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Original Article

CBCT Evaluation of Rotary vs. Reciprocating NiTi Systems for Gutta-Percha Removal: An Ex Vivo Study

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Abstract

Background: Endodontic retreatment is often complicated by complex molar anatomy and incomplete removal of root filling materials. This ex vivo study aimed to compare, using cone-beam computed tomography (CBCT) analysis, the efficacy of Mtwo rotary and Reciproc reciprocating systems in removing gutta-percha from the mesial root canals of human molar teeth.
Methods: Ninety mesial roots from extracted maxillary and mandibular first molars were included. Each root presented a closed apex and a curvature angle of < 20˚. The crowns were sectioned at the CEJ, and the canal lengths were standardized to 12 mm. The canals were prepared and obturated with gutta-percha and AH26 sealer using lateral condensation technique. Samples were randomly assigned to two retreatment groups: Mtwo (multi-file rotary system) and Reciproc (single-file reciprocating system). Gutta-percha removal followed standardized protocols, with CBCT imaging performed pre- and post-retreatment. Residual filling materials were evaluated at 2.5, 5, and 7 mm from the apex. Statistical analysis was conducted using chi- square and Wilcoxon tests.
Results: Complete removal of obturation materials was not achieved by either system. Residual material in the Mtwo group was 16.90%, 11.86%, and 7.45% at 2.5, 5, and 7 mm, respectively; in the Reciproc group, it was 24.61%, 19.83%, and 16.24%. No significant differences were observed at 2.5 and 5 mm ($P > 0.05$), while Mtwo showed superior efficacy at 7 mm ($P=0.042$).
Conclusion: Complete removal of gutta-percha was not achieved in any of the groups. Mtwo was more efficient in gutta-percha removal at 7-mm section. Moreover, the single-file design of the Reciproc system was associated with procedural simplification.
Key Words: Cone-Beam Computed Tomography; Endodontics; Gutta-Percha; Molars; Nickel-Titanium Instruments; Reciprocating Motion; Retreatment; Rotary Instruments.

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Introduction

Persistence or re-establishment of microorganisms within the root canal system after initial treatment can lead to post-endodontic diseases, which might necessitate orthograde endodontic retreatment (1). The main goal of retreatment is to regain access to the apical foramen by complete removal of the root canal filling materials (2, 3). Due to the anatomical complexity of the root canal system and the limitation of instrument design, complete removal of the root canal filling material can be difficult or even impossible (4). This challenge is even more pronounced in molar teeth, where curvature, isthmuses, and accessory canals frequently harbor residual filling material (5). Among different materials used for root canal obturation, gutta-percha with sealer is the most common. Various techniques are considered to remove gutta-percha, including ultrasonics, hand instruments with solvent, lasers, heat-carrying instruments as well as different rotary systems (2, 3, 6, 7). Several studies have compared the

efficacy of different files for removing the obturation materials. Neither rotary nor hand instruments were able to completely remove the materials from within the root canal system, especially at apical third (2). Studies have evaluated the percentage of root canal filling material removed with rotary and reciprocating systems, with rates ranging from 59.4% to 96.9% (8).

Many studies revealed that Mtwo system (VDW, Munich, Germany) with an S-shaped cross-section and increasing pitch could fulfill some requirements for root canal preparation as well as gutta-percha removal (3, 6, 9). The Mtwo system has inactive tips that lead to avoiding deviations during preparation of the root canal. Moreover, its large flute space facilitates removal of gutta-percha and sealer during retreatment (6, 7, 10) Some studies showed that NiTi instruments were safer with a reciprocating movement for root canal preparation compared to continuous rotary motion (7, 10). Reciprocation decreases torsional stresses on the instrument and improves cyclic fatigue resistance, contributing to greater overall durability(9-11). In 2010, instruments using reciprocal movement, such as Reciproc® (VDW, Munich, Germany), were developed to enhance safety and instrument durability. This instrument was developed with an S-shaped cross-section, non-cutting tip and sharp cutting edges and was recommended to be used through 150° counterclockwise and then 30° clockwise reciprocating motion with a speed of 300 rpm. This single-file system is available at three different sizes and tapers including 25/0.08, 40/0.06 and 50/0.05 (12).

