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Research Article

Exploring the Effects of Different Torque and Speed Parameters on Smear Layer and Microcrack Formation in Apical Dentin of Root Canals with Single File Instrumentation

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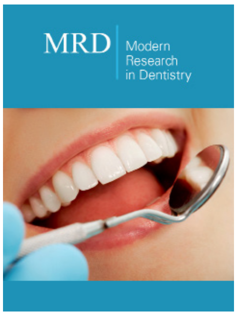

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Abstract

Purpose: Biomechanical preparation is a crucial stage in endodontic treatment, involves the cleaning and shaping of the root canal system. Generally, single file system is widely used which has a simple concept and continuous movement in a clockwise direction. The speed and torque of the endomotor are essential indicators to assess the cleanliness of the root canal. The extent of smear layer distribution and the possibility of microcracks in root canal are indicators of root canal cleanliness and safety considerations in root canal treatment. The present study aimed to evaluate the effects of different torque and speed parameters on smear layer and microcrack formation in apical dentin of root canals with single file instrumentation.

Materials and Methods: This laboratory experimental study used a Confocal Laser Scanning Microscope (CLSM) to observe the formation of a smear layer and possibility of microcrack in the apical third. Forty-eight samples of mandibular first premolars were prepared in different rotation speeds (250rpm, 400rpm) and torque (0.8N.cm, 2.5N.cm). Twenty-four samples observed the formation of smear layer based on Hulsmann score and 24 samples to observe the possibility of microcrack based on Shemesh score. Data were analyzed statistically by Chi-Square and Kruskal-Walls test.

Result: The smear layer evaluation results in the current study only showed scores of 2, 3, and 4. Meanwhile, microcrack analysis shows all scores 1,2, and 3. However, statistical analysis revealed no difference that was significant.

Conclusion: According to the findings of this study, it is recommended to utilize rotary instruments with low torque and speed to remove smear layers dan for safety consideration.

Keywords: Endodontic treatment; Smear layer; Microcrack; Root canal

Introduction

The efficacy of the root canal's biomechanical preparation is critical to the outcome of the endodontic procedure. Despite advancements in instruments, it is estimated that there is no instrument that can entirely clean the root canal system of all bacteria, pulp tissue, and their products. Preserving the original structure of the root canal system is among of the greatest critical concepts while preparing all root canal surfaces to avoid procedural errors such as zipping, ledging, perforation, and apical transport. Therefore, careful attention must be given to the continuous preparation of all surfaces to ensure that the procedure is successful and to prevent complications that may arise during the process [1-3].

The procedure of preparing root canals using rotary instruments has become a common practice in dentistry, as it has been found to increase efficiency and effectiveness. Numerous systems are offered for NiTi rotary instruments, with different blade designs, tapers, and tip configurations to cater to the unique needs of each patient. Additionally, various speeds and torques are used while using rotary instruments [4]. The design of the rotary instrument and its penetration into the root canal determines dentin's uptake and removal capacity exposed to bacteria and various adverse effects, such as forcing debris into the dentinal tubules [2,5-7].

In clinical practice, some dentists consider that using a single file system is more useful, effectiveness, and cost-effectiveness [8-12]. Although the concept of this instrument is straightforward compared to multiple file systems, research has indicated that the type of rotational motion and the number of rotations may impact to extensive root canal preparation and a tendency towards apical debris transport [13,14]. Therefore, while single-file systems may be a convenient option for dental professionals, it is important to exercise caution when using them and to consider the potential risks associated with their use. Ultimately, the choice of root canal preparation instrument should be based on a thorough evaluation of the patient's individual needs and the dentist's professional judgment, taking into account both the benefits and potential risks of each available option [2,5]. Accordingly, root canal instrumentation with single file, when connected between the design features and the capacity of the flute to accommodate debris with a large number of rotations, needs to be evaluated how the spread of the smear layer, especially in the apical third of the root canal, that is one of the critical areas affect the success of endodontic treatment [6,15,16].

