



A CBCT BASED DIGITAL ANALYSIS OF SHAPING ABILITY OF MAX WIRE® ALLOY FILE IN THE TREATMENT OF LARGE AND CURVED ROOT CANALS

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ABSTRACT

Aim: To evaluate the limits of the shaping ability of MaxWire® alloy file in the treatment of pre-created large and curved root canals with different apical sizes by using cone-beam computed tomography (CBCT).

Materials and methods: Forty-five permanent maxillary first molars with moderately curved palatal roots (20°-30°) were divided into three groups, and large root canals were created with apical diameter #35 (Group 1), #40 (Group 2) or #50 (Group 3) by using BioRace NiTi System. Then, they were reshaped with the MaxWire alloy file, XP-endo Shaper®. Canals were scanned before and after instrumentation by using the CBCT scanner. Canal transportation (CT), centering ratio (CR), % increased prepared area (PA), and % increased prepared outline (PO) at 2, 3, and 4 mm from the apex were calculated. Data were statistically analyzed at $P < 0.05$.

Results: There was a significant difference in the mean increase in PO in all apical sizes and all three levels. At both 3 mm and 4 mm levels the maximum PA and PO were achieved in apical size 35, while at 2 mm level the maximum values were obtained in apical size 40. There was no statistically significant difference in CT and CR within groups at 2 mm distance from the apex.

Conclusion: Max Wire alloy technology of this novel instrument makes it possible to clean and touch the dentin walls of large and curved root canals. Small FOV and small voxel size of CBCT could also be used in shaping ability studies in endodontics.

KEYWORDS: Curved root canals. Cone beam computed tomography. Digital analysis. Large root canals. Max Wire alloy. XP-endo Shaper
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INTRODUCTION

The main aim of root canal treatment is the elimination and prevention of microbial infection.¹ Previous studies have shown that the

size of apical instrumentation is an important factor in removing root canal bacteria effectively. It was claimed that larger instrumentation would cause fewer bacteria to remain and induce healing by improving the efficacy of root

canal irrigation.²⁻⁴ But if the root canal is already large and also curved, achieving this goal is not easy. Dental trauma, internal resorption, pulp necrosis, persistent infection, and incomplete root formation may result in the

formation of large root canals. To completely remove all bacteria from these types of root canals, large instruments with higher taper should be used, which are less flexible and do not stay in the center of the canal. These may cause untouched dentine walls and transportation of the main root canal.⁵

When some specific materials such as nitinol are cooled, a martensitic transformation which is a special crystal structure change occurs. The martensite phase occurs as a result of the martensitic formation, while the austenite phase is the crystal structure present at high temperature. The shape memory effect is the result of the transformation that occurred between these two phases. XP-endo Shaper® (FKG, La Chaux-de-Fonds, Switzerland) is the only instrument on the market which is made with MaxWire alloy technology. Owing to this proprietary alloy, the file transforms from the martensitic phase at room temperature to austenitic phase at body temperature, and so it can adapt to root canal morphology. According to the manufacturer claims, the initial taper of the file is .01 in its martensitic phase but can expand at least .04 taper when exposed to body temperature.⁶

To our knowledge, no study in the literature evaluates the shaping ability of this novel instrument in both curved and large canals. Hence, this study aimed to assess the limits of the shaping ability of the MaxWire® alloy file in the treatment of pre-created large and curved root canals with different apical sizes by using cone-beam computed tomography (CBCT).

MATERIALS AND METHODS

Forty-five freshly extracted maxillary first molars with moderately curved palatal roots (20°-30°) extracted for periodontal reasons were selected. Initial mesio-distal and bucco-lingual periapical radiographs were taken and the curvature angle of the canals was determined according to the method described by Schneider et al.⁷ Teeth with 20°-30° canal curvature, short radii <10mm, closed apices, uncalcified canals were included in the study, while those with calcified canals, root resorption, cracks, existing root canal treatments were excluded from the study. After the access cavity preparations, the patency of the root canals was checked with a size #10 K file. The crown of the teeth was decoronated to determine the working length (WL) easily. The mean WL of the samples was 19-21 mm. The determination of the WL was performed under a surgical microscope by inserting a #10 K file to the root canal terminus and subtracting 0.5 mm from this length. Specimen were coded and divided into three groups.

