Comparison of uninstrumented areas of oval root canals with circumferential filing using different rotary files

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Abstract. Mechanical preparation of an oval root canal is challenging due to the irregular shape, which results in some areas left uninstrumented. This study compared the uninstrumented areas of oval root canals with circumferential filing using two different files. Thirty-two mandibular premolars were dyed with China ink and then cleaned with the Mtwo® or ProTaper Next® file. The uninstrumented areas were analyzed using Adobe Photoshop CS6 and ImageJ software. There were no significant differences between two files, although the uninstrumented areas were smaller with the use of the ProTaper Next® vs. the Mtwo® file (p = 0.231). There were uninstrumented areas of the oval root canal with both the Mtwo® and ProTaper Next® files.

1. Introduction

Root canal treatment is performed to eliminate pulp infection and support the healing of periarticular tissue, which involves three important steps, known as the endodontic triad: access, preparation (cleaning and shaping), and obturation [1]. The objective of root canal treatment, as stated by Walton and Rivera [2], is to remove residual organic material and shape the canal to create a hermetic obturation in all spaces. Therefore, preparation is especially important to achieve successful treatment.

Root canal preparation varies depending on anatomic variation [3]. The root canal system has various shapes, which include oval, curved, branched, and merged. These variations create difficulties in both the preparation and obturation of the root canal. Of these root canal shapes, about 25% of teeth have an oval canal [4]. An oval root canal has a comparatively longer buccolingual diameter of at least two times greater than the mesiodistal dimension. With an oval shape, it is more difficult to clean all of the walls, especially the buccal and lingual sides [5,6], and uninstrumented areas are often left that contain microorganisms and necrotic tissue substrates that result in non-hermetic obturation [7].

There are many techniques to achieve optimal instrumentation results with an oval root canal, such as the use of a tapered file to clean the buccolingual area, although this technique may weaken the mesiodistal walls. Therefore, a circumferential technique has been proposed using small files to clean the oval root canal. With this technique, the file is moved around the oval area and makes contact with all walls without the risk of weakening the mesiodistal wall [4]. Wu et al.[6] stated that instrumentation of an oval root canal using circumferential filing will result in a smaller uninstrumented area, as compared to the balanced force filing technique (42% vs. 61%, respectively).
Endodontic technologies have been developed to achieve optimal results for instrumented cleaning of the root canal. A nickel-titanium material was first used in endodontics in 1988. This material offers some advantages over stainless steel, such as elasticity, flexibility, and better resistance towards torsion fracture [8]. Furthermore, various files have been developed with different designs to optimize instrumentation of the root canal, especially curved and oval canals.

The Mtwo® nickel-titanium file (VDW, Munich, Germany) has an S cross-sectional design and non-cutting tip with a positive rake angle and slightly sloping radial land to effectively cut the dentin, while preserving the anatomy of the root canal [8,9]. Although this file is not appropriate for the early coronal enlargement technique, a circumferential technique can be used to create selective coronal enlargement [10,11]. For oval canal preparation, El-Ayouti et al. found that circumferential filing with rotary nickel-titanium files (Mtwo® and ProTaper®) to clean the root canal was more efficient than with manual nickel-titanium files, although the extent of thinning of the dentin wall was greater due to high tapering of the two rotary files. Also, the instrumentation with a Protaper® file resulted in thinner dentin than with the use of Mtwo® files [12].

Dentsply Maillefer (Ballaigues, Switzerland) released a nickel-titanium file, called the ProTaper Next®, which has an off-center rectangular cross-sectional design that is more efficient for cutting and debris removal than files that rotate from the center. Furthermore, the the ProTaper Next® file is made from M-wire, which has superior flexibility and stress torsional resiliency [13,14].

The ProTaper Next® is the newest file using the basic concept of the ProTaper® file, but with a smaller taper than previous files. Therefore, further studies are needed to evaluate the results and quality of instrumentation of oval root canals by comparison of uninstrumented areas between the Mtwo® and ProTaper Next® files.