Following instrumentation with either rotary instruments or endodontic files, a surface coating of debris known as the "smear layer" is left on the dentin or other tooth surfaces, such as cementum and enamel. Prior to canal obturation, the smear layer is needed eliminated to increase the endodontic sealer's adherence and penetration, producing a better seal [16,17]. A smear-layer-free root canal wall is one of the markers used to evaluate the cleanliness of the root canal. Until now, a scanning tool applied to the root canal wall's surface served as the evaluation technique for determining cleanliness. Observations with a 3D Confocal Laser Scanning Microscope provide accurate optical aspects and are easier to use [18,19].

Furthermore, properly adjusting the torque and speed is of utmost importance when it comes to dentin removal during root canal procedures. It is crucial to avoid setting the maximum speed and torque, as doing so can significantly increase the likelihood of microcracks. These microcracks, particularly in the apical third of the root, often go unnoticed visually but can lead to vertical root fractures. To mitigate this risk, it becomes essential to meticulously configure the speed and torque setting on the endo-motor [6]. This aspect deserves careful attention, considering that some clinicians may opt for hinger speed and torque to expedite root canal preparation. Consequently, it becomes imperative to conduct research and identify the safest parameters for speed and torque, with the goal of minimizing the occurrence of microcracks. The current study uses One Curve as a single file system that has unique quality lies in its ability to shape the root canal, with variations in cross-sectional cutting zones (pitch) in the coronal, middle, and apical regions. However, the impact of this file on dentin removal and microcracks remains a subject of controversy [20,21].

Therefore, this study aimed to evaluate the smear layer and microcrack formation on the apical third of the root canal after single file technique instrumentation at different torques and speeds. The cleanliness of the root canal, specifically the removal of the smear layer, is widely regarded as a crucial factor contributing to the success of endodontic treatment, moreover, it is imperative to carefully consider the risk factors associated with microcracks, particularly in the apical third of the root canal. By addressing this factors, endodontic treatment can be optimized, promoting favorable outcomes and enhancing overall success rates.

Materials and Methods

Sample preparation

Forty-eight single-rooted mandibular first premolars extracted for orthodontic reasons with an average length of 20 ± 2mm were selected in this study, which fulfilled the following criteria: mature root; the absence of root filling material, and root resorption. The sample was cleaned and immersed in saline solution while waiting for the research process to begin. The patency of the apical foramen was standardized by inserting a K-file #15 (VDW, Germany) until the tip was visible. Then the working length of each sample was measured to be 0.5mm shorter than the working length of K-file #15 at this position. The working length of each sample that has been measured is then recorded. Subsequently, the endodontic access was made using an access bur (Endo Access Z, Dentsply Maillefer, Switzerland).

Root canal preparation

Samples were prepared using a One Curve file (Micromega, Besancon, France) with an endo-motor (XSmart Plus, Dentsply Sirona, USA). The root canal preparation uses a direct one-shape system throughout the working length with a brushing motion without pressure, a rotation speed of 250-400rpm, and a torque of 0.8-2.5N.cm, which is adjusted to the manufacturer's instructions with irrigation. The samples were then divided into four groups based on the rotation speed and torque used during preparation. The root canals were prepared with a rotation speed of 250rpm and a torque of 0.8N.cm, 250rpm and 2.5N.cm, 400rpm and 0.8N.cm, 400rpm, and 2.5N.cm are denoted as group 1, group 2, group 3, and group 4, respectively. After preparation, the root canals were rinsed with a chelating agent (MD Cleanser, Meta Biomed Co Ltd., Korea), and rinsed again with NaOCl 5.25%. Then the entire root canal was dried using a paper point, then the orifice was covered with cotton pellets and filled with glass ionomer cement.

Smear layer distribution analysis

Twenty-four prepared samples were split vertically from coronal to apex using a carborundum disc with a water-cooled low-speed handpiece. The split prepared sample was then placed on a glass plate then placed on the object table and then observed using a confocal laser scanning microscope (CLSM; LEXTTM OLS4000 3D, Evident Olympus, Japan) with 1000x magnification to evaluate the cleanliness of the smear layer of each sample. The cleanliness of the smear layer was then evaluated using a scoring system (Hulsmann score) with a score of 1 indicating that no smear layer and the surface of the dentinal tubules was exposed, a score of 2 indicated that small amount of smear layer and only slightly exposed dentinal tubule surface, a score of 3 indicates that homogenous smear layer and only slightly exposed dentinal tubule surface, a score of 4 indicates complete covering by a homogenous smear layer and no opening of dentinal tubules, and score 5 indicates a heavy, non-homogenous smear layer covering the entire root canal wall.

