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Change of the oval shaped root canals in mandibular premolar using Ni-Ti Rotary Systems

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Abstract
The purpose of this study was to compare the effects of 3 different rotary Ni-Ti instruments on change of the oval-shaped root canal through measuring of canal circularity and dentin thickness removal by using multislice computed tomography. Thirty extracted single-rooted permanent mandibular premolar teeth with single oval-shaped root canal were selected and randomly divided into three equal group according to the type of Ni-Ti rotary system used for root canal preparation: Alpha, RaCe and ProTaper system. The amount of dentin thickness removal was assessed through comparing pre and post-instrumentation CT scan at different root canal levels (cervical, middle and apical third) by using image analysis software to measuring the distances from canal wall to the external root surface at the mesial, distal, buccal and lingual dentin sides of each root. The results of root canal circularity showed that, the three groups in all levels increase in value toward 1.0, that is mean all canal in the three groups change from oval shape toward circle and become more round shape. The results showed that there was no satisfactory significant difference between the percentages of change of canal circularity with the three preparation system in all thirds except in the middle third where RaCe system showed the highest statistically significantly percentage of change in circularity of root canal. Regarding dentin thickness removal, the results showed that the dentin not removed equally from four sides at each level with all tested group. And also, in most cases the dentin removed from mesial and distal sides more than buccal and lingual sides which lead to change oval shape of canal to more round, this result consistent with result of circulatory in this study.

Key Words: *Oval-shaped Root Canal , Multisilice CT, Dentin Thickness.*

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Successful endodontic treatment depends on major factors, such as the anatomy and morphology of the root canal system, the disinfection of the root canal, and a good sealing. Among these factors, the root canal system is considered the first issue which should be known precisely due to the complexity of its anatomy and morphology. This system varies among populations even in individuals in the same population, the variations in root canal morphology are still a major issue for endodontists (1, 2, 3). The root canals could have various cross-sectional shapes, including round, oval, long oval, ribbon ones C-shaped, conical-pyramidal, eight-shaped, trapezoidal, or drop-shaped (4). In the literature, the authors have defined the canal shapes in the coronal third of the root canal, as round, oval, round oval, ribbon, irregular and C-shaped canals (5,6,7). Metrically, Jou et al (4) defined ‘‘oval’’ as having a maximum diameter of up to 2 times greater than the minimum diameter. A high prevalence of oval and long oval root canals even in the apical root canal portion has been reported (8,9). The root canal changes its shape during its course to apex, and this affects the canal instrumentation. In addition, the variations in the geometry of the cross-sectional root canal shape before forming and cleaning have a great influence on the changes that occur during root canal preparation and depend on the preparation methods. The preparation and treatment of the apical third of the root canal and apical foramen has been the subject of numerous studies (10, 11, 12). This complex anatomy may be regarded as one of the major challenges in infection control through root canal preparation. One aim in the preparation of infected root canals is to remove the inner layer of dentin (13). This aim is particularly hard to achieve when preparing long oval root canals. Furthermore, after preparation, uninstrumented recesses may be left in many oval canals, irrespective of the instrumentation technique, thus leaving debris and unprepared root canal surfaces behind (13, 14, 15, 16,17,18). Various instrumentation techniques have been recommended to facilitate the preparation of oval root canals (18). The most common technique using hand instruments is circumferential filing with K-type or Hedströ¨m files. After the introduction of rotary NiTi instruments, laboratory research on extracted teeth has also addressed their ability to shape oval root canals (17). However, in that study, rotary instruments, even if used in a circumferential filing motion, were not superior compared with hand instrumentation techniques. More recently, the use of rotary instruments with taper larger than 4% was shown to be more efficient than hand files in preparing oval root canals (19). However, the tapered NiTi instruments used in that study were unable to completely prepare oval root canal walls.

