Comparison of Root Canal Wall Cleanliness In Retreatment Using Rotary and Reciprocal Movement

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Abstract

Nonsurgical treatment of root canal failure entails thorough removal of root canal filling material. The objective of this study was to analyze the difference in cleaning of root canal filling material with use of continuous rotary motion (ProTaper Universal Retreatment System) and reciprocating motion (Reciproc® Blue).

Forty-two mandibular premolars extracted post-endodontic treatment were divided into two equal groups. Group 1, R25 (reciprocating system, n = 21) and group 2, ProTaper Universal Retreatment System (rotary system, n = 21). Samples were scanned using micro-computed tomography; data were reconstructed and analyzed by CTAnalyser (Bruker). Volume of residual filling material was calculated. Differences between the groups were assessed using Mann–Whitney test ($p < 0.05$). Filling remnants were observed within the canal of all examined teeth. Statistically, significant differences in the residual volume of the filling material were observed in both groups.

Compared with the rotary motion instrument, the reciprocal motion instrument removes a larger amount of filling material from the root canal, particularly at the 1/3 apical area.

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Introduction

Endodontic treatment was reported to have a success rate of 86–98%. Despite the high success rate, treatment failure occurred in 14%–16% of the patients. Failures are often caused by persistence of both intra- and extra-canal bacteria.[1] There are four approaches to manage treatment failure, such as observation, extraction, nonsurgical treatment, and surgical retreatment. Root canal retreatment success rate ranges from 50%–90% and is largely contingent on the elimination of necrotic tissue, bacteria, and the infected infiltrate from the root canal system. Complete removal of filling material from the root canal is the key to successful root canal retreatment; this eliminates the mechanical barrier that prevents the contact of the irrigation solution and the medicament with the dentine wall in the root canal. Retreatment aims to disinfect the root canal system by eliminating persistent microorganisms that cause infection in the root canal.[2] Anatomical variations in the 1/3 apical area of the root canal (such as apical ramifications) may sometimes make it difficult for cleaning. Therefore, the 1/3 apical area of the root canal should be free of any obstruction and apical patency should be maintained during retreatment of root canal.

Gutta-percha and root canal sealer are standard filling materials used in endodontic treatment. These materials have rapidly evolved in recent years because of advances in adhesive technology, which make it challenging to remove for retreatment of the root canal. The residual filing material prevents the clearance of microorganisms from the root canal and inhibit the work of disinfectants.[3] Bio-ceramic sealer is one of the latter developed materials that is widely used in clinical settings. Bio-ceramic materials contain calcium phosphate which when hardened have a chemical composition and

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crystal structure akin to that of apatite crystals in teeth and bones; this increases their bonding to the dentine wall of the root canal. However, the difficulty in removing the bio-ceramic sealer during retreatment of root canal is a major shortcoming.[4,5]

Several techniques have been developed for removal of the filling material, such as, the use of manual endodontic instruments (H file, rotary systems), ultrasonic instruments, lasers, heat instruments, and use of chemical solvents. Removal of filling material using manual endodontic instruments takes considerable time which causes fatigue in both the operator and the patient. Therefore, flexible machine-powered rotating instruments made of Nickel-Titanium (Ni-Ti) that exhibit continuous rotary and reciprocal motion have been developed over the last decade.[6,7]

The purpose of this study was to analyze the difference in the extent of removal of filling material from the 1/3 apical and across the root canal area using continuous rotary and reciprocal motion systems post-obturation using gutta-percha and bio-ceramic-based sealer. Micro-computed tomographic scan (micro-CT) was used to measure the volume of the residual filling material in the root canal. The advantages of this tool are non-invasive and provide three-dimensional image results so as to have a high degree of accuracy.

Materials and methods

Selection of teeth, preparation and obturation of root canals

After approval from the Dental Research Ethics Committee (KEPKG), Faculty of Dentistry, Universitas Indonesia, forty-two mandibular premolar teeth were selected from a random collection of teeth extracted for orthodontic and periodontal reasons. Inclusion criteria were: presence of only a single root canal; no previous root canal treatment; roots of similar length and not having a curvature >20°; completely developed root apices (as observed in the digital periapical radiographs); and perfectly formed root canal. The exclusion criteria were: caries at the root; any resorption defect in the root; fractured or cracked tooth; and calcified root canal.

All specimens were cleaned using an ultrasonic scaler and soaked in 0.9% sodium chloride (NaCl) solution until the preparation and obturation of the root canal. Access was prepared using round and cylindrical diamond burs to obtain a straight access into the root canal.

