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Assessing Dentinal Microcracks in Molar Root Canals Following Preparation with OneShape, 2Shape, and OneCurve Rotary Files: An In Vitro Micro-CT Study

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Abstract:

Objective(s): Microcrack formation during endodontic treatment is a major concern because it can compromise the success of the procedure. Although rotary nickel-titanium files have become the standard of care for canal shaping, there is some concern that they may be more likely to cause microcracks than other types of files. This study evaluated the incidence of microcracks in mandibular and maxillary molars after using three different rotary file systems. **Methods:** This in vitro experimental study investigated 51 canals in 30 periodontally compromised mandibular and maxillary molars. Prior to root canal instrumentation, micro-computed tomography (micro-CT) imaging was conducted. The canals were subsequently categorized into three groups (N=17), prepared using the OneShape, 2Shape, and OneCurve rotary file systems; and re-evaluated using micro-CT. Statistical analysis was performed using the Shapiro-Wilk and Levene's tests. Intergroup comparisons were conducted using ANOVA with Tukey's honestly significant difference (HSD) post-hoc tests. Categorical data were analyzed using chi-square tests at $p<0.05$. **Results:** There was a statistically significant difference in the mean number of microcracks after canal preparation among the groups ($p = 0.02$). A statistically significant increase in crack formation was observed in the OneShape group compared to both the OneCurve group ($p < 0.001$) and the 2Shape group ($p < 0.001$).

Conclusion: During canal preparation, rotary files can lead to the development of dentinal microcracks. OneShape rotary files caused a higher incidence of microcracks than the 2Shape and OneCurve files.

Keywords: Root Canal Preparation; Root Canal Therapy; Tooth Fractures

Introduction

Endodontic treatment seeks to prepare the root canal system while preserving its original anatomical form and promoting effective irrigation for comprehensive disinfection. Nevertheless, the instrumentation process inherent in endodontic procedures can inadvertently compromise the structural integrity of the root canal and the tooth itself. This iatrogenic effect may manifest as defects, such as dentinal microcracks or vertical root fractures, which can ultimately culminate in endodontic treatment failure.[1-3]

Rotary nickel-titanium file systems, characterized by their superelastic properties and adjustable torque, speed, and rotational parameters, have facilitated the treatment of challenging root canal anatomies, such as those exhibiting narrow or curved configurations.[4] Nevertheless, microscopic investigations have revealed a link between the utilization of both rotary and reciprocating instrumentation techniques and the incidence of dentinal microcracks.[5] These iatrogenic cracks, typically a consequence of mechanical stresses generated during canal preparation, can propagate into vertical root fractures under the influence of occlusal and physiological forces, frequently leading to tooth extraction.[4-6] Canal curvature is a recognized predisposing factor, as it increases the contact area between the file and the canal wall, thereby elevating the risk of dentinal damage.[7] Research has demonstrated that maxillary molars exhibit an average canal curvature within the range of approximately 20-30 degrees.[8]

Rotary systems employ two distinct techniques for root canal preparation: Multi-file or serial file systems, which utilize a sequence of files, such as Flex Master, ProTaper, Mtwo, and Hero; and single-file systems, including Neoniti, OneCurve, OneShape, F360, and WaveOne, which are gaining popularity because of their simplicity. While some research has challenged the correlation between nickel-titanium files and microcrack development [10, 11], the issue remains contentious. This ongoing debate underscores a gap in our understanding of crack formation during canal preparation with nickel-titanium rotary instruments, particularly concerning the impact on initiating new cracks within curved canals. This study, utilizing micro-computed tomography (micro-CT), aimed to examine microcrack generation in mandibular and maxillary molars subsequent to canal preparation employing OneShape, 2Shape, and OneCurve files. The null hypothesis posited that neither file type nor motion would significantly influence microcrack formation within the root canal system.

Methods

The ethics committee approved the study. (Ethics code: IR.SBMU.DRC.REC.1398.008).

Determination of the sample size was predicated on an effect size calculation derived from a prior micro-CT study that investigated the quantity of microcracks resulting from root canal preparation. A robust effect size of 1.54 was adopted, with a Type I error (alpha) level set at 0.05.[7] This analysis dictated a requirement of at least 10 samples per group.