During the last few decades, a number of methodologies have been described to evaluate endodontic instrumentation, including plastic models, histologic sections, scanning electron microscopic studies, serial sectioning, radiographic comparisons, and silicone impressions of instrumented canals. All the above methods have been successfully for many years. However, a number of inherent limitations have been identified. Moreover, many previous studies were performed on roots of extracted teeth, which were sectioned before the preparation of the root canals. Then, root cross-sections were assessed before and after preparation, thus representing two-dimensional analyses. In contrast, the technique of Multislice Computed Tomography (MSCT) scanning allows a complete description of three dimensional effects that root canal preparation exerts on root canal anatomy without altering the root during the experiments and become established modalities in endodontic research.

The purpose of this study was to compare the effects of 3 different rotary Ni-Ti instruments on change of the oval-shaped root canal of extracted single-rooted permanent mandibular premolar teeth by measuring the root canal circularity and dentin thickness of pre and post-instrumentation C.T images at three levels of each root by using MSCT and image avalysis soft ware.

II. Material and Methods

Specimen Preparation

Thirty extracted single-rooted permanent mandibular premolar teeth were used in the study. Only teeth with one single oval-shaped root canal were selected with mature root apices. The selected teeth were scaled to remove any calculus deposits and washed under running water and immersed in 5.25% sodium hypochlorite for 30 minutes to remove any soft tissue or organic debris on the root surface. The teeth were stored in 0.9% normal saline solution. The crowns were sectioned at 15 mm from the apex, perpendicular to long axis of the tooth, using a tapered fissure bur rotating at high speed with water coolant. A size 10 K-file was placed into each canal until its tip was just visible at the apical foramen. The working lengths were established to be 1mm from the apical foramen. The teeth were mounted into the mold with acrylic resin to provide a fixed position for correlation pre and post radiographic images. Teeth were divided into 3 equal groups (n= 10 each) according to the instrument used to prepare root canals. Group I used Alpha system (Komet, Lemgo, Germany).In group II, canal preparation was carried out by RaCe system (FKG Dentaire, La Chaux-de-Fonds, Switzerland.).While in group III, ProTaper system (Dentsply Maillefer, Ballaigues, Switzerland) were used for preparation. Root canal preparation with NiTi rotary systems was carried out in strict accordance with manufacturer's recommendations. Electric motor with torque control (X-SMART; Dentsply) was used with NiTi systems. Each instrument was coated with RC Prep (Premier Products, Plymouth Meeting, and PA) as lubricant. Irrigation was performed with 10 mL 2.5% NaOCl after each file. Canal patency was performed with no. 10 K-file for each canal. In each of the three groups, each five canals were prepared by one set of the file system tested.

Image Analysis

The single roots were scanned both before and after instrumentation by using multidetector CT (Somatom Definition 128 CT Scanner; Siemens, LTD, Berlin, Germany). The teeth were aligned with the buccal surface in the anteroposterior position , with each tooth being scanned at 1.0- µm intervals for a total of approximately 433 cross-section CT views per tooth, with the following protocol parameters: effective milliampere: 90 without care dose 4D; kilovolt: 120 with the total scan time 29.66 seconds, slice thickness 1.5mm, collimation 64 + o.6 without gantry tilt 0 and 6.6 mm Feed/Rotation. The acquired images were reconstructed with sharp kernel (H60s). For the purposes of this study, a total of three horizontal cut-planes for each root were reconstructed from the voxel model to obtain three images at cervical, middle and apical third of each root. The first cutplanes were at cervical level. Second (middle) and third (apical) sections were recorded, dividing the distance between first cut to apex into three equal lengths 5mm for each third. The pre- and postoperative cutplanes were programmed to be in identical positions through the voxel model.

Measurement of root canal circularity

The root canal circularity of pre and post-instrumentation C.T images at three levels (cervical, middle and apical) of each root were measured by using Image J 1.29 software to evaluate effects of instrumentation with three Ni-Ti rotary systems on the oval shaped root canal, in which a circularity value of 1.0 indicates a perfect circle. As the value approaches 0.0, it indicates an increasingly elongated polygon (20).

