BCD
WOGSC	16	9.74	4.84		AB
RGC	16	15.53	7.59		D
RBGC	16	8.46	3.47		A
WOGC	16	13.93	6.93		CD
WOGGC	16	16.53	6.20		D



**Fig. (3)** Percentage volume of the remaining single-cone (A) and GuttaCore (B) obturation material

**3. Volume of the remaining obturation material according to the obturation techniques irrespective to the file systems used**

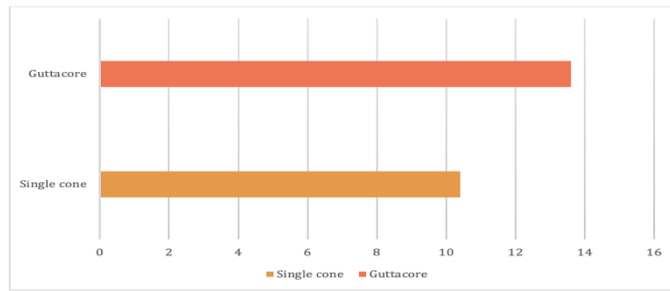
The mean volume of remaining single-cone and GuttaCore root filling material was  $(10.41 \pm$

$4.6)$  and  $(13.61 \pm 6.9)$  respectively (Figure 4). There was statistically significant difference in the mean volume of the remaining obturation material when single-cone and GuttaCore obturation material were removed from curved root canal by single file systems (Table 3)

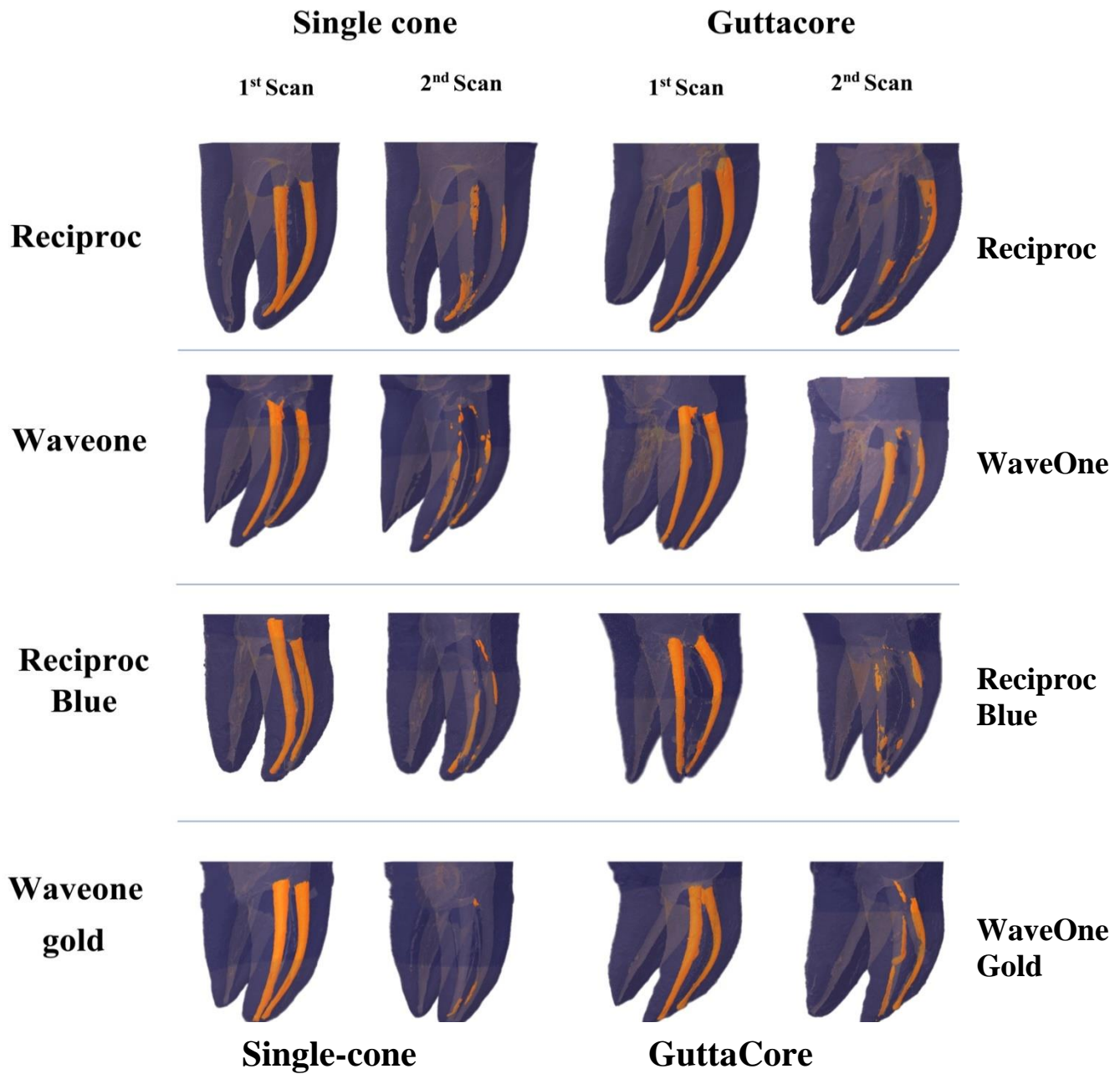
**Table (3):** Descriptive and statistical analysis (Unpaired t-test) of residual root canal filling according to the obturation techniques used