Microcrack imaging analysis

Twenty-four prepared samples were separated by using a carborundum disc and a low-speed handpiece with water cooling to facilitate horizontal cutting at apical third. Each sample was randomly selected after being sectioned, then fixed, and subsequently measured. The marked specimens were carefully positioned on a glass plate and then placed on the object table for observation using a Confocal scanning Laser Microscopy (CLSM, LEXTTM OLS4000 3D, Evident Olympus, Japan) with 1000x magnification. The microcrack imaging of each group used in this study were categorized by Shemesh score. The scoring system included the following categories: score 1, no defects, indicating dentin in the root canal without any lines or cracks on the external or internal surfaces of the root canal walls. Score 2: Incomplete defects, including any visible lines that do not extend from the internal root canal to the external root surface (e.g., craze lines, lines extending from the outer surface into the dentin but not reaching the canal lumen, lines extending from the inner wall of the root canal without reaching the outer surface). Score 3: Fracture, representing lines extending from the root canal space to the outer surface of the root canal.

Statistical analysis

A SPSS statistic software (Version 24, SPSS Inc., Chicago, IL, USA) with the Chi-Square test was used examine the relationship or correlation between the response variable and predictors, while, Kruskal-Wallis analysis test was used to determine whether there is a difference in the level of cleanliness of the root canal wall surface in all groups and continued with the Mann-Whitney post hoc analysis test to determine the significance between the sample groups. A value of $p<0.05$ was indicated statistically significant.

Result

Smear layer distribution analysis

This study evaluates the single file technique instrumentation on the formation of a smear layer on the dentin of one-third of the root canal. The smear layer description of each group used in this study was grouped using the Hulsmann score. The image of the dentin wall of the root canal after instrumentation with One Curve file at a speed of 250rpm and a torque of 0.8N.cm shows a slight smear layer on the dentin surface of the root canal wall (Figure 1a). The image of the dentin wall of the root canal after instrumentation with Curve file at a speed of 250rpm and a torque of 2.5N.cm exhibit a slight smear layer and slightly exposed dentinal tubule surface in the dentinal wall of the root canal (Figure 1b). The picture of the dentin wall of the root canal after instrumentation with a One Curve file at a speed of 400 rpm and a torque of 0.8 N.cm reveal smear layer on the dentin surface of the root canal wall with only slightly exposed dentinal tubule surface (Figure 1c). The picture of the dentin wall of the root canal after instrumentation with a One Curve file at a speed of 400 rpm and a torque of 2.5N.cm express complete covering homogenous smear layers and a small portion of the dentinal tubules (Figure 1d).

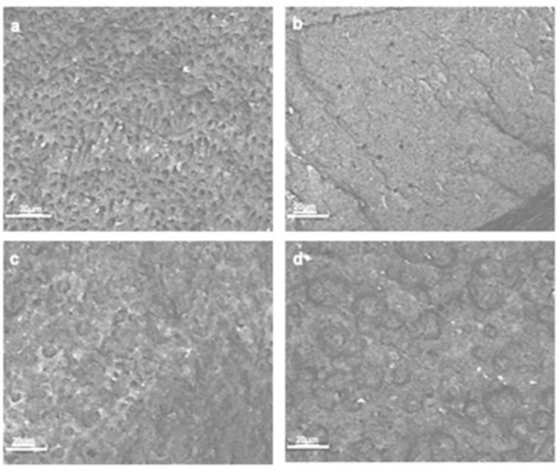

Figure 1: Overview of smear layer on the dentin of one-third of the root canal after instrumentation with One Curve file: (a) Group 1 with scoring 2; (b) Group 2 with scoring 3; (c) Group 3 with scoring 4; (d) Group 4 with scoring 4.