Specimens were instrumented using a crown-down technique with ProTaper Next (Dentsply, Switzerland) until file X3, and then filled with gutta-percha and bio-ceramic-sealer-base (IRoot® Sp, Innovative Bioceramix,Inc, Canada). The working length was determined using a #10 K-File ± 0.5 mm short of where the file tip exits onto the root surface. Two milliliters of 5.25% sodium hypochlorite (NaOCl) solution was used as the irrigant and administered using a 30-G Max-i-Probe irrigating needle (Dentsply). The canals were dried with paper points and iRoot® SP sealer was applied into the root canal using a factory-supplied syringe. Then the gutta-percha cone (ProTaper Next) was coated with the iRoot® SP sealer and then inserted into the root canal at the working length. The excessive sealer was cleaned and the gutta-percha cone was cut using a heated instrument. The coronal access cavity was closed using temporary filling material (Cavi-G; 3M ESPE, Seefeld, Germany) to obtain the coronal seal. Quality of root canal obturation was evaluated with the aid of micro-CT scan. The specimens were stored in a 37^{o}C incubator with 100% humidity for thirty days to allow full setting of the sealer.

For root canal preparation, 17% ethylenediaminetetraacetic acid (EDTA) gel was used as a lubricant. After root canal preparation was completed, all canals were irrigated with 2 mL of 17% EDTA solution and allowed to stand for a minute, then rinsed with 5.25% NaOCl, and activated with sonic instruments *(*Endoactivator, Dentsply) for a minute.

Retreatment protocol using rotary system

ProTaper Universal Retreatment System (Dentsply) consists of three files. The D1 is used to remove filling material in the 1/3 coronal area, followed by D2 for the middle 1/3 area and D3 for the 1/3 apical area. Instruments were driven by Endomotor machines (X-Smart Plus, Dentsply) at a constant speed of 500 rpm, 2 Ncm of torque. During preparation and change of instrument, the root canal was irrigated with 2 mL 5.25% NaOCl using side vented syringe. Treatment was completed when no gutta-percha and sealer was found on the instrument surface.

ProTaper Universal Retreatment System is used for a single time or removed if there are signs of deformation.

Retreatment protocol using reciprocal system

R25 Reciproc® Blue (VDW, Switzerland) is driven by Endomotor (X-Smart Plus, Dentsply, Switzerland) on a particular factory setting of Reciproc. After three pecking motions, the instrument was removed from the root canal and cleaned with sterile gauze; the root canal was irrigated with 2 mL 5.25% NaOCl using 30G side vented syringe. This procedure was repeated until the instrument reached the working length. Treatment was considered complete when no gutta-percha and sealer was found on the instrument surface.

R25 Reciproc® Blue instrument is a single-use instrument as per the manufacturer's instructions.

Micro-CT scanning procedures and evaluation

The CT images were examined using Micro CT Scan Skyscan 1173 (Bruker, Belgium). Data pertaining to the initial volume and residual volume of the filling material in the root canal were collected. The cleanliness of the root canal wall was calculated by measuring the volume of the remaining filling material inside the root canal. The samples were scanned at high resolution (1 pixel = 29.8 micrometers), 130 kV, 60 mA, and 0.1° rotation step. The scan lasted for 5 hours. All the slices were then reconstructed with the aid of NRecon and DataViewer (Bruker, Belgium) software and analyzed by CTAnalyser (Bruker, Belgium). We studied two areas at 16 and 5 mm from the apical. These areas were named as the root canal area and 1/3 apical, respectively. The filling material volume was calculated from the binarized area inside the region of interest. The results of morphometric analysis included the volume of root canal filling material (in mm^3), measured before and after the retreatment procedure.

Data analysis

Data pertaining to residual volume of filling material in root canal were analyzed by parametric statistical tests using SPSS 21 software. Normality of distribution of variables was assessed using Normality test - Shapiro Wilk.

Between-group differences with respect to normally distributed variables were assessed using paired *t*-test; those with respect to non-normally distributed variables were assessed using the non-parametric Wilcoxon test. The threshold for statistical significance (α) was 0.05.

Results

Residual filling material was observed in all specimens regardless of the group identity. No instances of instrument fracture occurred during the removal of filling material in any of the groups. Data pertaining to volume of residual filling material in both groups exhibited a non-normal distribution; therefore, the Mann–Whitney test was used for analysis. The median residual volume of filling material in the rotary group was significantly higher than that in the reciprocal group ($p < 0.001$) was seen in Table 1. The results suggest that reciprocal instruments were more effective than rotary instruments for removal of filling material.

Instrument System	n	Median (mm^3)	Range	p value
Reciprocal	21	0.637	0.014–3.577	<0.001*
Rotary	21	5.553	0.132–8.507	

*Mann–Whitney test, $p < 0.05$

Table 1. Volume of Residual Filling Material in The Two Groups.