Experimental groups	N	Mean $\pm$ SD	P-value
SC	64	$10.41 \pm 4.6$	<b>0.002*</b>
GC	64	$13.61 \pm 6.9$	

SC: Single-cone, GC: GuttaCore. SD; Standard deviation



**Fig. (4):** Percentage volume of the reaming obturation material according to the obturation techniques used



**Fig. (5):** Three-dimensional micro-CT model of teeth from mesio- buccal direction of selected specimen prior (left) and after (right) removal of obturation material

## DISCUSSION

In order to ensure creating enough space for irrigation solution and instrument, comprehensive removal of the bulk of obturation material is mandatory. Regardless of the morphology of the root canal systems, the reciprocating files are just as effective in retreatment as the rotary ones (Rossi-Fedele and Ahmed, 2017).

The reciprocating instruments R, RB, WO, and WOG employed in this investigation were not specifically developed for retreatment but have been already tested for this purpose in other studies (Bago et al., 2020; Limoeiro et al., 2021; Nevares et al. 2016; Alakabani et al., 2020; Kırıcı et al., 2020) with controversial results.

In the present study, GuttaCore were investigated which consists of cross-linked gutta-percha carriers that can be removed during retreatment by simply trephining through the core (Scavo et al., 2018). The brittleness of GuttaCore's carrier, insolubility in solvents, heat resistance, and inability to remove the core in one piece are all potential drawbacks to its retrieval (Faus-Llácer et al., 2021).

In this study for standardization, the same tip size of 0.25 of the four file systems was used since the larger file of the four systems have different tip sizes. Additionally, the removal of too much dentine could induce dentinal defects that may lead to vertical root fracture (Siqueira et al., 2014). Nevertheless, the use of the same file tip size or larger than that used for the initial canal instrumentation is mandatory for the retreatment procedures (Bago et al., 2020; Crozeta et al., 2021)

Micro-computed tomography is utilized in this study for assessing the residual filling material, as it is a non-destructive technology that accurately reproduces the tooth in three dimensions without destroying the specimens or losing root material during sectioning (Aksoy et al., 2021)

The aim of the present in vitro study was to compare the efficiency of four reciprocating file systems (Reciproc, Reciproc Blue, WaveOne and WaveOne gold) in the removal of two root canal obturation materials (single-cone and GuttaCore) from severely curved root canals.

In the current study, neither of the four assessed files were capable of entirely removing the obturation material as the residues of obturation material were spotted in all samples, which mimics the result of previous

investigations conducted about the retreatment of single-cone (Fruchi et al., 2014; Canali et al., 2019; Kırıcı et al., 2020; Romeiro et al., 2020; Limoeiro et al., 2021) and GuttaCore (Nevares et al. 2016, Rödig et al., 2018; Alakabani et al., 2020; Faus-Llácer et al., 2021).

Based on the findings, regardless of the obturation material removed, Reciproc Blue file possessed more efficiency rather than other reciprocating files in the removal of obturation material from curved root canals.

The design of the Reciproc Blue instrument, which has an S-shaped cross-section with 2 sharp cutting edges and a big chip space, is what gives it exceptional retreatment capability. The larger an instrument's chip space, the greater its escape area, and as a result, the greater its removal capacity. (Giansiracusa Rubini et al. 2014). The Reciproc Blue instrument is made from a nickel-titanium alloy with a Blue-Wire surface heat treatment. The thermomechanical manufacturing process used, results in the formation of a proprietary-specific oxide surface layer that gives the instrument, its blue color and enhances its mechanical properties. This type of alloy demonstrates better flexibility, fatigue resistance, and microhardness reduction while maintaining similar surface characteristics. It is advantageous as the instruments have both flexibility and strength for the removal of obturator material in curved canals (De-Deus et al., 2017).

