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ORIGINAL ARTICLE

Influence of different torque control and apex locator settings on apical debris extrusion

ABSTRACT

Aim: *This study evaluated the effects of torque control settings and automatic stop functions on apical debris extrusion during root canal preparation using a continuous rotation file system.*
Methodology: *Forty-eight extracted human lower premolars were randomly divided into four groups based on two torque control settings and two auto-stop functions. The extruded debris was collected in pre-weighed Eppendorf tubes and subsequently quantified.*
Results: *Statistical analyses were conducted using SPSS, and the Kruskal–Wallis test and the Mann–Whitney U test revealed that the auto-stop mode significantly reduced debris extrusion, while the torque control settings did not.*
Conclusion: *These findings suggest that clinicians can potentially minimise debris extrusion by utilising the auto-stop mode during root canal procedures.*

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Received 2024, December 9
Accepted 2056, January 9

KEYWORDS *Ni-Ti instruments, endodontics, root canal preparation, root canal therapy*

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Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2025.39.01.01

Introduction

During the chemomechanical preparation of root canals, dentinal chips, pulp tissue residues, microorganisms, and irrigation solutions could be extruded from the root canal, causing postoperative pain, inflammation, and delayed periapical healing (1, 2).

All contemporary preparation techniques result in some degree of debris extrusion. The factors influencing the degree of debris extrusion include the number and structure of the files used in root canal preparation (radial lands, the number and width of flutes, and cross-sections), kinematics, preparation technique, tooth anatomy, and working length (WL) (3, 4). Although Ni-Ti rotary file systems have been shown to generate less debris extrusion than other systems, there exists no consensus regarding the comparative efficacy of rotational versus reciprocation movements (5-7).

Developed in 2017, One Curve (MicroMega, Besancon, France) is a single file system made of Ni-Ti alloy and that operates with continuous rotations. Since it is made using C-wire technology, it possesses shape memory properties, offering clinicians the option of pre-curving for root canals with complex anatomies. Available in four different sizes (25/0.04, 25/0.06, 35/0.04, and 45/0.04) and three different lengths (21 mm, 25 mm, and 31 mm), this file system features variable cross-sections along its cutting edges, which enhance its centring ability and cutting efficiency (8, 9).

Integrated endodontic motors can monitor a file's position in the canal, allowing simultaneous canal preparation (10, 11). The VDW Gold Reciproc (VDW GmbH, Munich, Germany), an endodontic motor that can be controlled by a foot pedal, has adjustable torque and speed settings and is integrated with an electronic apex locator. Since it can be used with reciprocating and rotating Ni-Ti rotary file systems, clinicians can simultaneously control the WL during root canal preparation. Once it reaches a predetermined level in the root canal, it can perform different kinematics, including automatic reverse (ASR) upon reaching the set torque limit is reached, automatic stop upon reaching the apex ('Auto Stop On'), and no automatic stop upon reaching the apex ('Auto Stop Off'). These settings can be adjusted according to the clinician's preference (12).

Numerous studies have investigated the quantity of apically extruded debris produced when root canals are prepared using Ni-Ti file systems (4, 13-15). However, to our knowledge, there is only limited data about the impact of the various torque settings and apex-locating modes of integrated endodontic motors on apical extrusion during root canal preparation. Our study aimed to evaluate the effects of using a file system with continuous rotation under different torque control settings and auto-stop functions on apical debris extrusion. The null hypothesis stated that there would be no difference in the amount of apical debris extrusion produced by the various torque control settings and autostop functions hypothesis.

Materials and methods

Specimen Selection

Our study protocol was approved by the Ethics Committee of Kutahya Health Sciences University (No: 2023/14–24). The sample size was calculated using an effect size of 0.5, a type 1 error of 0.05, and a power of 0.80 using G* Power (version 3.1.9.7). We meticulously examined 60 extracted human mandibular premolars using a dental operating microscope (OMS 2350, Zumax Company, China) to exclude specimens with any signs of caries, cracks, or fractures. We obtained periapical radiographs (NewTom AG, Marburg, Germany) in both buccolingual and mesiodistal directions to confirm the absence of internal resorption, calcification, and previous root canal treatment and verify the presence of a single root canal. We included 48 extracted mandibular premolars that met the established criteria: approximately similar dimensions, single-rooted morphology, and without caries, fractures, calcifications, resorptions, or anatomic anomalies. All the collected samples were extracted for orthodontic or periodontal reasons, with informed consent, at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Kutahya Health Sciences University.