These design features, combined with the alternating rotation angles, help reduce internal stress accumulation and increase fatigue resistance during canal preparation (11). The Reciproc® system also offers clinical advantages such as simplicity of use and effective removal of filling material (13).

Previous studies have used several techniques to assess remaining filling material, such as the use of radiographs and digitized images (14) - which provide only 2D information for a 3D object- or clearing techniques and digitized images (15) as evaluation methods. Other studies used vertically sectioned roots and then digital images were carried out (16), but this might not be accurate because some remaining filling material might be lost in the process (17). Others used a stereomicroscope (SEM) (18-20). More recent studies used micro-CT to evaluate the remnants of filling materials in the root canal system (4, 8, 21-23). Cone-beam computed tomography (CBCT) is becoming more commonly used in endodontics due to its ability to provide three-dimensional images suitable for evaluation of periapical pathology, resorption defects, canal morphology, and endodontic surgery (1). CBCT has also been used to quantify residual filling material after retreatment (19, 20), offering the advantage of non-destructive assessment without root sectioning and with minimal risk of material loss. Zoluo et al. showed that Reciproc file system is as efficient as hand files for removing gutta-percha in anterior teeth (9). However, no efforts have been undertaken to compare Ni-Ti reciprocating systems with full rotary systems in removal of root canal filling materials from the mesial root canals of human molar teeth especially using a CBCT device.

Previous studies have demonstrated the efficacy of both rotary and reciproc motions in retreatment, but most were conducted on anterior teeth or artificial blocks, often lacking comparison in complex molar anatomy using CBCT evaluation (8, 9). Therefore, the aim of this ex vivo study was to compare the ability of Mtwo and Reciproc files in gutta-percha removal during retreatment from the mesial root canals of human molar teeth using a CBCT device.

Methods and Materials

This ex vivo study was designed to evaluate and compare the efficacy of two NiTi systems—Mtwo and Reciproc—for the removal of gutta-percha from the mesiobuccal canals of human molars. The methodology followed standardized guidelines for root filling removal experiments, including sample selection, instrumentation, imaging, and evaluation criteria, as outlined by Ajina et al. (24), who emphasized the importance of using reproducible and clinically relevant models in ex vivo retreatment studies.

The sample size of 90 mesial roots was chosen based on previous literature evaluating the efficacy of root canal retreatment instruments using CBCT (22, 25). This number was considered sufficient to achieve 80% statistical power to detect a clinically significant difference in the amount of residual filling material

between groups, assuming a medium effect size and a 5% significance level, as outlined by Ajina et al. (24).

Experimental Subject Selection

At the time the study was conducted, ethical approval was not required, as the investigation involved human extracted teeth and did not fall within the scope of research requiring review by an ethics committee under the applicable institutional and national regulations then in effect. A total of 90 mesial roots obtained from extracted maxillary and mandibular first molars with fully developed apices were included in the study. Only roots with Vertucci type I or type II canal configurations were selected. All specimens exhibited similar canal curvature (<20°), as determined according to Schneider's method. The roots were standardized to the same length and randomly distributed into the experimental groups (5).

There were no calcifications, internal resorptions, or previous root canal treatments in any of the selected root canals. The teeth were decoronated, and the length of mesiobuccal canals were standardized to 12mm. Access cavities were prepared using high-speed diamond burs (Teez Kavan Co, Tehran, Iran) with copious water spray. The apical size of each canal was measured by inserting a size #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) until it was 1mm short of the apical foramen. Root canals wider than size #15 K-file were excluded.

Canal Preparation and Obturation

Samples were prepared using step-back technique up to #30 k-file and flaring was done by reducing 1 mm from the working length up to #55 K-file. Between each file, canals were irrigated with 5.25% sodium hypochlorite (Bojneh Co., Tehran, Iran) using side-vented needles at all times (without ultrasonic activation), followed by 17% ethylene diamine tetra acetic acid (EDTA) for 3 min in order to remove the smear layer.