Microcracks imaging analysis

This study determined the safest speed and torque setting in relation to the occurrence of microcracks. After instrumentation with the One Curve file at a speed of 250rpm and a torque of 0.8N.cm, there were no visible microcracks on the dentin surface of the root canal walls (Figure 2a). Representation of dentin wall of the root canal after instrumentation with a One Curve file at a speed of 250rpm and torque of 2.5N.cm, showing incomplete defects (Figure 2b). The image depicts the dentin wall of the root canal after instrumentation with the One Curve file at a speed of 400 rpm and torque of 0.8N.cm, revealing the presence of an incomplete defect on the dentin surface of the root canal (Figure 2c). The image of the dentin wall of the root canal after instrumentation with a One Curve file at a speed of 400rpm and torque of 2.5N.cm reveals the presence of a fracture on the dentin surface (Figure 2d).

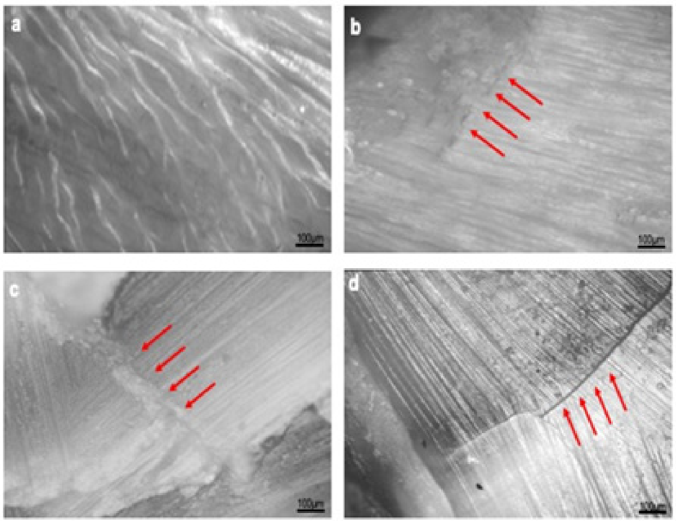

Figure 2: Overview of dentin surface of the root canal after instrumentation with One Curve file: (a) Group 1 with scoring 1; (b) Group 2 with scoring 2; (c) Group 3 with scoring 2; (d) Group 4 with scoring 3. (Red arrow indicate microcrack on dentin surface).

Analysis result

Correlation or relationship: The smear layer evaluation results in the current study only showed scores of 2, 3, and 4 which were based on the Hulsmann score. Meanwhile, microcrack analysis shows all scores are based on the Shemesh score. The association between the sample group and the scoring value of the root canal is exhibited in Figure 3. The chi-square test on the group variable in the smear layer data demonstrates a p-value (Sig.) of 0.430, which is greater than the significance level of 0.05. This indicates that the sample group variable does not exhibit a significant relationship with the scoring value in the context of this study. Whereas the group variable in the microcrack data shows a p-value (Sig.) of 0.01, which is smaller than the significance level of 0.05, which means that the treatment variable in the microcrack group has a significant relationship with the scoring value in this study. According to the data above, there is a slight but significant increase in the production of smear layers and a predisposition for microcracks in the root canal dentin with higher torque and speed applied to the endo-motor when using the file.

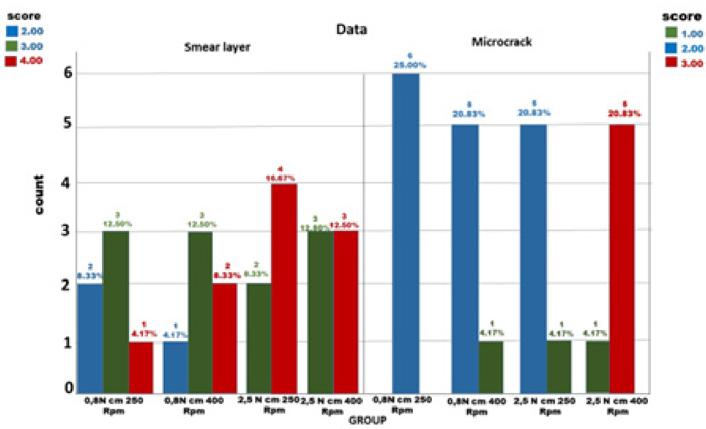

Figure 3: The relationship between sample group and scoring values in root canals (p<0.05: significant).