This study investigated the preparation of curved root canals in extracted human molars. Thirty periodontally compromised mandibular and maxillary molars, deemed clinically hopeless, were selected for inclusion. The inclusion criteria stipulated that the molars exhibited root canal curvatures between 20 and 40 degrees, and a maximum initial apical file size of 10 K-file. Specimens were excluded if they presented with visible cracks, resorption defects, horizontal or vertical root fractures, caries extending below the cemento-enamel junction (CEJ), prior endodontic treatment, or pulp calcification. Buccolingual radiographs were employed to assess canal curvature, radius angle, and additional exclusion criteria. This radiographic projection was chosen to enhance the clinical relevance of the study and facilitate comparisons with future in vivo investigations.

Following extraction, the teeth were immersed in a 5.25% sodium hypochlorite solution (PetroParsan, Iran) for 30 minutes, subsequently being transferred to a physiological saline solution. Fifty-one canals, derived from 30 teeth, were selected for this study. These canals were then divided into three groups of 17, with the distribution across groups stratified by canal curvature angle to ensure equivalent mean curvature angles across all groups. The grouping criterion was the rotary file system employed for root canal preparation:

Group 1 (OneShape, OSNG), consisting of 17 canals located in both the mesial and distal roots of mandibular molars, as well as in the mesiobuccal canals of maxillary molars.

Group 2 (2Shape, Micro-Mega, Besancon, France), involving 17 root canals, originated predominantly from the mesial roots of mandibular molars, as well as the distobuccal canals located in maxillary molars.

Group 3 (OneCurve, Micro-Mega, Besancon, France), comprising 17 canals, distributed evenly across the same tooth types as those used in the other groups.

Prior to any preparatory procedures, the teeth were consistently positioned and secured in groups of 6 to 7 within acrylic blocks. This standardized arrangement facilitated initial micro-CT imaging.

Micro-Computed Tomography Imaging Protocol:

High-resolution micro-CT imaging was performed on a LOTUS-in Vivo system (Behin Negareh Imaging Technologies Development Company, Iran). The acquisition parameters were an isotropic voxel size of 30 µm, an X-ray tube potential of 90 kV, a tube current of 200 µA, and an integration time of 500 ms. Image quality was assessed using a previously established endodontic micro-sieve. Experimental scans were performed across a range of voxel sizes. Subsequent to image acquisition, the specimens were subjected to filtration through a 0.1 mm copper filter.

To replicate the periodontal ligament, a compressed silicone layer was applied to the teeth, with only the apical tips remaining exposed for observation. Working length was determined in each tooth by subtracting 1 mm from the visually determined apical length, as measured with a #10 K-file (Mani, Japan). Subsequent canal preparation was performed utilizing the rotary files in each group.

Group 1 (the OneShape Protocol):

Following access cavity preparation, coronal constrictions were eliminated utilizing an ENDOFLARE file (Micro Mega, Besancon, France) operated at 400 rpm with a 3 N.cm torque setting. Instrumentation proceeded until 3 mm apical to the pulp chamber floor. A #10 K-file (MMC) was employed to establish a glide path. In instances where the #10 K-file failed to achieve full working length, G-files (G1 and G2) were implemented at 400 rpm and 1.2 N.cm torque until working length was attained, subsequently followed by a #15 file. Root canal shaping was executed with the OneShape file, driven at 400 rpm and 2.4 N.cm torque, without apical pressure, until the designated working length was reached. The OneShape file was initially advanced to two-thirds of the canal length, subsequently withdrawn, cleaned of debris, and the canal irrigated with a 5.25% sodium hypochlorite solution. The file was then re-introduced to a point 3 mm short of the apex, and the aforementioned cleaning and irrigation procedures were reiterated. This iterative process was continued until the OneShape file reached the established working length.

