Influence of Operator's Experiences on Shaping a Curved Canal with a Rotary Single-File Reciprocating Motion

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Abstract

The study aims to assess the shaping ability using a single-file reciprocating motion among two groups of undergraduate dental students, focusing on differences in experience. Shaping ability, encompassing canal transportation, instrument separation, and working length control, was evaluated post-preparation with Reciproc Blue size 25/06 in a 30°resin block. The study included a group of 4th-year students (n=20) with less experience and a group of 6th-year students (n=20) with more experience. Additionally, a group of endodontic instructors (n=9) with over ten years of experience was included to provide a benchmark for accuracy and reliability.

Canal transportation was assessed by comparing pre-and post-preparation superimposed images, evaluating the deviation of the original canal at the inner and outer curves 6 mm from WL to determine the centering ability. WL control was categorized as over, under, or at the WL, and instances of separated files post-preparation were documented.

The result revealed no statistically significant difference in canal transportation between the two student groups ($p>0.05$). The intra-group analysis identified transportation at all levels, with greater occurrences observed at 5-7 mm from WL compared to at 1-4mm, a statistically significant difference. However, there was no significant difference in WL control among the students, and none of the instruments were separated.

In conclusion, a single-file reciprocating motion system demonstrated favorable acceptance among undergraduate dental students, as evidenced by minimal deviation errors across all levels. WL control was consistently within 0.25-1 mm from working length, and no instrument separation was recorded.

Keywords: *Operator's Experience, Canal Transportation, A Reciprocating Single File Technique, Teaching and Learning*

1. Introduction

Providing teaching and learning for dental students at the undergraduate level to be able to prepare root canals without procedural errors remains an important problem in many dental schools worldwide. Problems are more common in curved root canals, such as canal transportation and instrument separation (Hayes et al., 2001). These will prevent the process of complete elimination of intracanal bacteria at the apical end of the canal, which will directly affect the success of treatment (Haapasalo et al., 2003). There are not many studies concerning the influence of the operator's experience on the problems. Some found a larger number of fractures in the learning stage than in the practical period (Al-Omari et al., 2010) and demonstrated that more deformities and fractures occur when rotary NiTi instruments are used by novice operators (Mandel et al., 1999; Yared et al., 2000; Yared, & Kulkarni, 2002).

Teaching continuous rotary instrumentation at the undergraduate level showed that the 3rd-year dental student group was able to prepare curved root canals with more excellent preservation of tooth structure, a lower risk of procedural errors, and much quicker than hand instruments (Baumann, & Roth, 1999; Gluskin et al., 2001). However, rotary instrumentation was associated with instrument separation without warning signs. Students are afraid of using rotary instrumentation, especially in teeth with complex canal anatomy. The system needs numerous instruments, which are time-consuming and have long learning curves.

This leads to the latest mechanical root canal preparation developments with reciprocating single file techniques (Bürklein et al., 2013; Yared, 2008). Usually, only one file is necessary for complete preparation with no glide path, which saves time and reduces the risk of ledging caused by preparing a glide path, with hand stainless steel. Preflaring was no longer mandatory (Bartols et al., 2017; De-Deus et al., 2013). Moreover, continuous rotary motion was changed to reciprocating movement, in which instrument fatigue and fracture were reduced (De-Deus et al., 2010).

Later, in 2014, the "Reciproc" instrument was introduced with unequal angles of rotation and lower than the angle at the elastic limit of the instrument (RC; VDW GmBH, Munich, Germany 2014). The instrument rotates at a certain angle in the cutting direction and shortly after in the opposite direction over a much smaller angle (Kim et al., 2012). Consequently, these instruments complete a full rotation over several cycles of reciprocating movements. The resistance to cyclic fatigue is enhanced with reciprocating motion (Pedullà et al., 2013). Previous studies have shown that reciprocation extends the flexural cyclic fatigue life of the tested instrument in comparison with continuous rotation (De-Deus et al., 2010; De-Deus et al., 2017).