The above-mentioned results are consistent with those results observed by Boetto et al., 2022 where Reciproc Blue file left significantly less remaining gutta-percha/sealer compared to WaveOne Gold file in retreating simulated curved root canals.

However, the findings of the current research oppose the earlier reports of retreatment of curved root canals with Reciproc and Reciproc Blue files (Romeiro et al., 2020; Kırıcı et al., 2020) In those studies, no significant difference was found between the files with the consideration of using R40 file instead of R25 file for removal of obturation material that was used in this study.

In the present study, no significant difference was found between Reciproc, WaveOne and WaveOne Gold files in the removal of obturation material which can be explained by the fact that the instruments used in the removal of root canal obturation material have the same tip size (0.25) as the last instrument used during the retreatment of the root canals (Canali et al., 2019).

Variability in cross sectional design and metallurgy of the file regardless of the obturation material to be removed potentially has not influenced definitive amount of obturation material remained.

The findings of this study validate those of comparable micro-CT studies with a similar experimental setup of WaveOne and WaveOne Gold (Canali et al., 2019), Reciproc and WaveOne Gold (Bago et al., 2020).

Fruchi et al., 2014 compared Reciproc with WaveOne in the removal of obturation material from severely curved molar with the use of one drop of xylene and found no significant difference between these two files. However, in order to prevent gutta-percha from becoming chemically plastified and the adherence of a thin layer of this material to the canal walls., the solvent was not used in the current study. (Bhagavaldas et al., 2017; Dotto et al., 2021).

In the removal of GuttaCore obturation material, Reciproc, WaveOne, and WaveOne gold have not shown significant differences between each other while, significantly different from Reciproc Blue. No previous study has compared these files in the retreatment of GuttaCore obturation material.

The single-cone obturation material removal with Reciproc blue left a significantly lower volume of obturation material than WaveOne file which is thought to be contributed to the difference in their metallurgy with the WaveOne instrument possession of a triangular or modified triangular cross-section design with a comparably small chip area (Kwak et al., 2019). However, the current study results are counter to a recent study conducted by Limoeiro et al., 2021 on moderately curved root canals in which size 25 of Reciproc blue and WaveOne files were utilized to remove single-cone obturation material and no significant differences were found between the two files in the volume of remaining filling materials.

Also, in the present study Reciproc Blue file did not differ significantly from WaveOne Gold (which can be justified by their flexibility from the chemo-mechanical treatment of the two files) and Reciproc file (similar design and taperness) in the removal of single-cone obturation material.

Bago et al., 2020 found no significant difference among all three files (Reciproc, Reciproc Blue and WaveOne Gold) when size 25 of the files was used to remove gutta-

percha/AH plus sealer obturated utilizing continuous wave vertical compaction from the severely curved canal.

Considering the two obturation material eliminated, GuttaCore obturation material's residual percentage was (8.46-16.53%) which is lower than research performed by Rödiger et al., 2018 on curved canals and higher than that reported in earlier research on straight root canals (Alakabani et al., 2020; Faus-Llácer et al., 2021)

The single-cone obturation material's residual percentage was (8.57-13.36%). These values are higher than comparable micro-CT research on curved canals (Canali et al., 2019; Kırıcı et al., 2020), lower than the studies reported by (Romeiro et al., 2020; Limoeiro et al., 2021).

In the current research, irrespective of the file instrument used and regarding the effect of type of obturation material on retreatment, the residual percentage volume of GuttaCore obturation material was higher and statistically significantly different from single-cone obturation material. The gutta-percha plasticized by heating can be better integrated into the canal system. This results in a significantly higher filled proportion of the canal system and fewer cavities in the root canal filling than with single-cone. As a result, the plasticized gutta-percha is removed to a lesser extent. GuttaCore had higher rigidities (indentation resisting ability) than Conventional gutta-percha which changes the mechanical ability of the file in engaging the gutta-percha in the root canal (Patel and Owen, 2016). This can be linked to the reinforced central core of GuttaCore.

## CONCLUSION

Under the condition of this study and according to the numerical measurements, it can be concluded that none of the reciprocating single files were successful in the complete removal of the root canal obturation material. RB left less proportion of GuttaCore compared with R, WO, and WOG which showed equivalent cleaning ability. The removal of obturation materials from severely curved root canals obturated with GuttaCore is more difficult than the single cone.

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