Comparison: Table 1 shows the results of the Kruskal walls test on the smear layer group variable with a p value (Sig.) >0.05, which means that there is no significant difference between treatments 0.8N.cm 250Rpm, 0.8N.cm 400Rpm, 2.5N.cm 250Rpm, 2.5N.cm 400Rpm based on the scoring values in this study. Whereas the microcrack group variable shows a p-value (sig.) that is <0.05 which means that there is a significant difference between the 0.8N.cm 250Rpm, 0.8N.cm 400Rpm, 2.5N.cm 250Rpm, 2.5N.cm 400Rpm treatments based on the scoring value. In this study, it was further shown that the 2.5N.cm 400Rpm treatment was different from the others group treatments.

Table 1: The comparison between sample group based on scoring values on root canals.

Variable	Group	(Mean±SD)	Median (Min – Max)	P-Value
Smear layer	0.8N.cm 250Rpm	(1.833±0.753) [a]	2 (1 – 3) [a]	0.186
	0.8N.cm 400Rpm	(2.167±0.753) [a]	2 (1 – 3) [a]	
	2.5N.cm 250Rpm	(2.667±0.516) [a]	3 (2 – 3) [a]	
	2.5N.cm 400Rpm	(2.5±0.548) [a]	2.5 (2 – 3) [a]	
Microcrack	0.8N.cm 250Rpm	(1±0) [a]	1 (1 – 1) [a]	0.000*
	0.8N.cm 400Rpm	(1.167±0.408) [a]	1 (1 – 2) [a]	
	2.5N.cm 250Rpm	(1.167±0.408) [a]	1 (1 – 2) [a]	
	2.5N.cm 400Rpm	(2.833±0.408) [b]	3 (2 – 3) [a]	

Note: The values with different superscript letters in a column are significantly different, * = p<0.05.

Discussion

The purpose of this study was to evaluate the effectiveness of the single file technique instrumentation at different speeds and torques by examining the distribution of the smear layer and microcrack formation in the dentinal wall of the apical third of the root canal. The results indicated that even with the use of a single file technique, the smear layer and occurrence of microcrack remained visible, particularly in the apical third of the root canal. Basically, there are no instruments or instrumentation techniques that can provide a completely clean result free of debris and smear layers on the root canal walls. Furthermore, microcracks typically develop on the dentin walls of root canals during root canal preparation procedures, and their occurrence is often associated with the use of high torque and speed settings on the endo-motor. However, the use of One Curve files with a small taper (0.06) and various cross sections can help minimize the occurrence of microcracks by allowing for adjustments in speed and torque [22]. Therefore, it is important for endodontists to be aware of the limitations instrumentation techniques and adopt appropriate measures to minimize the formation of microcracks during the root canal treatment process, while still prioritizing the cleanliness of the root canals which is reflected in the formation of a smear layer to ensure the best results for the patient.

In spite of non-significant results, current research indicates that increased speed and torque will result in a substantial smear layer. Because of the high speed and torque of the endodontic instruments used, a smaller amount of time and minimal effort are needed to prepare infected root canal which produce large amounts of debris and smear layer. This indicates the good cutting efficiency of the endodontic instruments used in this study [7,13,23]. Nonetheless, an additional consequence that may arise is the accumulation of debris and smear layer within the root canal, which may even be pushed apically and make cleaning the root canal more challenging and, in certain situations, result in a screw-in effect [7,13,24]. Conversely, the instrument utilized in this study's cutting efficiency is demonstrated by its capacity to remove the smear layer even when applied with low speed and torque, as demonstrated by the smear layer removal achieved with a score of 2 to 4.