Experimental Design

After creating the access cavity, we performed the initial canal entry using a stainless steel #10 K-file (Dentsply Maillefer). The WL was determined by withdrawing the file 1 mm from the point where it first appeared at the apex under the dental operating microscope. To standardise our length measurements, we flattened the cutting edges to achieve a uniform root canal length of 18 mm (16). We carefully adjusted silicone stoppers to the flattened surfaces and used a digital caliper (Hogetex, Germany) to measure, under magnification, the distance between the stoppers and the file tip. We took each measurement thrice to confirm a root canal length of 18 mm. Teeth with any inconsistencies in these measurements were excluded and replaced.

We modified the previously described method of Myers and Montgomery (17) to collect the extruded debris and integrate an electronic apex locator into the experimental model, as described by Tınaz et al. (6). To measure the quantity of the extruded apical debris, we prepared Eppendorf tubes, and the weights of empty tubes, with their covers removed, were measured thrice using an electronic balance (Precisa XB 220A, Precisa Instruments) with an accuracy of 0.0001 g. We created a hole in the plastic covers of the Eppendorf tubes, through which we placed the teeth and fixed them using cyanoacrylate. A 21-G needle was then inserted into the cover as a drainage cannula. After we filled the tubes with 0.9% saline solution, we placed them in bottles and covered them with aluminium foil to ensure operator blinding.

Table 1
Experimental groups and different integrated endodontic motor functions

Groups	Torque Setting and Auto-Stop Function
Group 1	ASR Off/Auto Stop Off
Group 2	ASR Off/Auto Stop On
Group 3	ASR On/Auto Stop Off
Group 4	ASR On/Auto Stop On

ASR Off: 'Auto stop only' (the file stops when it encounters resistance and rotates in the opposite direction with pedal movements).
ASR On: 'Auto stop reverse' (the file automatically stops and reverses when it encounters resistance).
Auto Stop Off: The file continues to rotate when it reaches the apex.
Auto Stop On: The file stops automatically when it reaches the apex.

Shaping Procedures

The One Curve #35.04 Ni-Ti system with the VDW Gold Reciproc endomotor (VDW GmbH, Munich, Germany) was used for the root canal preparation of all the samples at the manufacturer's recommended speed and torque settings (300 rpm and 2.5 N.cm). The samples were divided into four groups according to the two different torque control settings and two different auto-stop functions (Table 1). When the device was in rotation mode, the 'Automatic Stop Reverse' (ASR) mode was adjusted by pressing the ASR button. During preparation in ASR-on mode, the micromotor automatically rotated counterclockwise upon reaching the pre-set torque value, as specified by the manufacturer's instructions. Once the file no longer encountered resistance, the micromotor resumed clockwise rotation automatically. In ASR-off mode, the micromotor rotated counterclockwise without torque control. When the file encountered resistance, the micromotor stopped automatically and resumed counterclockwise rotation when the foot pedal was pressed again. When the auto-stop on mode was active, the file automatically stopped upon reaching the apical termination point. However, in auto-stop off mode, the file did not stop at the apical termination point, and the working length was controlled manually by the clinician. The same clinician performed all the preparation procedures. After every three pecking motions, the file was removed and cleaned. The root canals were irrigated with 2 mL of distilled water using a 30-gauge endodontic irrigation needle (EndoEze, Ultradent, UT), and recapitulation was performed using a #15 K-file. This sequence was repeated until the WL was attained. To ensure a similar number of apical pecking motions for each file across all specimens, the WL was advanced in three increments: coronal third, middle third, and apical third. The total volume of the saline solution used for cleaning and shaping was standardised to 10 mL per sample. Once the ASR mode was deactivated, the file encountered resistance in the root canal and stopped rotating. Once the foot pedal was reactivated, the file first rotated in the reverse direction and then in the forward direction to resume canal preparation.

Conversely, when the ASR mode was activated, the file automatically reversed its rotation upon encountering resistance without foot pedal reactivation. Once the resistance ceased, the file automatically resumed its forward rotation. When the auto-stop mode was deactivated, a predetermined WL was marked on the file using a digital caliper and a tight stopper. Upon reaching the reference point on the tooth, the file continued to rotate and was manually removed from the root canal under operator control. When the auto-stop mode was activated, the file automatically stopped rotating upon reaching the apex, and using foot pedal activation, the file was removed from the root canal. Following root canal preparation, we removed the samples from the model and rinsed the root surfaces with 5 mL of distilled water. To evaporate the water and measure the dry debris weight, we placed the Eppendorf tubes in an incubator at 70 °C for 5 days. For each sample in all the experimental groups, we took three consecutive measurements and calculated their average. By subtracting the weight of the empty Eppendorf tubes from the weight of the tubes with debris, we determined the weight of the apically extruded debris.

Statistical analysis

We used the SPSS software (SPSS Inc, Chicago, IL, USA) to conduct statistical analyses and the Kolmogorov–Smirnov test to assess data normality. We analysed the data using the Kruskal-Wallis one-way analysis of variance and the Mann-Whitney U test. A p-value of less than 0.05 was considered statistically significant for all comparisons.