Group 2 (the 2Shape Protocol):

Following access cavity preparation, the removal of coronal constrictions was achieved utilizing an ENDOFLARE file operated at 400 rpm and a torque of 3 N.cm until a point 3 mm apical to the pulp chamber floor was reached. A #10 K-file (MMC) was subsequently employed to establish a glide path. This was followed by the use of a One G file, operated at 400 rpm and 2 N.cm torque, advanced to the working length, after which a #15 file was utilized. Root canal shaping was then executed with two 2Shape files, driven at 300 rpm and 2.5 N.cm torque, without apical pressure, until the working length was attained. The initial shaping file possessed a #25 tip and a 4% taper, and it was employed first. This was succeeded by the second shaping file, also with a #25 tip but exhibiting a 6% taper.

Group 3 (the OneCurve Protocol):

Following access cavity preparation, coronal constrictions were eliminated utilizing an ENDOFLARE file operated at 400 rpm and a torque of 3 N.cm until a point 3 millimeters apical to the pulp chamber floor was achieved. A size #10 K-file (MMC) was subsequently employed to establish a glide path. Subsequently, a One G file, operated at 400 rpm and 2 N.cm torque, was advanced to the working length, followed by a size #15 file. Root canal shaping was then executed using the OneCurve file, driven at 300 rpm and 2.5 N.cm torque, with minimal apical pressure, until the working length was attained.

Root canal shaping was performed by a skilled endodontist in all experimental groups. A pecking motion of approximately 3 mm was employed using an E-connect motor (Eighteen, China) until the designated working length was achieved. The apical force exerted on the file was comparable to that used when writing with a #B2 pencil.

Files were cleaned with a moistened gauze pad after every 3 mm of insertion. Prior to each use, files were immersed in RcPrep (MD-ChelCream, META BIOMED COLTD, Korea). Irrigation with a 25.5% sodium hypochlorite solution (PetroParsan, Iran) and normal saline was performed between each instrumentation step, using a 30-gauge needle (AVA Luerlock Syringe, Iran). To maintain hydration, the teeth were wrapped in moist gauze and kept at a constant temperature of 37°C. Specimens were mounted in acrylic blocks, with each block holding 6-7 teeth (Figure 1). Post-preparation micro-CT imaging was then performed using the same protocol as the initial imaging (Figure 2).

Micro-CT scans, each consisting of 100 cross-sectional images (1 mm thickness) acquired both pre- and post-procedure, were analyzed using ONDEMAND3D software. A double-blinded protocol was employed for data extraction. Specifically, two independent examiners quantified the number of microcracks within each cross-sectional image. Any discrepancies in counts were resolved through discussion between the examiners. The total number of microcracks per canal, both before and after the procedure, was recorded. The difference between these pre- and post-procedural counts was subsequently subjected to statistical analysis.

Data Analysis:

Descriptive statistics, along with the Shapiro-Wilk and Levene's tests, were employed to analyze the data. To compare group means, a one-way analysis of variance (ANOVA) was conducted, followed by Tukey's honestly significant difference (HSD) post-hoc test to determine specific group differences. Categorical data were analyzed using chi-square tests. All statistical analyses were performed using IBM SPSS 21, with a predetermined alpha level of 5% for statistical significance.

Results

Statistical analysis of canal curvature demonstrated no significant intergroup differences. The mean canal curvature was 27.3 degrees for the OneShape group, 28.2 degrees for the 2Shape group, and 27.8 degrees for the OneCurve group. A one-way ANOVA revealed no statistically significant variation in mean canal curvature among the three groups ($p > 0.05$). This indicated comparable canal curvature across all experimental conditions. The assumptions of normality and homogeneity of variance were met, as confirmed by the Shapiro-Wilk ($p > 0.05$ for all groups) and Levene's tests ($p > 0.05$), respectively (Table 1).

Table 1- Mean and standard deviation of canal curvature in different groups

File Type	Mean Canal Curvature	Standard Deviation	Standard Error
OneShape	27.3	8.71	1.33
2shape	28.2	9.12	1.34
OneCurve	27.8	12.1	1.34

Table 2 presents the mean number of cracks observed in each group prior to canal preparation. Statistical analysis revealed no significant intergroup differences in the pre-preparation crack counts ($p = 0.13$).