The reciprocating movement also helps decrease the chance of canal transportation (Saber et al., 2015). In addition, the flexibility and cyclic fatigue resistance of M-wire nickel-titanium can keep canal centering and decrease the chance of instrument separation (Keskin et al., 2018; Keskin et al., 2017)

In 2011, Reciproc Blue (RC Blue; VDW GmBH, Munich, Germany 2011), an improved version of the original "Reciproc", was introduced with identical reciprocating motion and kinematics as Reciproc. The design, geometry, and size of Reciproc Blue instruments are identical to those of Reciproc instruments. The thermal treatment of Reciproc Blue was associated with a finer structure with smaller grains than Reciproc, which increased resistance to cyclic fatigue with greater flexibility and less surface microhardness, which enabled a safer and smoother canal preparation procedure (Keskin et al., 2018). Another innovation of the Reciproc Blue system is the ability to prebend the instrument.

Many studies confirmed the ability to maintain original canal curvature and the low risk of instrument fracture from the greater flexibility and cyclic fatigue resistance of the Reciproc Blue (De-Deus et al., 2017; Generali et al., 2020; Kırıcı et al., 2020). Thus, the problems of canal transportation and instrument fracture found among undergraduate dental students should be solved by teaching them Reciproc Blue.

This study then aimed to confirm that Reciproc Blue would be beneficial for undergraduate dental students. Two groups of 4th-year students who have only laboratory experiences and 6th-year students who have laboratory and clinical experiences were selected. The result of the two groups' competency in preparing curved canals will be part of a guideline for providing them with a proper teaching and learning process.

2. Objectives

The study aimed to assess the shaping ability of Reciproc Blue among experienced and inexperienced undergraduate dental students in preparing curved canals.

3. Materials and Methods

3.1 Materials

Forty-nine resin models simulating 30°curved root canals (V04 0245, VDW, Munich, Germany) were employed in this study. Before instrumentation, all resin models were examined manufacturing defect under 4x magnification from DSLR (Digital Single-lens Reflex, Sony a7rlll camera, Sony FE 90mm f2.8 Macro G OSS case, Sony Corporation, Wuxi, Jiangsu, China). The resin models were taken with pre-instrumentation and post-instrumentation images with a custom fixed stand and 4 x magnifications from DSLR by the same setting: a shutter speed of 1.6 and a F-stop of 22.

3.2 Group selection

Group 1: Fourth-year dental student. The inclusion criteria: they must have exclusively performed single-root endodontic treatment using a hand file, with or without prior experience using a rotary file.

Group 2: Sixth-year dental students: The inclusion criteria are that they must have experience performing rotary files in clinically endodontic treatment on molar teeth.

Group 3: Endodontists stipulate a minimum of ten years of experience in the field of root canal treatment.

A sample was selected at random from the divided group. Endodontists, fourth-year students, and fifth- or sixth-year groups (participants) will receive instruction from a single instructor on how to use the Reciproc Blue mechanical reciprocating files in accordance with the manufacturer's guidelines. Then, immediately begin testing preparations for one root canal of the premolar tooth using Reciproc blue, followed by one simulated root canal resin block.

3.3 Reciproc Blue Instructions

Determine the working length by inserting K-file#10 into the root canal; the tip of the file will stop at the opening of the resin canal. Measure the length of the resin canal and shorten it to 0.5 mm to be used as the working length. The Reciproc Blue preparation will use only one file to complete one root canal preparation. Whilepreparing, Reciproc Blue moves up and down three strokes along the resin canal as one cycle, the length of one cycle covers 3-6 mm. When moving in and out for 3 complete strokes, remove the instrument from the root canal. The instrument was cleaned with alcohol-soaked gauze. of Rinse the root canal with a normal saline solution of 2 ml and be patient with K-file#10. The specified working length will be reached with Reciproc blue, clean, and dry root canal with normal saline and paperpoints.

The post-instrumentation image will be taken in the same position as the pre-instrumentation image by placing the Reciproc blue gutta-percha match cone at the working length.