Results

The preoperative data analysis conducted using the Kolmogorov-Smirnov test confirmed the normal distribution of specimen morphology and group comparability ($p>0.05$).We observed debris extrusion in all groups. Table 2 presents the mean, standard deviation, minimum, and maximum values of the debris amounts (mg).

When comparing the auto-stop modes ('Auto-stop on'/'Auto-stop off'), significantly lower amounts of debris extrusion were observed in the 'Auto-stop on' groups (0.0002642 mg and 0.0002350 mg in group 2 and group 4, respectively; $p<0.05$). In 'ASR-off' mode, there was a statistically significant difference between the 'Auto-stop on' mode (group 2) and the 'Auto-stop off ' mode (group 1), with less debris extrusion observed in the 'Auto-stop on' (group 2) mode ($p<0.05$). Similarly, in 'ASR-on' mode, a statistically significant difference was noted between the 'Auto-stop on' mode (group 4) and the 'Auto-stop off' mode (group 3), with less debris extrusion observed in the 'Auto-stop on'(group 4) mode ($p<0.05$).

However, no statistically significant differences were found between ASR modes ('ASR on'/'ASR off') within the 'Auto-stop on' mode (groups 2 and 4) ($p>0.05$). Similarly, in the 'Auto-stop off' mode, there were no statistically significant differences between ASR modes ('ASR on'/'ASR off') (groups 1 and 3) ($p>0.05$). The lowest amount of debris extrusion was observed in the 'ASR on'/'Auto-stop on' group (group 4), while the highest was observed in the 'ASR off'/'Auto-stop off' group (group 1) ($p<0.05$).

Discussion

We investigated the influence of different torque control settings and auto-stop functions on apical debris extrusion using the One Curve single file system. While the

Table 2
Mean and standard deviation of apically extruded debris by group

Groups	n	Mean (mg)	Standard Deviation	Minimum	Maximum
Group 1	12	0,0004233[a]	±0,00011268	0,00023	0,00059
Group 2	12	0,0002642[b]	±0,00005534	0,00016	0,00036
Group 3	12	0,0003933[a]	0,00009538	0,00027	0,00055
Group 4	12	0,0002350[b]	0,00006375	0,00014	0,00038

**Different alphabetical letters indicate a significant difference for groups (p<0.05).*

automatic reverse mode did not significantly affect debris extrusion, the apex locator modes affected it. The null hypothesis was thus partially accepted.

The One Curve file system features three cutting angles at the tip and two cutting angles near the shaft, facilitating debris removal and reducing apical extrusion (18, 19). While numerous studies have compared this file system to other Ni-Ti file systems in terms of apical extrusion (13, 18, 20), only one study has investigated its use with different kinematics (16). In addition, a study that examined the effects of Ni-Ti instrument kinematics on the accuracy of root canal WL measurements performed using an integrated endodontic motor reported more accurate results when the WL was measured using rotary kinematics (21). We also preferred the rotary system in this study and used the same file system in all the groups to standardise them and exclude other variables that could affect our findings.

Apical foramen size is one of the factors affecting debris extrusion. Tınaz et al. (6) observed that debris extrusion increased with an increase in apical foramen size. To standardise our samples and minimise the effect of apical foramen width on our results, we examined the apical foramen size using a dental operating microscope with a #10 K-file during tooth selection. We achieved apical patency with a #15 K-file during root canal preparation. Following previous research, a #35.04 file, three sizes greater than the initial file, was thus chosen as the master apical file. The quantity of debris extruded into periapical tissues can vary based on the file system design and preparation techniques. Numerous studies have investigated the impact of rotary and reciprocation movements on apical debris extrusion (14, 22-25). However, a consensus on the superiority of either system remains elusive, with conflicting reports of increased debris extrusion associated with both. Importantly, only one study has independently evaluated the influence of apical movement on debris extrusion, disentangled from preparation kinematics, across the different apex locator modes of integrated endodontic motors (26). The versatility of integrated endodontic motors with customisable apex locator modes enables files to execute diverse kinematics upon reaching their predetermined root canal levels. These modes, which clinicians can adjust according to their preferences, include the cessation of file movement with reverse rotation or automatic reversal upon encountering resistance and automatic stop or continued rotation upon reaching the apex (12).

We found a significant reduction in debris extrusion when using the ‘Auto stop on’ mode. Kılıç et al. (26) examined how apical debris extrusion is affected by the use of different apical movements (apical stop, apical reverse, continuous rotation, and slow-down rotation) during root canal preparation with an integrated endodontic motor. The apical stop mode, the authors found, reduced debris extrusion, which they attributed to the lack of an integrated mode support for continuous rotation preparation in the automatic stop mode, which relies solely on rubber stoppers to determine the WL. This increases the risk of overpreparation and subsequent apical debris extrusion. Conversely, the automatic stop mode was found to offer an integrated mode support for apical control, thereby enhancing operator control. These findings are consistent with our findings.