Data pertaining to volume of residual filler in 1/3 apical exhibited a non-normal distribution; therefore Mann–Whitney test was used for analysis. The median residual volume of filling material in the rotary group seen in Table 2 was significantly higher than that in the reciprocal group ($p < 0.001$). These findings suggest that the reciprocal instrument allows for more efficient removal of filling material from the 1/3 apical root canal as compared to the rotary instrument.

Instrument system	n	Median volume (mm^3)	Range	p value
Reciprocal	21	0.13	0–0.597	<0.001*
Rotary	21	0.571	0.018–2.610	

*Mann–Whitney test, $p < 0.05$

Table 2. Volume of Residual Filling in The 1/3 Apical of Root Canal in The Two Groups.

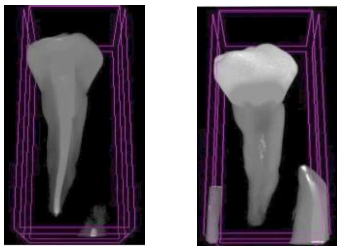

Figure 1. Pre- and post-treatment micro-CT images of a specimen treated with reciprocal system.

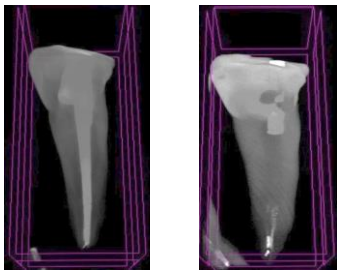

Figure 2. Pre- and post-treatment micro-CT images of a specimen treated with rotary system.

Discussion

This study aimed to compare the final residual volume of root canal filling material after retreatment procedure using reciprocal and rotary instruments. The final residual volume of filling material reflects the cleanliness of the root canal. Success rate of endodontic retreatment directly hinges on the maximal removal of the filling material. Poorly instrumented and obturated root canal systems can lead to necrotic tissues and microorganisms that are responsible for failure of endodontic treatment.

The mandibular premolar teeth were chosen for this study because they exhibit the characteristics of single and straight root canal for easier preparation. Besides, these teeth are typically easy to obtain because they are more commonly removed in orthodontic treatment. The sample was controlled by performing radiograph of the mesial-distal and buccal-lingual view to minimize bias in this study.

Several techniques have been introduced to measure residual filling material in the root canal. In some previous studies, two-dimensional images were used to compare the ability of multiple instruments to clean gutta-percha and sealer from root canals.[8,9] However, this method only provides two-dimensional information about three-dimensional structures, which is a limitation. In another study, vertically sectioned teeth were examined under magnification. A drawback of this technique is that part of the sample is lost during the sectioning process, and the remaining filling material can only be calculated from its surface area, and not in three dimensions.[9-12] In this study, the cleanliness of the root canal was measured with the aid of micro-CT scan and the three-dimensional images obtained were analyzed using CTAnalyser software. The analysis was performed after calculating the initial volume and the residual volume of the filler in the root canal after cleaning with both instruments. The analytical method using micro-CT is non-invasive, accurate, and reproducible method for quantitative assessment of residual filling material in three dimensions. This method also minimizes the possibility of bias during interpretation. However, micro-CT cannot be used to evaluate debris and smear layers in dentine tubules, which is a limitation of this method.[13]

In this study, none of the samples was perfectly cleaned of the filler. These findings are consistent with those of several previous studies that involved the use of different instruments and methods.[9,11,14–17,6] Comparative analysis of root canal hygiene in the two groups showed significant differences in the residual volume of filling material between the PTURS® and Reciproc® Blue groups; the latter group exhibited greater cleanliness than the former group. This difference is likely attributable to the material difference between the two instruments and the difference in the size D0 of each instrument. Reciproc® Blue is made from heat-treated titanium-nickel alloy, which improves cyclic fatigue resistance and is more flexible. Once the instrument reaches its working length, its greater flexibility allows for brushing motion against the root canal wall, which helps lift the filling material out of the root canal. In addition, in PTURS®, D0 in D3 file is 0.2 mm while in Reciproc® Blue the size of D0 in R25 is 0.25 mm. All samples were prepared with ProTaper Next X3 and were obturated with gutta-percha X3. The size of D0 on X3 is 0.3 mm. Since the D0 size in the D3 file is larger, this reduces the extent of removal of gutta-percha due to the smaller file size. Till date, no studies have investigated the use of Reciproc® Blue for retreatment of root canal.