3.4 Canal Preparation Evaluation

3.4.1 Instrument separation

Instrument separation evaluation records the number of broken instruments in each group. Including recording the length and position of the broken tools in the simulated root canal. The length of the broken instrument will be measured using the Photoshop program (Adobe Photoshop 2023; Adobe Systems Inc., San Jose, CA), along with recording the instrument's length before and after use by the participants.

3.4.2 Ledging or apical perforation

Ledging or apical perforation will be recorded after root canal preparation from the post-instrumentation image. The root canal wall will be examined at 5 mm from the beginning of the curvature level to the apical foramen. The ledging of the root canal wall will be recorded when the simulated root canal wall shows signs of canal transportation, steps, or deviation of the root canal from the original canal. The apical perforation will be recorded when the root canal preparation extends over the specified working length (1 mm from the apical foramen).

3.4.3 Canal transportation

Pre- and post-instrumentation images will be evaluated with Photoshop software (Adobe Photoshop 2023; Adobe Systems Inc, San Jose, CA) using “Scripts/Load file into Stack” to determine the difference between the canal configuration before and after preparation in a mesial (inner curvature) and distal (outer curvature) aspects of the canal as seen in figure 1. Both mesial and distal sides will be incremented by 1 mm level under high magnification and using the “ruler tool” of the Photoshop software. Measuring starts at the WL (0mm), and the last measuring point is 6mm from the WL. If the difference between the mesial and distal measures at a given point was equal to 0, the canal was considered non-deviated and uniformly enlarged.

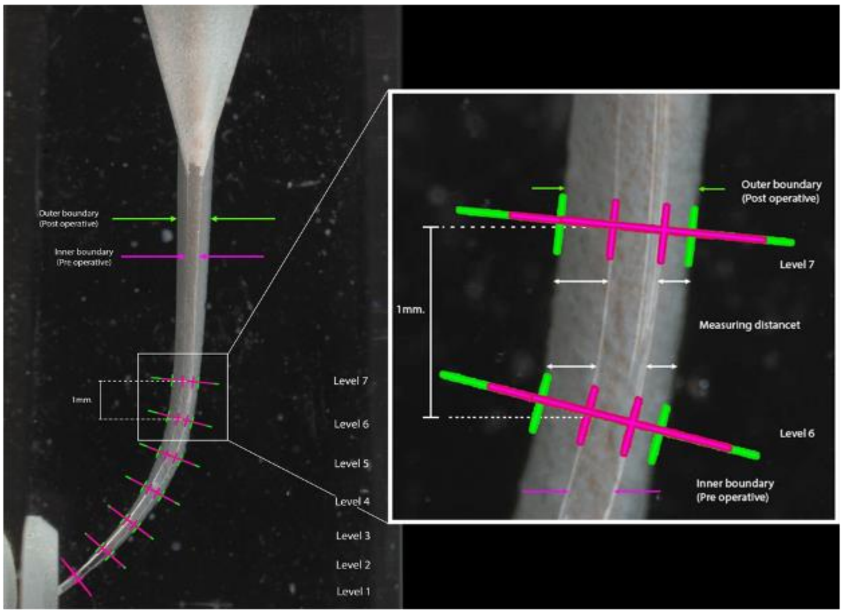

Figure 1 Pre- and post-instrumentation superimposed images were compared to evaluate the mesial (inner curvature) and distal (outer curvature) aspects of the canal wall before and after preparation. This assessment was conducted using Photoshop software with seven measuring points

3.4.4 Working Length Control

The distance from the reference point to the endpoint during preparation and obturation was 17.5 mm. The Gutta-percha master cone, with a length matching the root canal (17.5 mm), was placed and photographed within the root canal of the resin block (which has a canal length of 18 mm). The working length control was determined by measuring the distance from the end of the resin block to the end of the Gutta-Percha master cone. If this distance exceeded 0.5 mm, it was recorded as shorter; if it was less than 0.5 mm, it was marked as over (Figure 2).