Measurement of Dentin Thickness

The distances from canal wall to the external root surface at these three cut-planes (cervical, middle and apical section) were measured at the mesial, distal, buccal and lingual dentin sides of each root by image analysis software (Syngo CT SoftwareVB20; Siemens). In addition, the average thickness of the three cut-planes was calculated for each side separately; the cut-planes were viewed with fixed window width and window center to standardize the measurements.

Statistical Analysis

Data were presented as mean and standard deviation values. One-way analysis of variance (ANOVA) was used for comparison between means. The Tukey post hoc test was used for pairwise comparison between the means when ANOVA test was significant. The significance level was set at $p \leq 0.05$.

III. Results

Changes of root canal circularity

In the cervical third

The highest percentage of change was recorded with RaCe System 6.91 ± 4.21 followed by Alpha System 6.37 ± 5.83 and then ProTaper System 5.65 ± 4.29. Statistical analysis of ANOVA and Tukey's tests for comparison between the three groups showed that, there was no statistically significant difference between percentage of changes for circularity of root canal (Table 1), (Fig 1).

In the middle third

RaCe system showed the highest statistically significantly percentage of change for circularity of root canal 14.79 ± 15.96. There was no statistically significant difference between Alpha system 7.01 ± 4.73 and ProTaper system 5.31 ± 3.22 which showed the lowest statistically significantly mean percentages in circularity of root canal of the three groups (Table 1), (Fig 1, 2).

In the apical third

There was no statistically significant difference between percentage of changes for circularity of root canal of Alpha System 3.80 ± 3.65, RaCe System 7.04 ± 3.29 and ProTaper System 3.95 ± 4.21 (Table 1), (Fig 1)

TABLE 1. Mean percentage of changes for circularity of root canal of the three groups.

Group / Third	I (Alpha system)		II (RaCe system)		III (Pro Taper system)		*P*-value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Cervical	6.37	5.83	6.91	4.21	5.65	4.29	**0.844**
Middle	7.01 [b]	4.73	14.79 [a]	15.96	5.31 [b]	3.22	**0.048***
Apical	3.80	3.65	7.04	3.29	3.95	4.21	**0.110**

[a,b,c]Means with different letters are statistically significantly different according to Tukey's test.
*Significant at $P \leq 0.05$.

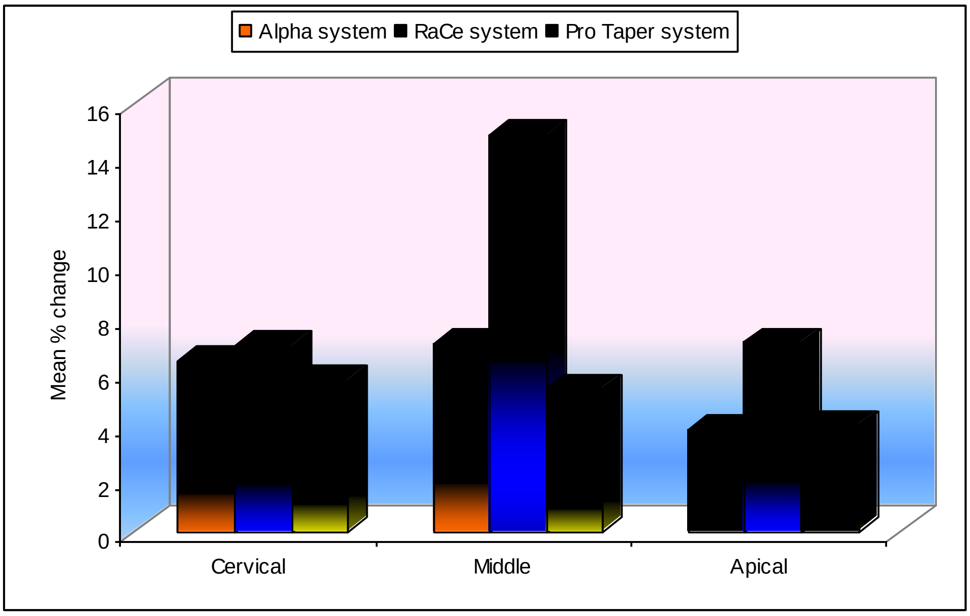
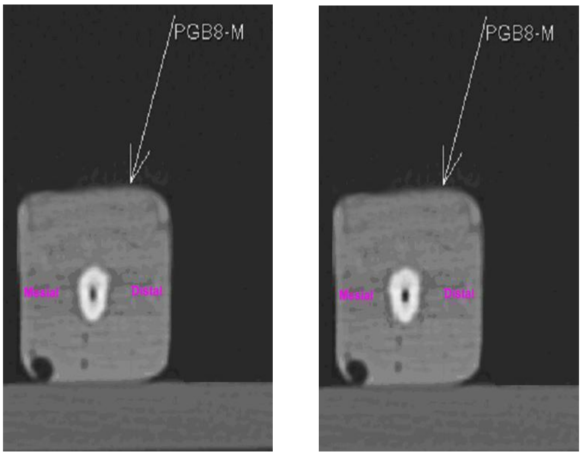