After root canal preparation, the canals were dried with # 30 paper cones (Gapadent , Seoul, South Korea) and obturated by using gutta-percha (Gapadent , Seoul, South Korea) and AH26 sealer (Dentsply, Detry, Konstanz, Germany) using lateral compaction technique. All samples were temporarily sealed with Cavit G (3M ESPE, Seefeld, Germany).

The samples were stored in 100% humidity at 37°C for 2 weeks. Subsequently, the samples were mounted in the desired position using a silicone-based impression material (Speedex, Coltene/Whaledent, Altstätten, Switzerland). The samples were inserted in parallel position to the walls of the plastic mold so that the most apical point of each root touched the base of the mold. Then CBCT scans were obtained using a NewTom VGi unit (QR Srl, Verona, Italy) with a small field of view (5 × 5 cm), a voxel size of 0.125 mm, exposure parameters of 110 kV and 3 mA, and a scan time of approximately 15 seconds. Images were reconstructed and evaluated using NNT Viewer software (QR Srl, Verona, Italy). All measurements were performed using identical software settings for all samples.

Retreatment Procedure

Samples were randomly assigned to two experimental groups of 40 each according to the retreatment technique. Random allocation was performed using PASS 11.0.2 software (NCSS, LLC, Kaysville, UT, USA).

Group 1 (Mtwo): In these samples, gutta-percha was removed from the coronal 3 mm using #2 and #3 Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland) and 0.5 mL per canal of chloroform (Kimia Co., Tehran, Iran) between each instrument. First, a size #10/04 Mtwo file was inserted into the canal. The remaining gutta-percha was then removed using Mtwo files from size #15/04 to #30/05, with a 1:16 reduction gear rotary handpiece (Sirona, Italy) powered by an electric torque-controlled motor (Silver; VDW GmbH, Munich, Germany). The Mtwo instruments were operated in continuous rotation at approximately 280 rpm, with torque values set according to the manufacturer's recommendations for each file size. Finally, the apical portion of the canal was prepared with size #35/04 and then #40/04 Mtwo files. Irrigation was performed with 2.5 mL of 5.25% sodium hypochlorite between each file.

Group 2 (Reciproc): In this group, gutta-percha was removed from the coronal 3 mm with Gates Glidden drills and chloroform (0.5 mL per canal), as in Group 1. The coronal two-thirds of the canal were then prepared with a size 25/0.08 Reciproc file using four in-and-out pecking motions until the working length was reached. The instrument was operated in a

reciprocating motion under the manufacturer's standard program. After three pecking motions, the instrument was removed from the canal to clean the flutes, and the canal was irrigated with 2.5 mL of 5.25% sodium hypochlorite.

The positive control group (n=5) included prepared and unobturated samples and the negative control group (n=5) comprised of obturated samples without retreatment.

Evaluation

After gutta-percha removal, all samples were again fixed in the previously mentioned silicone-based mold, and CBCT images were acquired using the aforementioned parameters. Pre- and post-obturation CBCT images were compared for each sample (Figures 1 and 2). Evaluation of the remaining gutta-percha and sealer was carried out at 2.5, 5, and 7 mm from the apical foramen. NNT Viewer (NNT Software Corporation, Yokohama, Japan) was used for image reconstruction, and Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, CA, USA) was used for visualization and linear measurements.