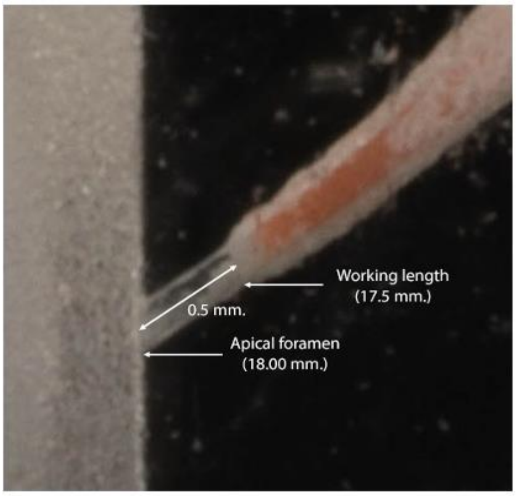

Figure 2 Post-instrumentation image with gutta-percha main cone to determine working length

4. Results and Discussion

4.1 Ledging and broken instruments

Ledging and Instrument separation were not found in any experimental group.

4.2 Canal transportation

The intragroup analysis found that all experimental groups showed deviations at virtually all levels. This was evaluated by comparing the expanded resin canal with material removed from the mesial and distal resin canal walls along the level of 7 measuring points (Figure 3). There was a significant difference at all levels for all groups ($P < .01$). But there was no significant difference in canal transportation between the experimental groups ($P>0.05$, two-way repeated ANOVA test), except for the 2-mm level in the endodontist group ($P = .02$). The canal was divided into two sections, with L1-L4 denoting the under-curve and L5-L7 the over-curve. The over-curve showed greater canal deviation than the under-curve, which was significantly higher ($P<0.05$ independent T-test).