Table 2- Mean and standard deviation of the number of cracks in each group before preparation.			
File Type	Mean	Standard Deviation	p-Value
OneShape	73.95	23.67	0.13
2shape	63.60	24.71	
OneCurve	57.67	26.21	

Table 3 displays the mean number of cracks observed in each group following canal preparation. A statistically significant difference in post-preparation crack counts was noted among the groups (p = 0.02). Specifically, the OneShape group exhibited the highest mean number of cracks, while the OneCurve group demonstrated the lowest.

Table 3- Mean and standard deviation of the number of cracks in each group after preparation.			
File Type	Mean	Standard Deviation	p-Value
OneShape	127.60	33.89	0.02
2shape	92.40	40.87	
OneCurve	83.06	40.79	

A comparative analysis of crack incidence before and after canal preparation was conducted across different file types (Table 4). Post-hoc analysis employing Tukey's HSD test demonstrated a statistically significant increase in crack formation in the OneShape group compared to both the OneCurve group (p < 0.001) and the 2Shape group (p < 0.001). Conversely, the difference in crack formation between the OneCurve and 2Shape groups was not statistically significant (p = 0.756) (Table 5).

Table 4- Difference in the number of cracks before and after preparation in each group			
File Type	Mean	Standard Deviation	p-Value
OneShape	53.80	19.19	< 0.05
2shape	28.80	22.55	
OneCurve	24.28	15.77	

Table 5- Post-hoc pairwise comparison (Tukey's HS) of mean difference of cracks before and after preparation			
	OneCurve	2shape	OneShape
OneShape	<0.001	<0.001	
2shape	0.756		<0.001
OneCurve		0.756	<0.001

Discussion

While rotary instrumentation offers benefits like decreased canal transportation and preparation time, it may compromise the biomechanical properties of radicular dentin by potentially inducing microcracks.[12] The impact of instrumentation techniques on microcrack formation remains contentious, largely due to inconsistencies in evaluation methodologies.[13] This study employed micro-CT imaging to evaluate microcrack incidence in mandibular and maxillary molars following canal preparation with OneShape, 2Shape, and OneCurve files. The results demonstrated an increase in dentinal microcracks across all experimental groups post-preparation. Notably, the OneShape rotary file system induced a significantly greater number of microcracks compared to the 2Shape and OneCurve systems. Consequently, the null hypothesis was rejected.

The OneShape system is characterized by a single, size 25 instrument with a 0.06 taper and a non-cutting tip. Its design incorporates three distinct cross-sectional areas along its length: A triangular cutting edge configuration at the apical portion, transitioning to a two-cutting-edge configuration in the middle segment, and finally, an S-shaped cross-section with two cutting edges in the coronal segment.[14, 15] In contrast, the OneCurve system (Micro-Mega, Besancon, France) leverages C-wire technology, controlled memory, and a variable cross-sectional design to enhance centering, particularly within the apical third of the root canal.[16] Consequently, the OneShape file exhibits greater rigidity and reduced flexibility compared to the OneCurve file, rendering it more susceptible to stress concentration and microcrack propagation, particularly in canals with curvature.[17, 18] The 2Shape file system (Micro-Mega, Besancon, France) features a triple helix cross-section, incorporating one secondary and two primary cutting edges, which promotes effective debris removal and improved cutting efficiency. This system mitigates stress on the canal walls and minimizes the microcrack formation through a two-stage tapering approach, utilizing a smaller taper initially and a larger taper for final canal shaping.[19, 20]

In this study, all specimens were prepared using rotary files from a single manufacturer, ensuring a consistent taper across all instruments. This standardization eliminated the potential influence of file taper variation on the experimental outcome. Furthermore, extracted human teeth were employed to maximize the clinical applicability of the findings, as this model is considered superior to resin blocks for assessing post-instrumentation alterations.[21] Critically, the tooth crowns remained intact (i.e., were not sectioned) to more accurately simulate clinical conditions and to preclude any impact of access cavity preparation on the canal shaping procedure.[10]

Various methodologies exist for comparing instrumentation systems across different file types. These include, but are not limited to, plastic models, histological sections, scanning electron microscopy, radiographic comparison, serial sectioning, silicone impressions of instrumented canals, CT, micro-CT, and cone-beam CT (CBCT).[22]