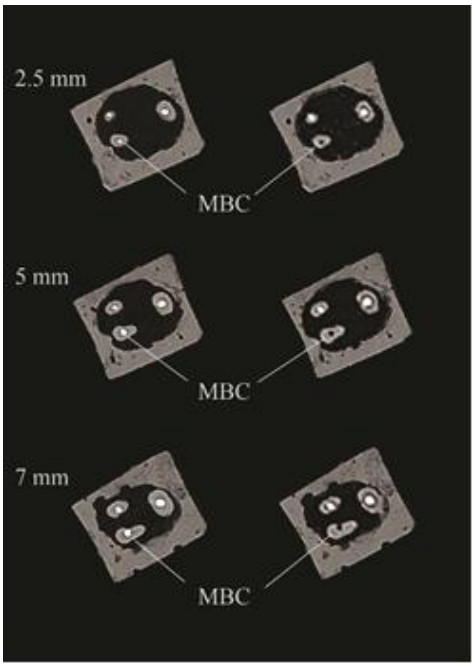

Figure 1. Representative CBCT images before (left) and after (right) gutta-percha removal using Mtwo instrumentation in mesiobuccal canals (MBCs) at 2.5, 5, and 7 mm from the apex

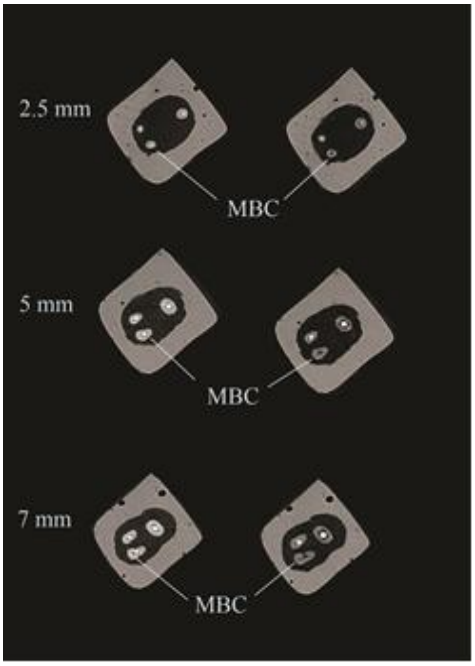

Figure 2. Representative CBCT images before (left) and after (right) gutta-percha removal using Reciproc instrumentation in mesiobuccal canals (MBCs) at 2.5, 5, and 7 mm from the apex

Image analysis was performed independently by three examiners: one final-year dental student (M.R.) and two experienced endodontists, each with over 10 years of clinical and research experience. Prior to evaluation, all examiners were calibrated using a set of sample images to ensure consistency in measurement criteria. In cases of discrepancy, the images were re-evaluated jointly, and a consensus was reached through discussion.

Statistical Analysis

Data were analyzed using chi-squared test, with a P-value < 0.05 considered statistically significant. Wilcoxon signed-rank test test was also used to perform the pairwise comparisons. SPSS version 15 for Windows (SPSS Inc., Chicago, IL, USA) was used as the statistical software package.

Results

Complete removal of obturation materials was not achieved by either system. In the Mtwo group, the mean percentages of residual filling material at 2.5 mm, 5 mm, and 7 mm from the apex were 16.90%

(range: 0%–100%), 11.86% (range: 0%–75%), and 7.45% (range: 0%–59%), respectively (Figure 3). In the Reciproc group, the corresponding values were 24.61% (range: 0%–100%), 19.83% (range: 0%–79%), and 16.24% (range: 0%–64%). All 40 specimens in each experimental group were evaluated at all three levels. At the 2.5 mm and 5 mm levels, no statistically significant differences were found between the two systems (P = 0.479 and P = 0.238, respectively; Wilcoxon test). At the 7 mm level, the Reciproc group showed significantly more residual material than the Mtwo group (P = 0.042) (Table 1).

Table 1. Comparison of residual root canal filling material between the two groups at 2.5, 5, and 7 mm from the apex

	Mean±SD		
Distance to the apex (mm)	**Reciproc**	**Mtwo**	**p-value**
2.5	24.62 (0-100)	16.9 (0-100)	0.479
5	19.8 (0-79)	11.86 (0-75)	0.238
7	16.24 (0-64)	7.45 (0-59)	0.042