Cutting ability is a key attribute of instruments especially for removal of filling material. Factors that influence the cutting ability of instruments include the helical angle, rake angle, and the cross-sectional design. Helical angle is the angle formed between the cutting edge and the longitudinal wall of the dentin. According to Grande et al. (2012), instruments with a helical angle like reamer (45°) provide more aggressive cutting capability (rotationally or reciprocally) than that of instruments that have a smaller helical angle (such as the K files). Reciproc® Blue has a larger helical angle than PTURS®, which explains the better cutting ability of the former.[18] **(Figure 3A, 3B)**

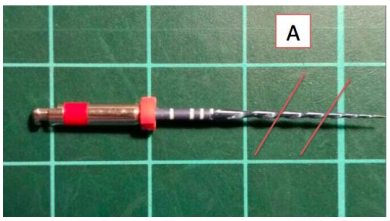

Figure 3A. Helical Angle in Reciproc® Blue

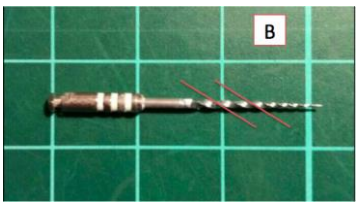

Figure 3B. Helical Angle in PTURS®

Rake angle also influences the cutting ability of the instrument. Reciproc® Blue has a positive rake angle that at the time of movement induces a cutting motion. PTURS® has a neutral rake angle, which induces a threading motion during movement. The better cutting ability of the Reciproc® Blue explains the more efficient removal of filling material in the Reciproc® Blue group in this study.

The cross-sectional design of the instrument also determines the cutting efficiency.[19] Reciproc® Blue has an "S" shape cross-section with two cutting edges, which produces more space to facilitate debris collection and removal. PTURS® has a larger convex triangular cross-section that produces less room for debris collection; therefore, the debris is liable to be trapped between the instrument and the root canal wall, which reduces the cutting capacity of the PTURS instrument. The better cutting ability of Reciproc® Blue likely explains its better performance in the present study. **(Figure 4)**

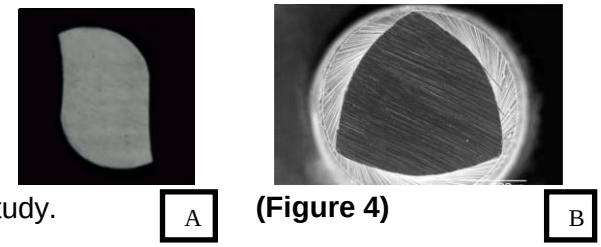

Figure 4. Cross-sectional design:
A = Reciproc® Blue; B = PTURS®

Another factor that explains the better cleaning performance in the Reciproc® Blue group is the nature of motion of the two instruments the PTURS® instrument employs an in and out motion, while the Reciproc® Blue instrument employs a combination of in and out motion and brushing motion after achieving the working length. Thus, the Reciproc® Blue instrument allows for a more thorough preparation of the root canal wall.

The ability of the PTURS® instrument to remove filling material has been compared with that of reciprocal motion instruments in previous studies. In one study, PTURS® instruments achieved lower hygiene values.[11] However, other studies found no significant difference between the cleanliness achieved with PTURS® instrument and reciprocal motion instrument (Reciproc, Wave One). In the present study, hygiene values achieved with Reciproc® Blue instrument was better than that achieved with the PTURS® instrument. This discrepancy is likely attributable to the different methods used for assessment of results. In this study, the final volume of the filling material was measured with the help of micro-CT, which provides three-dimensional measurements, and is hence more accurate. Most previous studies employed longitudinal sectioning of the tooth as well as retrieval of radiographic images of the buccal and mesial directions; since this method allows for two-dimensional measurements, it is liable to be less accurate. Besides, some filling material is liable to be wasted during the procedure of teeth sectioning.[10,12,14]

Bio-ceramic sealer binds to the dentine wall in the root canal and forms hydroxyapatite. Sagsen et al. (2011) reported that the binding

ability of iRoot SP is stronger than that of the Fillapex MTA. In addition, in a study by Ghoneim et al. (2011), iRoot SP was shown to improve fracture resistance in post-root canal teeth *in vitro*, which is a potential indicator of the high bond strength of the sealer.[20,21] Due to the high strength of bonding with the dentin of the root canal, removal of bio-ceramic sealer is typically challenging in retreatment cases. Nonetheless, in this study, the Reciproc® Blue and PTURS instruments were shown to remove the iRoot SP quite appreciably.

In this study, significant differences were observed between the Reciproc® Blue group and PTURS® group, both with respect to the residual volume in the entire root canal area and in the 1/3 apical area. Thus it can be concluded that use of Reciproc® Blue instrument allows for better cleaning performance during retreatment of root canal than the PTURS® instrument.

Conclusions

Reciprocal instrument system was more effective at removing filling material from the root canal walls as well as from the 1/3 apical area of the root canal than rotary instruments system as presented in this study.

Declaration of Interest

The authors deny any conflicts of interest related to this study. All authors have made substantive contribution to this study and/or manuscript, and all have reviewed the final paper prior to its submission. Funding resources was obtained from HIBAH PITTA UI 2018.

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