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Apical micro leakage evaluation using Reciproc and WaveOne files

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Abstract. This research aimed to evaluate the apical seals of root canals prepared with WaveOne and Reciproc files utilizing either the rotary or reciprocating preparation techniques. **Materials and methods.** Sixty human single-rooted premolar (bicuspid) teeth were prepared and randomly divided into 4 groups which received different preparations: WaveOne files using rotary and reciprocating techniques and Reciproc files using rotary and reciprocating techniques. Single-cone technique was used for the obturation of the teeth, with zinc oxide eugenol sealer. The apical seals were evaluated using a dye penetration technique. The degree of micro leakage was assessed via measurement stereomicroscope (mag. 10x). **Results.** There is a significant difference between all groups in the extent of micro leakage ($p<0.05$). The mean value of WaveOne file reciprocation group (0.73 μm) is lower than that of WaveOne file rotation group (2.39 μm), and the mean value of Reciproc file reciprocation group (0.71 μm) is lower than that of Reciproc file rotation group (2.42 μm). There is a significant difference between the measurements for the groups with reciprocation movement and rotational movement (between Group 1 and Group 2 and between Group 3 and Group 4), at $p<0.05$. **Conclusion.** Using either WaveOne or Reciproc files, much lower apical micro leakage resulted when applying the reciprocation method compared to the rotary technique.

Key words: dye, premolar, root canal preparation, root canal therapy, technique

Оценка апикальной микропроницаемости при использовании эндодонтических файлов по типу Reciproc и WaveOne

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Реферат. Цель данного исследования — оценка герметичности апекса корневых каналов, обработанных с помощью эндодонтических файлов WaveOne и Reciproc, с использованием вращательной или возвратно-поступательной техники препарирования. **Материалы и методы.** Было использовано 60 однокорневых премоляров человека, случайным образом разделенных на 4 группы, в которых проводили различную эндодонтическую обработку корневых каналов с использованием машинных инструментов: файлы WaveOne с использованием ротационной и возвратно-поступательной техники и файлы Reciproc с использованием ротационной и возвратно-поступательной техники. Для обтурации корневых каналов применяли технику одиночного штифта с использованием цинк-оксид-эвгенолового герметика. Апикальные уплотнения оценивали с использованием техники проникновения красителя. Степень микроподтекания оценивали с помощью измерительного стереомикроскопа при 10-кратном увеличении. **Результаты.** Между всеми группами наблюдается значительная разница в степени микропроницаемости ($p<0,05$). Среднее значение в группе реципрокного движения файла WaveOne (0,73 мкм) ниже, чем у группы файла WaveOne (2,39 мкм) с ротационным движением, а среднее значение группы реципрокного движения файла Reciproc (0,71 мкм) ниже, чем у группы файла Reciproc (2,42 мкм) с ротационным движением. Между измерениями для групп с реципрокным движением и ротационным движением (между I и II группой и между III и IV группой) наблюдается значительная разница при $p<0,05$. **Заключение.** При использовании файлов WaveOne или Reciproc при применении метода реципрокного движения наблюдалось гораздо меньше апикальной микропроницаемости по сравнению с ротационной техникой.

Ключевые слова: краситель, премоляр, препарирование корневого канала, лечение корневого канала, способ обработки

INTRODUCTION

The primary purpose of root canal therapy is to clean the root canal system of bacteria in order to prevent or treat apical periodontitis [1]. In recent practice the root canal is mechanically shaped after which chemicals are used to disinfect it. This reduces apical micro leakage and removes any remaining germs from the root canal system. A considerable amount of irrigation solution is required for root canal cleaning and disinfection, and this can only be applied to the apical third of the root canal once the canal has been widened coronally [2]. The root canal smear layer may function as a physical barrier that prevents the sealer from adapting to and penetrating the dentinal tubules, which may lead to micro

leakage [3]. Apical micro leakage may be minimized by using chemically active and adhesive root canal sealers [4]. Rotary devices made of nickel-titanium alloy (Ni-Ti) have become popular for root canal shaping due to their consistent, predictable, and repeatable shaping ability. Since the effectiveness of the instrumentation is affected by predictability in shaping, so too are the outcomes of obturation [5].