Discussion

This ex vivo study compared the efficacy of Mtwo rotary and Reciproc reciprocating NiTi systems in removing gutta-percha from the mesiobuccal canals of human molars using CBCT imaging. In agreement with previous studies (2-4, 8, 21), complete removal of root canal filling material was not achieved by either system. However Mtwo left significantly less residual filling material than Reciproc only at the 7-mm level from the apex, whereas no statistically significant differences were observed at the 2.5 mm and 5 mm levels. These findings therefore suggest a modest advantage of the multi-file MTwo sequence over the single-file Reciproc system at this specific level, rather than a general superiority throughout the canal. Since the 7-mm cross-section lies in the middle–coronal region rather than the apical third, the present results may indicate that multiple shaping instruments can contact a greater canal wall area in mesial roots with complex anatomy.

Multiple studies have compared rotary and reciprocating systems for gutta-percha removal, although their methodologies and clinical models differ substantially. Zuolo et al. (9) found Reciproc to be more effective than Mtwo R and hand files in anterior teeth , where canals are generally straighter and more accessible than the mesial canals of molars examined in the present study. In contrast, the present study used the R25 file in molars with more complex curvatures, potentially explaining the different outcome.

Daniel Pinto de Oliveira et al. (26) found no significant difference between Reciproc and Mtwo in plastic blocks; however, their lack of solvent use and reliance on two-dimensional digital radiographs limit the applicability of those findings to clinical practice and to the three-dimensional retreatment conditions assessed in the present study. Cardoso et al. (27) similarly observed no significant difference between reciprocating (Reciproc R25) and rotary retreatment (Mtwo-R) in mandibular molars with 20° and 40° curvature. However, their analysis was based on longitudinally sectioned specimens photographed under an operating microscope at ×10 magnification, a technique that may result in loss of residual filling material during sectioning and provides only partial three-dimensional information compared with CBCT or micro-CT. CBCT-based and micro-CT-based investigations further confirm that none of the currently available systems can completely remove filling material, even when advanced NiTi instruments and supplementary techniques are used (19-23, 28, 29). Madhu et al. (19), Gad et al.(20), Wahane et al. (28), and Varghese (29) reported comparable retreatment efficacy among different rotary and reciprocating files using CBCT, although instrumentation time, use of solvents, and adjunctive activation protocols varied between studies (19, 20, 28, 29). In addition, Kiraz et al. (22) demonstrated that supplemental devices such as the XP-Endo Finisher, Self-Adjusting File, or Er,Cr:YSGG laser could enhance cleaning efficacy but still leave remnants, particularly in apical areas. Interestingly, Varghese et al. (29) found that full counter-clockwise Reciproc kinematics enhanced removal of gutta-percha and bioceramic sealer

compared with conventional Reciproc and Mtwo-R, although this motion is not routinely used in daily clinical practice. Taken together, these differences highlight how variability in study design, tooth type, root morphology, instrument sizes, evaluation methods, and use of adjunct techniques can strongly influence retreatment outcomes and complicate direct comparison between studies (8, 11, 19, 23, 27, 30-32).

From a clinical standpoint, both systems have practical advantages. Reciproc, with its single-file design, simplifies the procedure, shortens working time, and reduces instrument changes, which previous reports have associated with greater efficiency and reduced operator fatigue , (11, 13, 30). This makes it ideal for general practice or in cases requiring efficient, simplified protocols. However, the present study did not measure instrumentation time or operator fatigue, so these aspects should be regarded as potential advantages based on the literature rather than conclusions derived from our data. On the other hand, the Mtwo system, with its multi-file sequence and increasing taper design, enhances control and shaping ability, and wall contact, particularly in curved and narrow canals, which could help explain the lower residual material observed at the 7‑mm level in the present study). The apical third remains critical for disinfection, and the risk of persistent infection is highest in this region (7); however, our evaluation at 2.5, 5, and 7 mm does not permit direct conclusions about the entire apical third. It is worth noting that although the Reciproc system was originally designed for canal preparation, several studies, including those by Monteiro et al. (8) and Bis et al. (21) , have confirmed its efficiency in retreatment. However, caution is advised when using Reciproc in curved canals due to the risk of apical transportation (32, 33). Furthermore, while chloroform improves efficiency in gutta-percha softening (8), it may leave more residue on canal walls and raises concerns, especially near the apex in view of its potential toxicity (14). Clinically, instruments that rely on heat or mechanical friction, such as reciprocating systems may perform adequately without solvents and reduce chemical exposure risk. However, this potential advantage was not assessed in the present ex vivo model and should be interpreted with caution.