2. Methods
The samples used in this research were extracted human mandibular premolars. The samples were X-rayed from the mesiodistal and buccolingual sides. The inclusion criteria were intact whole teeth, 20–23 mm in length, with a single root canal and a buccolingual to mesiodistal diameter ratio of ≥2, which had not received any prior root canal treatment, as well as a perfectly closed apex and no defect on root aspect. Exclusion criteria included root caries, cracks, or fractures, and initial file > #20.

The samples were all cleaned using 2.5% NaOCl and 70% alcohol, then soaked in saline liquid until assayed. The samples were allocated to one of two groups of 16 samples each, instrumentation using the Mtwo® file and instrumentation using the ProTaper Next® file.

Samples were prepared using a round carbide bur (Endo Access Bur, Dentsply) and the cavity walls were smoothed using a safe-ended tapered carbide bur (Endo-Z, Dentsply). Residual pulp tissues were removed using an extirpation needle. The root canals were irrigated with 2.5% NaOCl. Working length measurements were performed using a #10 K-file until reaching the apical foramen, then 0.5 mm was subtracted. Initially, all samples were cleaned with a #20 K-file. Chinese ink was then injected into root canal from the orifices using an insulin syringe and 30G irrigation needle until the pulp chamber was filled. The ink was vibrated using a sonic instrument (EndoActivator, Dentsply) for 1 min until no ink remained in the apical foramen, which is considered as better penetration of the root canal.

In the first group, samples were prepared using Mtwo® and X-Smart Plus® endomotor at a speed of 280 rpm and torque of 1.2 Ncm. Instrumentation was performed by inserting the file towards the root canal without touching the wall, then using light pressure, the file touched the canal wall. Circumferential filing movement was performed in the coronal direction without removing the file from the canal more than 1 mm shorter than the working length. Then, the file was slowly moved up and down until the file reached the working length. After the working length was achieved, a #25/.06 Mtwo® file was exchanged with a #25/.06 file and finally a #30/.06 file. At each step, the canal was irrigated with 2 mL of 2.5% NaOCl and then dried with a paper point. Each file was only used for five canals.
In the second group, samples were prepared using the ProTaper Next® file and X-Smart Plus® endomotor at a speed of 300 rpm and torque of 2 Ncm. Instrumentation was performed by inserting an X1 file with circumferential filing movements 1 mm from the working length. Then, the file was moved up and down until reaching the working length. Instrumentation was then continued with an X2 file and ended with an X3 file. At each step, the root canal was irrigated with 2 mL of 2.5% NaOCl and the canal was dried with a paper point. Each file was only used for five canals.

After preparation, all samples were dried for 24 h and then split vertically in the mesiodistal direction using a stainless steel chisel. The root canal length was then measured from the dentinoenamel junction (DEJ) to the apex and divided into three thirds: apical, middle, and coronal. Samples were placed under a stereo microscope and observed under 21x magnification, then documented using a digital camera. The obtained data were saved in a computer. The remaining Chinese ink was measured using Image J software and the Adobe Photoshop CS6 program (Adobe Systems, San Jose, CA, USA) in pixel units. First, the border of the canal was outlined using Adobe Photoshop CS6 with black color, then the black area was analyzed using ImageJ software. Analysis of the residual black Chinese ink was also performed using the ImageJ program. The area of residual Chinese ink was divided by the area of the root canal and then multiplied by 100%. From buccal and lingual aspects, measurements of the apical, middle, and coronal areas of each root canal were obtained. Measurements of all samples were performed by two of the authors.

Differences in the uninstrumented root canal wall areas after instrumentation using the Mtwo® and ProTaper Next® files were analyzed using the unpaired t-test. Normally distributed data were analyzed using the unpaired t-test, while data with an abnormal distribution was analyzed using the Mann–Whitney U test. A probability (p) value of <0.05 was considered statistically significant.