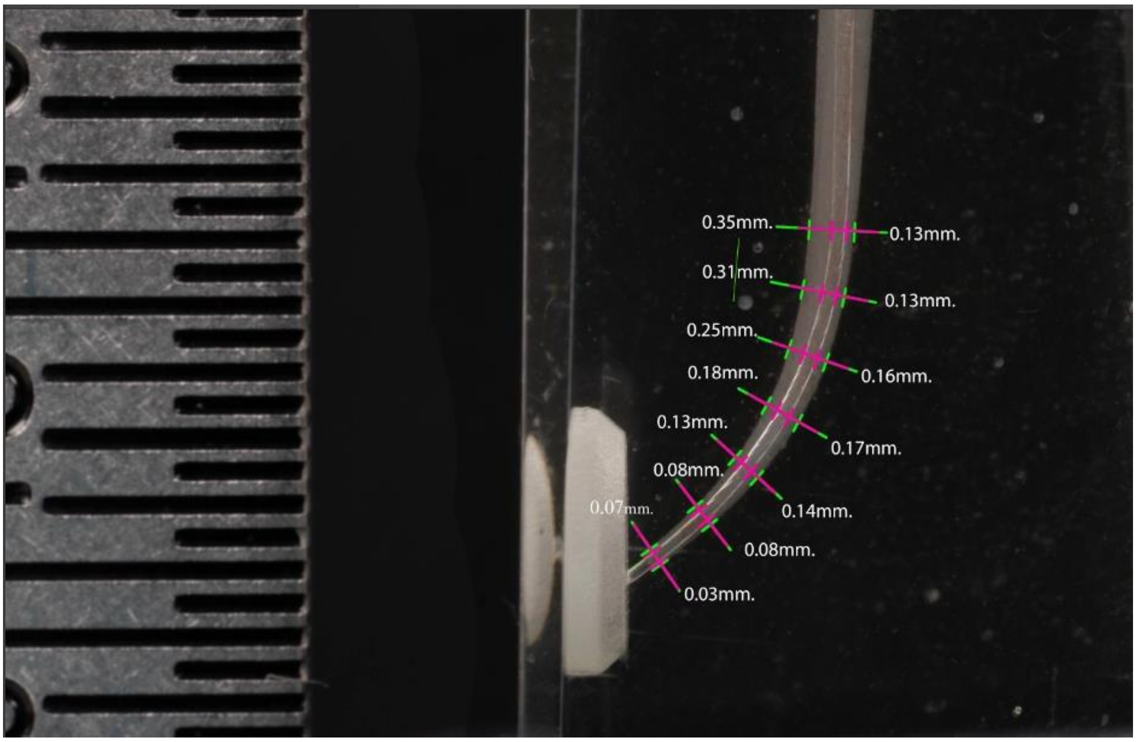

Figure 3 Superimposed pre-instrumentation and post-instrumentation images for evaluating canal transportation, seven levels of measurement (1 mm at each level)

Table 1 Positive values included the canal deviated to the mesial or inner curvature side. Negative values indicate the canal was deviated to the distal or outer curvature side (Different number of (*) shows a significant difference between groups)

Level	4th-year students Mean ± SD (mm.)	6th-year students Mean ± SD (mm.)	Endodontists Mean ± SD (mm.)
Level 1	0.01±0.02	-0.01±0.04	-0.01±0.01
Level 2	-0.01±0.023*	0.01±0.02*	-0.04±0.02**
Level 3	0.00±0.04	0.01±0.04	0.01±0.04

Level 4	0.05±0.06	0.07±0.05	0.06±0.03
Level 5	0.11±0.04	0.13±0.05	0.10±0.04
Level 6	0.16±0.04	0.18±0.06	0.16±0.05
Level 7	0.17±0.06	0.19±0.05	0.16±0.04
Under-curve	0.01±0.02	0.01±0.03	0.00±0.02
Over-curve	0.14±0.04	0.17±0.05	0.14±0.04

4.3 Working length

The number of root canals with short-working length, controlled working length, and over-working length were 15, 1 and 4 in 4th years students' group, and 7, 6 and 7 in 6th years students' group and 1, 1 and 7 in Endodontist group as see in Figure 4. Data analysis with the Chi-square test found no statistically significant difference within experimental groups (P>0.05).

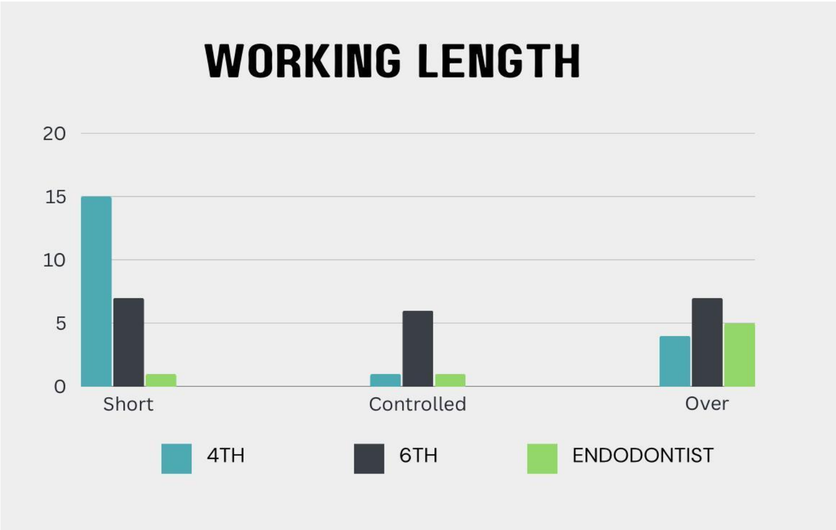

Figure 4 The number of root canals with short-working lengths, controlled working length, and over-working lengths from each group

4.4 Discussion

This present study investigated the reciprocating Ni-Ti one-file system's ability to shape canals at a 30-degree angle, based on errors such as ledging, instrument separation, and canal transportation at different levels of endodontic treatment experience. The result showed that every participant group could prepare canals completely without any instrument separation or ledging. Even when an operator had no experience with this file system, the result might have stemmed from the high flexibility properties of the instrument. The NiTi alloy of Reciproc Blue has repeatedly undergone a heat-treating process to improve its mechanical properties. It is characterized by a more martensitic phase at room temperature. The martensitic instrument, like the blue heat treatment file, can be deformed because of the reorientation of the martensitic crystalline structure, but it will recover its shape upon heating above the transformation temperature (Shen et al., 2013). Metallurgically, gold heat-treated files are more ductile, providing higher flexibility than conventional NiTi files and the first generation of M wire files.