As with all ex vivo studies, this research has limitations. Although decoronation and standardized canal length enhance reproducibility, they do not reflect clinical variability in tooth morphology (25). Furthermore, although CBCT provides valuable 3D data without destroying specimens, its resolution is limited compared to micro-CT, and it may underestimate or overlook thin remnants (1, 21-23, 34). irrigation activation techniques were not used in the present study, which may have influenced the efficacy of filling material removal. In clinical scenarios, apical extrusion, canal transportation, and dentinal microcrack formation may also impact the decision between single- and multi-file systems (13, 35). All procedures were performed by a single operator, which reduces inter‑operator variability but may introduce operator bias. Retreatment time, apical extrusion, canal transportation, and dentinal microcrack formation were not recorded, although these factors are important when comparing single‑ and multi‑file systems in clinical scenarios (13, 35). Finally, only two instrument systems were evaluated, and the present results cannot be generalized to other rotary or reciprocating systems or to alternative kinematic protocols. Further research is recommended to validate these findings in vivo and assess long-term clinical outcomes. Investigations that simultaneously evaluate apical transportation, debris extrusion, and dentinal crack formation when using MTwo, Reciproc, and other systems under realistic clinical conditions would provide a more comprehensive risk–benefit profile (33, 35) Additionally, combining instrumentation with adjunctive aids like ultrasonic irrigation, Self‑Adjusting File, XP-Endo Finisher, or Er,Cr:YSGG laser may improve retreatment outcomes and warrants further exploration (22). Finally, future studies should prioritize patient‑centred outcomes—including postoperative pain, procedural time, and retreatment success rates—to support evidence‑based selection between single‑ and multi‑file retreatment strategies (27, 31).

Conclusion

Within the limitations of this ex vivo study, neither the Mtwo nor the Reciproc system achieved complete removal of gutta-percha from the mesiobuccal canals of human molars, as assessed by

CBCT. Although both systems demonstrated comparable efficacy in the coronal and middle thirds, Mtwo exhibited significantly superior cleaning at the 7 mm level, suggesting enhanced debridement in a region relevant to retreatment success. These findings must be considered in light of the study's ex vivo design, the inherent resolution limits of CBCT, potential operator influence, and the use of chloroform as a solvent. Further in vivo research incorporating supplementary irrigation or activation techniques is warranted to validate these observations and inform clinical practice.

Declarations

Ethical Approval and Consent to Participate

This ex vivo study used extracted human teeth that were obtained following routine dental extractions and would otherwise have been discarded as clinical waste. No additional procedures were performed on patients for research purposes. As such, formal ethical approval was not applicable in accordance with institutional and local guidelines governing the use of anonymized discarded biological material. Nevertheless, informed consent for the use of extracted teeth for research purposes was obtained from all patients prior to extraction.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request. All relevant data supporting the findings of this study are included within the manuscript.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' Contribution Statement

MR performed the laboratory procedures, acquired and analyzed the CBCT data, and drafted the initial manuscript. AK contributed to the study conception and design, supervised the endodontic procedures, and critically revised the manuscript. PB and HA conceived the study, participated in its design and coordination, supervised the data analysis, and contributed to the final manuscript review and editing. HA also performed the statistical analysis and prepared the visualizations. All authors read and approved the final manuscript.

Declaration of Generative Artificial Intelligence (AI) Utilization

During the preparation of this work, the authors used ChatGPT (OpenAI, San Francisco, CA) to assist with language editing, grammar refinement, and formatting. This tool was not used for data analysis, statistical interpretation, or the generation of scientific insights or conclusions. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the final content of the publication.

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