3. Results
Data normality was tested using the Kolmogorov–Smirnov test, which resulted in p = 0.059, confirming that the data were normally distributed. These data were then further analyzed using the unpaired t-test.

|          | n   | Mean ± s.d | p-value |
|----------|-----|------------|---------|
| Mtwo®    | 48  | 21.30296 ± 13.23478 | 0.231   |
| ProTaper Next® | 48  | 17.83669 ± 14.88371 |         |

As shown in Table 1, there were no significant differences in the uninstrumented root canal areas with the use of the Mtwo® vs. ProTaper Next® file (p = 0.231). Therefore, the hypothesis that the uninstrumented oval root canal area using Mtwo® instrumentation was less than that with the ProTaper Next® was rejected.

The uninstrumented areas were also been compared according to the location in the root canal (apical, middle, or coronal). Parametric one-way analysis of variance (ANOVA) was performed to identify differences between the two groups. As shown in Table 2, there were significant differences in uninstrumented areas among the groups (p = 0.016).

The post-hoc Bonferroni test was performed to identify differences among groups. As shown in Table 3, there were no significant differences among the apical groups (p = 0.209), middle groups (p = 1.000), or coronal groups (p = 1.000).
Table 2. Uninstrumented root canal areas with the use of the Mtwo® file vs. the ProTaper Next® file.

| Groups | n | Mean ± s.b                  | p-value |
|--------|---|-----------------------------|---------|
| MA     | 16| 21.31213 ± 13.45364         | 0.016*  |
| MM     | 16| 18.97845 ± 12.84177         |         |
| MC     | 16| 23.61829 ± 13.83616         |         |
| PA     | 16| 11.66073 ± 11.68136         |         |
| PM     | 16| 14.57103 ± 14.77804         |         |
| PC     | 16| 19.56982 ± 14.11699         |         |

*p = <0.05 (one-way ANOVA)

* Notes: MA: Mtwo® Apical   PA: ProTaper Next® Apical
MT: Mtwo® Middle          PT: ProTaper Next® Middle
MK: Mtwo® Coronal         PK: ProTaper Next® Coronal

Table 3. Comparison of uninstrumented root canal areas with the use of the Mtwo® file vs. the ProTaper Next® file.

|                | Mean difference | 95% Confidence interval | p-value |
|----------------|-----------------|-------------------------|---------|
| MA vs. PA      | 9.65139         | −4.68123 − 23.98403     | 0.679   |
| MM vs. PM      | 4.40742         | −9.92521 − 18.74005     | 1.000   |
| MC vs. PC      | −3.66000        | −17.99264 − 10.67262    | 1.000   |

*p < 0.05 (post-hoc Bonferroni test)

* Notes: MA: Mtwo® Apical   PA: ProTaper Next® Apical
MT: Mtwo® Middle          PT: ProTaper Next® Middle
MK: Mtwo® Coronal         PK: ProTaper Next® Coronal

4. Discussion

The root canal was prepared both mechanically and chemically from the infection zone for hermetic sealing [2]. Extensive knowledge of the root canal system is required for mechanical preparation to achieve suitable treatment [3,7]. Preparation is generally more difficult with an oval root canal, as the instrument may be unable to reach the buccolingual area [5,6]. The objective of this study is to compare the uninstrumented areas of oval root canals using two different files with circumferential filing movements. Circumferential filing was performed to reach all of the walls following the root canal anatomy without weakening the mesiodistal structure [4]. Nickel-titanium rotary instruments are conventionally used passively to clean the canal without lateral movements. At present, rotary instruments are used to optimize the efficacy of instrumentation, especially in an oval canal [10]. In this study, circumferential movements were performed three times until the files were able to move loosely.

Various techniques are used to evaluate mechanic preparation of the root canal, including micro computed tomography [15-17], scanning electron microscopy [18], root canal transparency [19], resin polyester root canal [19], and the ink method [20,21]. Micro computed tomography is used to identify the instrumentation results, as it is a non-invasive technique with three-dimension imaging of the root canal that does not damage the canal structures. With this technique, instrumentation is evaluated by measuring the residual mechanically uninstrumented area [17]. However, this method is comparatively
expensive, especially with a large number of samples. Measurement using scanning electron microscopy produces high-resolution images of dentinal tubule areas that are covered by debris and/or smear layers [18]. The disadvantages of this technique include the requirement of special processing of samples before analysis and the relatively high cost. The transparency method requires the use of chemical ingredients with low toxicity, but the demineralization process is dependent on dentin thickness, which is rather time-consuming. Root canal models made from polyester resins have standardized shapes and dimensions of actual canals, but the hardness level differs from that of dentin [22].