Although this is still up for debate, the rotary file's kinematic movement is believed to affect how debris and smear layers are removed [25]. Because reciprocating motion produces more debris and smear layers due to the dentin-cutting action, an *in vitro* study found that it is more effective at cleaning than rotating motion. However, using irrigation solutions to remove debris and dense smear layers on the dentin walls of the root canal will be more challenging and likely to cause the debris to be pushed apically [26]. Nonetheless, research has shown that rotational motion results in increased debris being extruded apically [27]. Other studies show that even after the irrigation routine has been followed, rotational motion is more efficient than reciprocal motion at clearing the root canal walls of debris and smear layer [23], according to the present research, which employs rotating instruments with kinetic movement and standard irrigation procedures using 5.25%NaOCl and 17% EDTA.

Using rotary files during root canal preparation produces rotational forces on the canal walls and pressure into the canal. Debridement of infected root canals is achieved by touching and lining instruments on the canal walls. Ultimately, accumulating force and resulting contact can cause microcracks that allow reinfection and even root fracture [7,28]. The coronal and middle areas receive more pressure during root canal preparation than the apical area [29]. So, the coronal and middle areas allow more cracks to occur than the apical ones. However, there is inconsistency in the incidence of cracks in the coronal, middle, and apical areas, although statistically, it is not significant [29-31]. This is due to the multifactorial causes of cracks in the root canal walls after root canal preparation. The use of rotary files can cause cracks in the dentin walls of the root canal, and various factors, including design, cross-sectional geometry, type of taper, kinematic motion, and single or multiple files, influence the degree of damage [7,14,29-32]. Therefore, varying results will be obtained if the assessment of root canal wall cracks is based on only one of these factors.

A study compared microcracks in the dentin walls of root canals resulting from using two endodontic instruments (Hyflex EDM and One Curve), which have similarities in terms of single file, kinematic motion, and controlled memory files, which are considered more flexible [31]. Hyflex EDM shows lower microcracks formation than One Curve, likely due to the recommended speed for Hyflex EDM being higher than One Curve, resulting in high cutting efficiency [31]. However, One Curve is faster in forming root canals than Hyflex EDM [31]. Conversely, current research shows that the higher the speed and torque applied to the rotary instrument, the greater the incidence of microcrack in the dentin walls of the root canal. In a meta-analysis, it was also stated that one of factors causing the high risk of root canal dentin wall microcracks was the large amount of root canal dentin expulsion, which is more in line with current research [32]. Finally, improper speed and torque can lead to a number of procedural errors in the instruments used, such as broken files, and in the tooth structure, such as ledges and perforations [33-35].

Based on the present research and statistical analysis conducted, the results between the groups in smear layer analysis did not show significant differences. However, this lack of statistical significance does not necessarily mean that there are no differences between the groups. Rather, the results suggest that the small smear layer distribution observed in group 1, which utilized low speed, low torque, and a rhythm with single file technique features used slowly, can be considered as a safe and effective method for root canal preparation. In line by the result of microcrack analysis indicated that utilized low speed, low torque statistically leads to minimal occurrences of microcrack in the dentin wall. Additionally, the use of a single file technique can simplify the root canal preparation process, reduce the likelihood of instrument separation, and improve overall treatment outcomes.

Conclusion

This study assessed the smear layer and microcracks in various treatment groups. The results, evaluated through Hulsmann scores and CLSM for the smear layer, as well as Shemesh scores and CLSM for microcracks, suggest that lower speed and torque settings during instrumentation reduce the presence of the smear layer and minimize microcracks compared to higher speed and torque levels. Statistical analysis revealed no significant relationship between the sample group variable and smear layer formation but did indicate a significant association between the group variable and the occurrence of microcracks. Therefore, it is recommended to use rotary instruments with minimum speed and torque to remove the smear layer and minimize the occurrence of microcracks for safety considerations

Author Contributions

Conceptualization, C.A.R., S.S. and C.-M.L.; methodology, M.Y., and N.W.; validation, N.N., M.T., and J.J.N.; investigation, M.Y., N.W., S.S. and C.A.R; resources, C.-M.L.; writing-original draft preparation, C.A.R., and S.S.; writing review and editing, C.A.R., and S.S.; visualization, C.-M.L.; supervision, N.N., M.T., and J.J.N. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

This study protocol was approved by the Ethics Committee Dentistry Faculty of Hasanuddin University (No.0010/PL.09/KEPK FKG-RSGM UNHAS/2020).

Data Availability Statement

Data is contained within the article.

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