In the last two decades, rotary instrument designs have evolved at a remarkable pace. The design of these devices has advanced tremendously, resulting in improved root canal preparation, better obturation and apical sealing, and a better prognosis for the treated tooth in the long term [6]. The vast majority of Ni-Ti rotary systems rotate indefinitely [7]; however, significant limitations to this type of system have been reported, as is the case with many other systems. Circular canal rotation may cause cyclic fatigue leading to file separation and fracture as a result of the repetitive application of tensile and compressive pressures [8]. The use of certain Ni-Ti files necessitates the prior building of a glide path using manual files, which might take considerable time when repeated file size exchanges are required [9]. Since then, single-file Ni-Ti reciprocating systems have emerged, one of which is the Reciproc system [9]. The three files which make up the single-file Ni-Ti system are the R25 (ISO 25; 8%), R40 (ISO 40; 6%), and R50 (ISO 50; 5%), each of which includes corresponding paper points and guttapercha. In comparison to traditional rotational Ni-Ti systems, this design has several advantages:

1) it is more efficient because only one file is needed to prepare all canals;
2) the files are made of M-wire (heated Ni-Ti alloy), which gives them the highest flexibility and cycle fatigue resistance;
3) they are reciprocating systems which rotate in reciprocal motions at balanced force with enormous rotation angles.

To prevent taper locking and to alleviate tension on the file, one movement is counter-clockwise so as to engage and cut the dentin, while the second is clockwise to disengage the file from the dentin and release the stress on it. This reduces the likelihood of file breakage and boosts their resilience to cyclic and torsional wear, thus making them more efficient [10]. WaveOne, a new single-file Ni-Ti reciprocation technology, has also been introduced in the market. There are three single-use files in this system: small (ISO 21; 6%), primary (ISO 25; 8%), and huge (ISO 25; 9%). Moreover, a new file has been added to this category, which is the ISO 25 (11%). The M-wire and reciprocal movement characteristics of Reciproc are shared by this system.

Several research projects had compared different types and brands of Ni-Ti system [11]. However, few studies have examined the geometric and structural characteristics of rotary files in order to provide a better understanding of root canal apical micro leakage.

MATERIALS AND METHODS

This study was reviewed and approved by the Research Ethical Approval Committee of the College of Dentistry, University of Babylon (Babylon, Iraq), with reference number (28) on (29/5/2024) as these our local internal features and requirements of the university authorities.

Sixty human single-rooted premolar (bicuspid) teeth with fully matured apices were collected after extraction for orthodontic and periodontal reasons. An ultrasonic scaler (woodpecker HW-1 scaler, China) was used to physically remove the soft tissue and plaque from each root's external surface. All specimens were examined under a microscope (mag. 10x) and then radiographed mesio-distally and bucco-lingually to verify the presence of any defect. Any teeth with defect such as cementum caries, root fracture, apical delta, accessory canals, external or internal resorption and sever curvature, the teeth was excluded.

A multipurpose diamond bur (Komet, Germany) and high-speed turbine were used to cut the teeth at the CEJ level. The teeth were then stored in 2.5% NaOCl solution for two hours followed by washing with normal saline solution. A barbed broach was used to remove the pulp tissue, and a #15 stainless steel K-files was used to examine for root canal patency. Each tooth's working length was determined by introducing a #15 stainless steel K-files into the canal with apical advancement until the tip of the file could be observed visually through the apex and then subtracting 1 mm from the distance travelled. Then irrigation was performed using 2.5% NaOCl with 2 ml for each tooth.

Sample grouping

All 60 samples were randomly assigned into 4 groups, each with 15 teeth. All of the teeth were contained in a single block of silicon impression material (putty and catalyst gel) and a #15 stainless steel K-files (Dentsply Maillefer, Switzerland) were used to predetermine a glide path, and instrumented using one of two distinct preparation processes:

- Group 1 — WaveOne file with reciprocation. A WaveOne file #25 with a 0.08 taper (Dentsply Maillefer, Switzerland) and an endomotor were employed in accordance with the manufacturer's recommendations utilizing a slow in and out pecking reciprocating action. After three cutting cycles in which the WaveOne file engages and disengages, it moves back and forth in a unique way. It may reach the required working length more rapidly.
- Group 2 — WaveOne file with rotation. A WaveOne file #25 with a 0.08 taper and a rotating technique with endomotor was employed with a gradual in and out rotational pecking motion. WaveOne 25/08 instrument was utilized in the same way as the single-length procedure, rotated 360 degrees at 250 rpm throughout the full root canal length.
- Group 3 — Reciproc file with reciprocation. The endomotor was used in a reciprocating manner and a slow in and out pecking action, as instructed by the manufacturer, using a Reciproc file #25 with a 0.08 taper (VDW, Germany).
- Group 4 — Reciproc file with rotation. A Reciproc file #25 with a 0.08 taper and an endomotor were used in a rotational manner following the manufacturer's instructions. The instruments were utilized in the same way as the single-length procedure at 250 rpm, throughout the full root canal length.

All of the teeth were contained in a single block of silicon impression material (putty and catalyst gel) and a #15 stainless steel K-files were used to predetermine a glide path.

For all groups, each procedure was followed by irrigation with 2 ml of 2.5% NaOCl and verification of apical patency with a #15 stainless steel K-file.