In the evaluation of canal transportation, the present study revealed that there was no significant difference in the outcomes among the three experimental groups using Reciproc Blue to prepare a 30-degree curved canal resin block. The transportation areas did not vary significantly when comparing each experimental group at all levels. Consequently, there was no significant variation in the outcomes of root canal preparation among the three experimental groups. However, at the second level of measurement, the Endodontist group exhibited a higher deviation toward the outer side of the canal compared to the 4th and 6th-year students. However, the width of canal transportation at this level was maximum at 0.29mm, on the inner curvature site and 0.09mm on the outer curvature, which may not cause a clinically significant problem. This could potentially be attributed to Reciproc Blue's aptitude for root canal preparation, which is facilitated by its flexible design and precise centering. A previous study found that the reciprocating motion of NiTi rotary files is associated with a decreased incidence of file fracture, increased fatigue lifespan, and preservation of the original canal (Goldberg et al., 2012).

However, a significantly greater deviation was observed in the root canal over the curve than in the segment under the curve. This discrepancy could be attributed to the presence of adherent resin. Initially challenging to cut, it was revealed through discussions with the experimenter that preparing the coronal part would cause the instrument to be pulled downward, applying force against the instruments. This tendency led to over-preparation in the coronal part (over the curve). Additionally, this phenomenon may be linked to the necessity of stroking the Reciproc Blue tool three times per cycle, resulting in a substantial number of instrument removals from the root canal and subsequent stroking in the coronal region.

Moreover, the results of working length control revealed 4th-year students who have done the most amount of short working length control; it might be caused less experience in using rotary instruments and not being confident of performing canal instrumentation. On the other hand, the endodontists group ten, experienced in using rotary instruments more than ten years, have almost matched the indicated working length control by a little bit overed about 0.5 mm. Considering the working length that should be shortened from apical foramen 0.5-1 mm theoretically, the previous study found the mean distances between apical constriction and apical foramen were 0.847 ± 0.33 mm in incisors and 0.709 ± 0.27 mm in molars. The mean distances between the apical foramen and anatomic apex were 1.23 ± 0.39 mm in incisors and 1.01 ± 0.38 mm in molars. The other study revealed that the distance from apical constriction to the apical foramen was found between 0.4-1.5 mm; the mean was found for the whole sample examined 0.864 mm. The length of the lower first premolar teeth ranged between 19.59 and 24.07 mm and the mean for the lower first premolar tooth length was found 21.59 mm. The outcome of 3 experimental groups was done in an acceptable working length range because it was indicated 0.5 mm shortened from apical foramen of resin training block that will not reach apical tissues in natural tooth or clinical.

The limitation of this study is that a simulated severely curved resin model may not fully replicate the clinical conditions under which endodontic instruments operate, primarily due to differences in hardness between resin and human teeth. However, resin models offer standardized samples because they are manufactured with consistent parameters such as diameter, taper, curvature, and material. The credibility of resin blocks as an ideal experimental model for analyzing endodontic preparation techniques has been established in previous studies (Dummer et al., 1991; Weine et al., 1975).

Therefore, further research could explore additional aspects of inexperienced dental students' learning and teaching processes. This may involve investigating the time allocated to both learning and teaching activities and comparing the preparation time required for root canal procedures using single-file systems versus multiple-file systems.

5. Conclusion

A rotary single-file reciprocating motion system seems to have a good acceptance to be used among inexperienced undergraduate dental students according to the results of errors that showed minimum deviation in all levels. Working length control was found to be only 0.25-1 mm. away from working length. No separate instrument was found.

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