Fig. (1): Showing percentage of changes for circularity of root canal of the three groups.



(A) **(B)**

Fig. (2): C.T image of Group II (RaCe System).at middle level showed change of root canal circularity. **(A)** Pre-operative and **(B)** Post-operative

Dentin Thickness

Group I (Alpha System)

In the cervical and apical thirds, there was no statistically significant difference between percentage of dentin thickness removal of the mesial (10.47 ± 3.61), (12.10 ± 4.27) and distal sides (10.08 ± 6), (16.65 ± 8.36) which showed the highest statistically significantly values. There was no statistically significant difference between percentage of dentin thickness removal of the buccal (6.32 ± 3.62), (9.85 ± 3.78) and lingual sides (4.62 ± 2.24), (5.48 ± 5.13) which showed the lowest statistically significantly values. (Table 2)

In the middle third, there was no statistically significant between the four sides. The highest removal was found at the distal (12.40 ± 7.29) side followed by mesial (10.66 ± 4.27), buccal (8.66 ± 4.5) then lingual sides (6.47 ± 4.90). (Table 2)

Group II (RaCe System)

In the cervical and middle thirds, there was no statistically significant difference between percentage of dentin thickness removal of the mesial (11.28 ± 5.32), (12.14 ± 6.05) and distal sides (10.35 ± 3.22), (10.70 ± 5.20) which showed the highest statistically significantly values. There was no statistically significant difference between percentage of dentin thickness removal of the buccal (5.79 ± 3.79), (7.54 ± 2.56) and lingual sides (6.58± 2.81), (6.93 ± 3.97) which showed the lowest statistically significantly values. (Table 2)

In the apical third, there was no statistically significant between the four sides. The highest removal was found at the distal side (11.65 ± 7.85) followed by mesial (8.78 ± 4.72), buccal (7.60 ± 4.67) then lingual sides (7.22 ± 4.51). (Table 2)

Group III (ProTaper System)

In the cervical and middle thirds, there was no statistically significant difference between percentage of dentin thickness removal of the mesial (10.9 ± 4.4), (9.23 ± 2.6) and distal sides (9.75 ± 4.04), (11.80 ± 5.55) which showed the highest statistically significantly values. There was no statistically significant difference between percentage of dentin thickness removal of the buccal (4.92 ± 3.68), (5.72 ± 3.54) and lingual sides (5.08 ± 3.74), (6.26 ± 3.89) which showed the lowest statistically significantly values. (Table 2)

In the apical third, the mesial side (12.39 ± 7.3) showed the highest statistically significantly value. There was no statistically significant difference between percentage of dentin thickness removal of the distal (9.62 ± 4.23), buccal (6.92 ± 4.43) and lingual sides (6.31 ± 3.5) which showed the lowest statistically significantly values. (Table 2)

TABLE 2**.** Mean percentage changes in mesial, distal, buccal and lingual dentin thickness of three groups at different levels.