We also found that using ASR modes (ASR on and ASR off) did not significantly influence debris extrusion. ASR modes provide valuable feedback to clinicians, particularly the 'ASR on' mode: the file is automatically reversed when encountering resistance, thus preventing excessive force. When ASR is activated, the micromotor automatically reverses its direction upon reaching a preset torque value and returns to its original direction when resistance ceases. In the 'ASR off' mode, the micromotor rotates counterclockwise without torque control, stopping when resistance is encountered. Upon reactivation by the clinician, it resumes its counterclockwise rotation and reverses its direction when resistance ceases (12). This automated or clinician-controlled reverse motion helps prevent file fracture. Though concerns have been raised regarding increased debris extrusion due to dentin shedding during file reversal, our results, consistent with those of previous studies (26), suggest that reverse motion does not significantly impact debris extrusion.

We used the experimental setup developed by Myers and Montgomery to collect the debris extruded from the apical region (17). However, a limitation of this method is its inability to simulate the physical backpressure at the root apex. Two solutions have been proposed to solve this: either use an artificial material to simulate the periapical tissues or conduct the study on cadavers or patients. When floral foam was used to simulate the periapical tissues, it was found to absorb the irrigant and debris, thus altering the results (14). Moreover, the studies conducted on patients have suggested that debris extrusion can be determined by adding a contrast agent to the irrigant or by measuring the concentration of inflammatory markers in the periapical fluid. However, the contrast agent may induce allergic reactions in some patients, and periapical radiographs alone may be insufficient for assessing bone quality and quantity (27). Additionally, cone-beam computed tomography exposes patients to unnecessary radiation (28). In light of all this, we chose Myers and Montgomery's experimental setup, which deemed the most practical and reproducible option for such measurements and allowed us to compare them with that of other studies (29).

The most commonly reported symptom that immediately follows root canal treatment is postoperative pain, often described as an uncomfortable sensation associated with an inflammatory response in the periapical tissues. Factors including age, gender, pre-treatment pulp status, tooth type, microbial load, and operative factors (such as chemical and mechanical instrumentation) influence postoperative pain (30, 31). Among these factors, chemical and mechanical instrumentation fall under the clinicians' control and can be manipulated to minimise postoperative pain. During the instrumentation and irrigation of root canals, the transport of infected dentin debris, pulp tissue, microorganisms, and irrigation solutions to the periapical region can generate postoperative complications such as pain and swelling (31). In addition to the instrumentation techniques used to prevent the apical extrusion of infected materials, accurately determining the WL and maintaining the apical construction are of paramount importance (32).

Based on our findings, we hypothesise that using the auto-stop mode of an integrated endodontic motor could reduce postoperative pain.

Another limitation of our study is that we did not use sodium hypochlorite. Though, owing to its organic tissue-dissolving and disinfecting properties, sodium hypochlorite is the gold standard irrigant in endodontic procedures, it might influence the weight of the extruded debris and generate sodium hypochlorite crystals, thereby compromising the accuracy of the findings. We thus chose distilled water as the irrigant solution (33). Despite the limitations of our study, we observed debris extrusion in all groups, although the automatic stopping of the file at the apex in the 'auto-stop on' mode significantly reduced debris extrusion. Debris extrusion is of great importance in terms of postoperative pain and healing, but, as in the in-vitro extrusion studies, our study does not fully reflect clinical conditions, as factors such as periodontal tissue pressure and host defence were absent (33). Extrapolating our findings to clinical practice should thus be cautiously approached. Using different endodontic motors, files with varying kinematics, or different tooth groups can produce a range of outcomes. Future clinical studies should focus on the effect of integrated endo-motors with different torque and apical mode settings on the acute flare-ups and postoperative pain associated with apical debris extrusion.

Conclusion

Variations in the auto-stop functions of integrated endodontic motors have been shown to influence debris extrusion. Our findings, however, indicate that alterations in automatic reverse mode not significantly impact debris extrusion. Clinicians may mitigate debris extrusion by utilising the auto-stop mode during root canal preparation.

Clinical Relevance

Debris extrusion in endodontic treatment significantly impacts the prognosis of the treatment and post-operative pain. The use of integrated endo-motors, which are widely used today, in different settings has shown different results in terms of debris extrusion. The auto-stop mode significantly reduced debris extrusion. In clinical practice, the use of the auto-stop mode may be effective in reducing post-operative pain.

Conflict of Interest

All authors declare that they have no conflicts of interest related to this study.

Acknowledgments

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Ethical approval

Ethical approval was obtained from the research ethics committee of Kutahya Health Sciences University (No: 2023/14-24).

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