In the present study, the ink coloring method described by Silva et al. and Grecca et al. was used to compare the efficiency of the instrumentation techniques by measuring the residual areas covered by ink after mechanical instrumentation [20,21]. There were apparent differences in imaging dimensions between micro computed tomography and the ink coloring method. With the ink coloring method, two-dimensional images are obtained. However, the focus of this research was the buccolingual area, which was imaged clearly at a relatively low cost.

Chinese ink is insoluble in water and is able to flow into dentinal tubules. However, mechanical instrumentation is needed to remove the ink from the dentinal tubules [23]. With this method, Chinese ink was inserted into canals and vibrated using sonic energy (Endoactivator®; Dentsply) for 1 min to allow the ink to penetrate equally. After drying for 48 h, the samples were instrumented and split, then observed under a stereo microscope to assess the amount of residual ink left in the root canal.

The Mtwo® file was chosen in this research, as it has a shape similar to that of the Hedström file, with a positive cutting angle that can effectively eliminate dentin with circumferential filing movements. Malagnino et al. stated that combining passive and circumferential filing movements, the Mtwo® file can achieve better instrumentation results, as compared to the K3™ nickel-titanium file (Kerr Dental, Biberach an der Riss, Germany) [24]. El-Ayouti et al. reported that the instrumentation of an oval canal using circumferential filing with Mtwo® and ProTaper® files was more efficient than with the use of a manual nickel-titanium file, assuming it is tapered similar to that of a non-rotary endodontic instrument [12]. The ProTaper Next® file, as the latest generation of the ProTaper® file, has a different cross-sectional design and composed of different material with smaller tapered edges (0.04, 0.06, and 0.07) as compared to the ProTaper® (0.07, 0.08, 0.09) [25].

As shown in Table 1, as a whole, there were no significant differences in the uninstrumented areas between the Mtwo® and ProTaper Next® files ($p = 0.231$). Based on the uninstrumented areas, neither of the instrumentation techniques were able to shape the whole oval canal. This result was in accordance with the findings of previous studies comparing various techniques, files, and movements in oval root canal instrumentation [12,18,19,20,26,27]. Therefore, to optimize the result of root canal instrumentation, active irrigation with sonic vibration or the use of a negative pressure system is required. Furthermore, intracanal medication can be administered between visits [28].

In this study, the uninstrumented areas using the Mtwo® and ProTaper Next® files were compared in specific areas (apical, middle, and coronal). As shown in Table 2, there were no significant differences in the root canal locations. In regard to the mean values of the apical and middle areas, the uninstrumented root canal area was smaller with the use of the the ProTaper Next® file than with the Mtwo® file, but not in the coronal third, where the uninstrumented area was smaller with the use of the Mtwo® file. This result could be explained by the greater flexibility of the ProTaper Next® file to follow the root canal anatomy. The flexibility of the ProTaper Next® file is derived from the novel nickel-titanium alloy of M-wire, which was introduced by Dentsply in 2007 [29,30] A thermo-mechanical process was performed to create a more optimal transition point of martensite and austenite phases. Therefore, M-wire is more flexible and resistant to cyclic fatigue [31,32]. Mtwo® is made from a nickel-titanium alloy with a design of an italic S, along with two blade edges and a larger central diameter [31]. This characteristic of the Mtwo® file allows more aggressive cutting, but the material is naturally hard and, therefore, effective for removal of residual Chinese ink from the coronal area.
5. Conclusion
The conclusion of this research was the two types of files, Mtwo® and ProTaper Next®, using circumferential filing, resulted in equal uninstrumented root canal areas. There were no differences in preparation of the apical, middle, and coronal areas with the use of the Mtwo® vs. ProTaper Next® file with circumferential filing movements.

6. References
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