Group	Side / Third	Mesial		Distal		Buccal		Lingual		*P*-value
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
I (Alpha system)	Cervical	10.47 [a]	3.61	10.08 [a]	6	6.32 [b]	3.62	4.62 [b]	2.24	**0.006***
	Middle	10.66	4.27	12.40	7.29	8.66	4.5	6.47	4.90	**0.098**
	Apical	12.10 [a]	4.37	16.65 [a]	8.36	9.85 [b]	3.78	5.48 [b]	5.13	**0.001***
II (RaCe system)	Cervical	11.28 [a]	5.32	10.35 [a]	3.22	5.79 [b]	3.79	6.58 [b]	2.81	**0.006***
	Middle	12.14 [a]	6.05	10.70 [a]	5.20	7.54 [b]	2.56	6.93 [b]	3.97	**0.048***
	Apical	8.78	4.72	11.65	7.85	7.60	4.67	7.22	4.51	**0.298**
III (ProTaper system)	Cervical	10.9 [a]	4.4	9.75 [a]	4.04	4.92 [b]	3.68	5.08 [b]	3.74	**0.002***
	Middle	9.23 [a]	2.6	11.80 [a]	5.55	5.72 [b]	3.54	6.26 [b]	3.89	**0.006***
	Apical	12.39 [a]	7.3	9.62 [b]	4.23	6.92 [b]	4.43	6.31 [b]	3.5	**0.043***

*** Significant at P ≤ 0.05, Means with different letters are statistically significantly different according to Tukey's test.**

IV. Discussion

Oval-shaped canals represent a great challenge for proper cleaning, shaping, and disinfection. Because in most current preparation techniques hand or engine-driven instruments are usually worked with reaming motion, the final preparation is usually round in cross-section and leaves uninstrumented recesses in oval, long oval, and flattened canals. These recesses have the potential to harbor persistent bacteria that may jeopardize the treatment outcome.

The present study was carried out in an attempt to assessment of the effects of instrumentation with three Ni-Ti rotary systems on the oval shaped root canal at 3 levels (cervical, middle and apical) of the roots, as one of the most important requirements of root canal preparation is the complete include the original canal and shape the dentin walls and consequently the root canal to the desired configuration without weakening of canal walls.

Extracted human single-rooted permanent mandibular premolar teeth. Only teeth with one single oval-shaped root canal were used. Single, oval root canal morphology was confirmed by means of radiographs made in a bucco-lingual and mesio-distal direction. Canals were determined oval-shaped if the bucco-lingual to mesio-distal dimensions had a ratio of at least 1.3- 1 as reported by Zmener et al. (21). The crowns were sectioned to 16 mm from the apex; consequently working length for root canals was 15 mm. In this manner, access was removed as a variable in this study and differences in root length were controlled (22).

One of the latest innovations in the industrial and medical field is the use of Multislice Computed Tomography (MSCT) for study purposes; this scientific tool could develop a potential in endodontic research as well Mahran and AboEl-Fotouh (23).