As a final irrigation for all groups, two mL of 17% EDTA, washed with two mL of normal saline, followed by five mL of 2.5% NaOCl solution were used to remove the dentinal smear layer from all specimens following biomechanical preparation.

Obturation

All of the canals were then dried with corresponding paper points (corresponding to the type and size of the files that were used in the above 4 groups), and obturated with the corresponding gutta-percha points (corresponding to the type and size of the files that were used in the above four group). For groups 1 and 2 the paper points and gutta-percha points were size #25 with a 0.08 taper. For groups 3 and 4, the paper points and gutta-percha points were size #25 with a 0.08 taper. After confirmation of tug back, a single-cone technique combined with a ZOE-based sealer Endofill (Dentsply, Brazil) was utilized.

Dye test preparation

The entire external root surface of each tooth except the apical 2 mm was coated with 2 layers of nail varnish (Flormar, Turkey) followed by sealing the coronal access of the canal system which was restored with high viscosity light-cured resin-reinforced glass-ionomer restorative material Riva light cure HV (SDI, Australia) so as to avoid micro leakage from anywhere other than the apex.

All samples were then dipped in a container filled with 2% methylene blue dye (pH=7) followed by incubation for 3 days at 37°C [12]. After that, a scalpel was used to remove the varnish and then the teeth were cleaned and dried. With the aid of a small-diameter double-faced diamond disc mounted on a slow-speed headpiece with dental lab micromotor and under constant water-cooling, a longitudinal groove was created on the root bucco-lingually, followed by the splitting of the teeth.

The split specimens were observed under a microscope 10x magnification and the images were captured by the camera connected to the microscope. Then, these images were analyzed digitally, and the length of the linear extension of the dye along the inner side of the canal was measured in millimeters (fig. 1).

Fig. 1. Microscopical image of sample showing dye (blue color) penetration from the root apex in linear way. The captured image was digitally analyzed and enhanced

Measurement of the linear extension

Intra- and inter-examiner agreements were verified via the calculation of values of Cohen's Kappa (κ) using 20 randomly selected cases used in this study. Values of κ of 0.88 and 0.81 indicated excellent intra- and inter-examiner agreements respectively.

Then, the final measurement of the linear extension was done independently by two examiners, and the mean reading for each sample was recorded.

Statistical analysis

For comparison between the 4 groups, the results were analysed statistically using the parametric test one-way ANOVA. For further analysis of the significance between groups, independent samples t-test was utilized between each two groups. The statistical difference was set at $p<0.05$.

RESULTS

The results obtained for the four experimental groups were summarized in table 1. Table 2 shows the mean micro leakage (in µm) for all of the groups. There is a significant difference between all groups in the extent of micro leakage. The mean value of WaveOne file reciprocation group (group 1) is lower than that of WaveOne file rotation group (group 2), and the mean value of Reciproc file reciprocation group (group 3) is lower than that of Reciproc file rotation group (group 4). There is no substantial difference in micro leakage between the measurements for the groups with reciprocation movement (group 1 and group 3). In addition, there is no substantial difference in micro leakage between the measurements for the groups with rotational movement (group 2 and group 4; table 2).

Table 3 shows no significant difference between the measurements for the groups with reciprocation movement (between group 1 and group 3), at $p<0.05$. In addition, it shows no significant difference between the measurements for the groups with rotational movement (between group 2 and group 4), at $p<0.05$. While, there is a significant

Table 1. The extent of micro leakage for all samples in each group (in µm)

Sample no.	Group 1 WaveOne file with reciprocation	Group 2 WaveOne file with rotation	Group 3 Reciproc file with reciprocation	Group 4 Reciproc file with rotation
1	1.02	2.49	1.06	2.50
2	1.00	2.40	1.00	2.44
3	0.98	2.40	1.05	2.43
4	0.94	2.40	0.33	2.39
5	0.93	2.40	0.73	2.39
6	0.88	2.40	0.60	2.34
7	0.79	2.36	0.93	2.39
8	0.74	2.40	0.71	2.49
9	0.71	2.40	0.39	2.40
10	0.67	2.40	0.29	2.50
11	0.60	2.39	0.93	2.49
12	0.54	2.40	0.96	2.50
13	0.48	2.40	0.43	2.49
14	0.38	2.40	0.98	2.40
15	0.25	2.19	0.27	2.15

Table 2. Statistical analysis of the extent of micro leakage for all groups (in μm)

Group	Technique	Mean	Min.	Max.	SE	*p*
1	WaveOne file with reciprocation	0.73±0.24	0.25	1.02	0.06	<0.001
2	WaveOne file with rotation	2.39±0.06	2.19	2.49	0.02	
3	Reciproc file with reciprocation	0.71±0.30	0.27	1.06	0.08	
4	Reciproc file with rotation	2.42±0.09	2.15	2.50	0.02	