In this study, micro-CT imaging was employed to investigate microcracks in dentin. Micro-CT was selected for its superior precision and clarity compared to other radiographic methods, enabling detailed examination of tooth structures without causing damage.[23, 24]

Prior research has demonstrated a link between root dentinal microcracks and rotary file instrumentation.[3, 23, 25-27] In alignment with the current study, Mariyam et al. [28] investigated the incidence of microcrack formation in root dentin using TruNatomy, Neoendo Flex, ProTaper Gold, and 2Shape rotary files. Their findings indicated that all rotary files tested induced dentinal microcracks, with TruNatomy and 2Shape exhibiting comparatively favorable outcomes in terms of microcrack formation.

Priya et al. [20] compared the incidence of microcracks in root canals prepared with OneShape (a single-file system), ProTaper (a multi-file system), and hand instruments. Their results demonstrated a higher prevalence of microcracks in the OneShape group compared to the ProTaper group. This observation is consistent with the findings of Liu et al.[29], who also reported a greater incidence of microcrack formation with the OneShape file compared to both the self-adjusting file and the Reciproc file.

Frater et al. [30] determined that the use of fourteen different rotary instrumentation systems resulted in dentinal microcracks. However, their analysis revealed no statistically significant differences in microcrack formation among the systems evaluated, a finding that encompassed both the 2Shape and OneCurve systems. This contrasts with the present study's findings, a discrepancy potentially attributable to methodological variations. Specifically, Frater et al. employed a technique involving tooth sectioning followed by stereomicroscopic examination for microcrack assessment. It is recognized that the sectioning process itself can introduce iatrogenic cracks, potentially confounding the accurate evaluation of pre-existing microcracks and thus influencing the observed results.[10] In their study, Capar et al. [31] investigated the incidence of dentinal microcracks associated with six different endodontic file systems: OneShape, ProTaper Universal, Twisted File Adaptive, ProTaper Next, Reciproc, and WaveOne. Utilizing CBCT for microcrack assessment, the authors reported no statistically significant differences in microcrack formation. However, the study's use of CBCT, with its inherent limitations in precision and resolution compared to other imaging modalities, may have influenced the observed results and potentially contributed to the discrepancy between these findings and those reported in the present study.

Several other micro-CT investigations support the conclusion that canal preparation with contemporary heat-treated rotary files does not induce new microcracks. Armugam et al. [32]), utilizing a variety of thermomechanically treated, engine-driven files across different kinematics and sequences, determined that these instruments did not generate new microcracks. These findings are consistent with those reported by Bayram et al. [33] and Aksoy et al..[34]

This research suggested a possible link between the specific rotary instrumentation system employed and the incidence of dentinal microcracks in natural teeth. However, the scope of this study was limited by its examination of a restricted set of rotary systems and its exclusive focus on mandibular and maxillary molars. Subsequent investigations should evaluate a wider variety of rotary systems to facilitate a more thorough comparative analysis of their influence on dentinal microcrack formation. Furthermore, the inclusion of other tooth types, such as premolars and incisors, in future research would broaden our comprehension of the effects of rotary instrumentation across diverse tooth morphologies.

Conclusion

This in vitro investigation, while subject to inherent limitations, revealed that the use of rotary files in canal preparation resulted in the formation of dentinal microcracks. Specifically, OneShape rotary files demonstrated a greater propensity to induce such microcracks compared to both the 2Shape and OneCurve file systems. This observed difference may be explained by the comparatively higher hardness and reduced flexibility of the OneShape files. These material properties could render them more susceptible to stress concentration, thereby increasing the likelihood of microcrack development, especially in areas of canal curvature.

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Author Contributions:
K.SH: Conceptualization, Funding Acquisition, Investigation, Writing – Original Draft, Supervision, and H.S: Formal Analysis, Project Administration, and B.Z:

Methodology, Software, Visualization, Supervision, and K.SH: Resources, Data Curation, and A.Z: Writing – Original Draft, Writing – Review & Editing, and M.S: Writing– Original Draft, Writing – Review & Editing.

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Conflict of Interest: The authors report there are no conflicts of interest to declare.

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