In our study, we used MSCT which provided a practical, reproducible and nondestructive technique for assessment of canal morphology before and after shaping according to Gluskin et al (24). Using pre and post-operative CT image to measuring canal circulatory and removal dentin thickness. The root canal circularity of pre and post-instrumentation C.T images at three levels of each root were measured by using Image J 1.29 software to evaluate effects of instrumentation with three Ni-Ti rotary systems on the oval shaped root canal, in which a circularity value of 1.0 indicates a perfect circle. As the value approaches 0.0, it indicates an increasingly elongated polygon (20). MSCT image analysis software (syngo CT softwareVB20) used in this study allowed measuring of dentin thickness of pre- and post-instrumentation at mesial, distal, buccal and lingual sides of root canal at different root level by obtaining images for apical, middle, cervical third of each root without complicating procedures, destructive sectioning of the specimens, or loss of the root material during sectioning. There are also no instrumentation problems passing through sections that could affect the instrumentation outcomes. Also, CT scans allow easy measurement of canal changes, because each image has an accurate scale, decreasing the potential of a radiographic or photographic transfer error Uyanik et al (25). Several author used traditional C.T, 3D Micro-C.T, or MSCT to evaluate the root canal system before and after preparation or for just anatomical studies including (11, 23, 24, 25, 26, 27, 28, 29).

The results of root canal circularity showed that, the three groups in all levels increase in value toward 1.0, that is mean all canal in the three groups change from oval shape toward circle and become more round shape. This result may be due to using rotary or reaming motion which produced round preparation of instrumentation. These findings were in agreed to by some authors(17, 26, 30) which resulted that the rotary instruments produced more round canal.

The results showed that, there was no statistically significant difference between the percentages of change of root canal circularity with the three preparation system at different levels except in middle third where RaCe system showed the highest statistically significantly percentage of change in circularity of root canal. These findings were in agreed to by other authors such as Paque et al. (31) who reported that in the middle region of the root canal ProTaper produced more regular cross-section than RaCe.

Dentin thickness was measuring by CT with digital measuring using image analysis software. In which, the amount of dentin removal mesiall, distally, buccally and lingually was calculated. This was done at three levels; cervical, middle and apical. Our result showed that the dentin not removed equally from four sides at each level with all tested group. This might be attributed to the design of rotary instruments was not suitable for complete preparation of oval root canal walls because of the difference between instrument design and canal geometry (20).

At cervical and apical thirds, Alpha group showed no statistically significant difference between percentage of dentin thickness removal of the mesial and distal sides which showed the highest statistically significantly values. There was no statistically significant difference between percentage of dentin thickness removal of the buccal and lingual sides which showed the lowest statistically significantly values.

At cervical and middle third, RaCe and ProTaper groups showed no statistically significant difference percentage of dentin thickness removal of mesial and distal sides which showed the highest statistically significantly values. There was no statistically significant difference between percentage of dentin thickness removal of the buccal and lingual sides which showed the lowest statistically significantly values.

These results indicated that in most cases the dentin removed from mesial and distal sides more than buccal and lingual sides which leade to change oval shape of canal to more round, this result consistent with result of circulatory in this study.

At apical third, ProTaper group showed the statistically significantly highest value at the mesial side when compared between the four sides. This might be attributed to ProTaper have the multitaper design, progressive different parabolic taper of finishing files, rate of increase in the diameter of the tip is therefore greater than that other rotary files and the result is a thicker instrument especially at apical third of instrument. In this part of study the instrumentation finished with the file F4, whereas the last file used in first part study was F2 for ProTaper system. This was in full agreement with Calberson et al. (32) and Uzun et al. (33) and. Calberson et al. (32) reported that, this result were more occur in wide canals than in narrower ones, who suggested that the ProTaper instruments might be better suited for curved and narrow canals than wide, but only during the initial phase of shaping.

At apical third, RaCe showed no statistically significant between the four sides. This was in full agreement with Paque et al. (31) who showed more regular cross-section produced by RaCe in apical part.

Under the condition of the present study, we concluded that the three rotary Ni-Ti systems had the same effect on changing shape of the root canal from oval shape towards circle at cervical level. The rotary Ni-Ti RaCe system showed highest percentage change of the canal shaped from oval to round shape at middle third.

Conflict of Interest

The authors declares that there is no conflict of interest

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