Table 3. Statistical analysis of the extent of micro leakage between each groups either using the same file instrument with different movements, or using different file instrument with the same movement

Groups	Technique	*p*
1 & 2	WaveOne file with reciprocation and WaveOne file with rotation	<0.001
3 & 4	Reciproc file with reciprocation and Reciproc file with rotation	<0.001
1 & 3	WaveOne file with reciprocation and Reciproc file with reciprocation	0.875
2 & 4	WaveOne file with rotation and Reciproc file with rotation	0.191

difference between the measurements for the groups with reciprocation movement and rotational movement (between group 1 and group 2 and between group 3 and group 4), at $p<0.05$ (table 3).

DISCUSSION

When performing root canal preparation, one of the primary goals is to retain the canal system's original configuration while shaping and cleaning it effectively. This will help to prevent complications like instrument fracture, external transportation, ledging or perforation that could occur as a result of iatrogenic causes [13].

An effective and thorough debridement of the entire canal system and the generation of a hermetic seal in the root apex followed by a 3-dimensional filling of the canal spaces are essential for perfect root canal treatment [14]. Moreover, the root apex is regarded as the most difficult part of the tooth to understand, due to the presence of a wide range of anatomical details and variations such as ramifications and tiny canals as well as lateral tubes that increase the ability of microorganisms to leak [15].

Endodontic sealer plays a key role in the success of endodontic treatment, and sealing effectiveness is determined according to the sealer's adhesion to the dentinal wall as well as its physical qualities.

There are several techniques for root canal obturation, but one that has been extensively employed by dental practitioners is the lateral condensation of gutta-percha [16].

The goal of this research was to determine the amount of apical micro leakage in canals produced using WaveOne and Reciproc files and lateral compaction techniques using rotary and reciprocation instrumentation. Assessment was performed with a dye penetration test due to its simplicity and low cost, which make it a practical investigation option [17—19] to measure micro leakage.

Single-file instrumentation systems are as effective as multi-file systems in cleaning the root canal system [20]. There is evidence to suggest that if less debris is generated during instrumentation then the adaptability of root filling materials and less apical micro leakage is improved [21], since the link between dentin and sealant will be compromised if the smear layer is thick or not completely removed [22].

Root canal filling should involve three-dimensional apical and coronal obturation in order to avoid apical leaking [23]. New materials and procedures, on the other hand, may enhance the likelihood of good results by improving the fit between the root canal walls and the filling material, hence reducing micro leakage [24, 25]. The anatomy of a root canal's middle and apical regions may be better preserved with the Reciproc method than other rotational systems; however, this improvement has not been found to be significant [26]. Reciproc, in addition, generates less alteration of root canal geometry and allows for safer root canal system obturation and closing, thus reducing apical micro leakage [27].

According to the findings of the current study, there was no significant difference between the apical micro leakage when applying WaveOne and Reciproc and the same instrumentation technique. This conclusion is in line with those of Rubio et al. (2015), who employed WaveOne, ProTaper, and F360 file systems to compare rotary systems [28]. WaveOne and Reciproc were employed by Yoon et al. (2015) for canal instrumentation [29], and the single-cone method (#25/08 and #30/06 gutta-percha) was used to fill the canals [29]. According to their findings, there was no significant difference in the gutta-percha-occupied area prepared using the two rotational systems.

A considerable spacing differential may make it difficult for the gutta-percha master cone to adapt to the surfaces of root canals. As noted above, there is a link between apex flaring and dye leaking. Root canal instrumentation should be performed with a limited number of pecking motions.

The reciprocating group exhibited the finest apical seal results using both file systems. This is a consequence of the unique, uneven bidirectional movement involved, which has three crucial characteristics. Its engagement angle is five times greater than its disengagement angle, making it superior to comparable reciprocating processes that use equal bidirectional angles [30]. The Wave-One file will have circled 360 degrees after three cutting cycles. Due to this file's distinctive reciprocating movement, it may reach the necessary working length faster. Moreover, the variable speed in both directions makes it easier to move debris outside the canal.

CONCLUSIONS

The apical seals achieved differ with the reciprocation method and the traditional rotational approach to prepare the root canals, using WaveOne files. In addition, the was a significant difference between the apical seals achieved with the reciprocation method and the traditional rotational approach to prepare the root canals, using Reciproc files. While, the difference in micro leakage between WaveOne and Reciprocal file (with rotational movement), and between WaveOne and Reciprocal file (with reciprocation movement) was not

statistically significant. A better apical seal was found when using WaveOne reciprocation rather than WaveOne rotary and the same was true for the Reciproc files.

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