Initial instrumentation (creating large canals) and initial scanning

For creating large canals, the BioRace Ni-Ti system (BR) (FKG, La Chaux-de-Fonds, Switzerland) was used with a rotational speed of 600 rpm and the torque was adjusted to 1 N.cm. Each instrument was used only once. During the instrumentation, 2 mL of 5.25% NaOCl solution with a 30-G side vented needle was used after each instrument. After instrumentation to the master apical file size, the canals were finally rinsed with 5.25% NaOCl for 1 minute,

followed by 17% EDTA and 5.25% NaOCl again.

Group 1: BioRaCe instruments were used as follows: BR1 (15/.04), BR2 (25/.04), BR3 (25/.06), and BR4 (35/.04) at WL. In this way, approximately 0.35 mm apical diameter was obtained.

Group 2: BioRaCe instruments were used as follows: BR1 (15/.04), BR2 (25/.04), BR3 (25/.06), BR4 (35/.04) and BR5 (40/.04) at WL. In this way, approximately 0.40 mm apical diameter was obtained.

Group 3: BioRaCe instruments were used as follows: BR1 (15/.04), BR2 (25/.04), BR3 (25/.06), BR4 (35/.04), BR5 (40/.04) and BR6 (50/.04) at WL. In this way, approximately 0.50 mm apical diameter was obtained.

After obtaining large canals by the initial instrumentation, teeth were embedded into a custom made silicone box. To acquire a closed system, apical foramen of all each sample was sealed (TOPDAM, FGM, Joinville, SC, Brazil). To place each sample in the same position during scanings, the silicone box attached to a custom holder was used. CBCT scanings (Planmeca, Promax 3D max, Helsinki, Finland) were operated at Endo Mode (96 kvp, 7.1 mA, 0.75 mm³ voxel size, 15s.) with the 5 x 5.7 cm field of view. The scanning data were acquired with the aforementioned parameters

Final instrumentation, final scanning and analysis

The root canals with large apical diameters were prepared with XP-endo Shaper® system (XPS) (FKG, La Chaux-de-Fonds, Switzerland). Manufacturer instructions were strictly followed during the procedures. The instrument was used in two steps; reaching WL and shaping the root canal. XPS was used at

1000 rpm and 1 N. cm torque with in-and-out motions of 3-4 mm amplitude in each time. During all the instrumentation procedures, root canals were irrigated with 5.25% NaOCl. In the first step, the working length was reached with 5 gentle strokes. In the second step, 15 strokes with the instrument were done up to the WL. To trigger the transformation of MaxWire alloy from the martensitic phase to austenitic phase; 1- 37°C cabinet was used, 2- NaOCl was waited in the root canal up to 10 seconds (sec) to equalize the temperature of the root canal and the cabinet during all procedures. Each instrument was used only once. Following the preparations of the root canals, 1 mL 17% EDTA and 3 mL 5.25 % NaOCl were used for final irrigation, respectively.

The same experimental set-up was used for the scanning of the instrumented canals. After the initial and final exposures, the DICOM version of the scanning was transferred to the onDemand 3D Dental software (Cybermed, Seoul, Korea). Pre and post-operative data sets were superimposed via the fusion module of the software (Fig. 1). 2 mm, 3 mm, and 4 mm levels were marked with the scale of the software on the coronal plane and the measurements were performed on selected axial slices. % increased prepared area (mm²) (PA) and % increased prepared outline (mm) (PO) were calculated by using the measurement tool of the software. The formula generated by Gambill et al.⁸ were used for the calculation of canal transportation (CT) [(a₁-a₂) - (b₁-b₂)] and centering ratio (CR)[(a₁-a₂) / (b₁-b₂) or (b₁-b₂) / (a₁-a₂)] (Fig. 2 and Fig. 3).

The shortest distance between the mesial edge of the root and created

large canal is represented by a₁ and distal edge of the same parameters is represented by b₁, the mesial edge of the root and canal instrumented with XPS is represented by a₂, and the distal edge

of the same parameters is represented by b₂ in this formula.

All measurements were taken by an experienced dentomaxillofacial radiologist. Radiographic analysis of the

Figure 1: Axial image of primary data set (created large root canals) (A). Axial image of secondary data set (following the instrumentation of root canals with experimental files) (B). Fused images before using auto-registration mode (C). Fused images after using auto-registration mode (D).

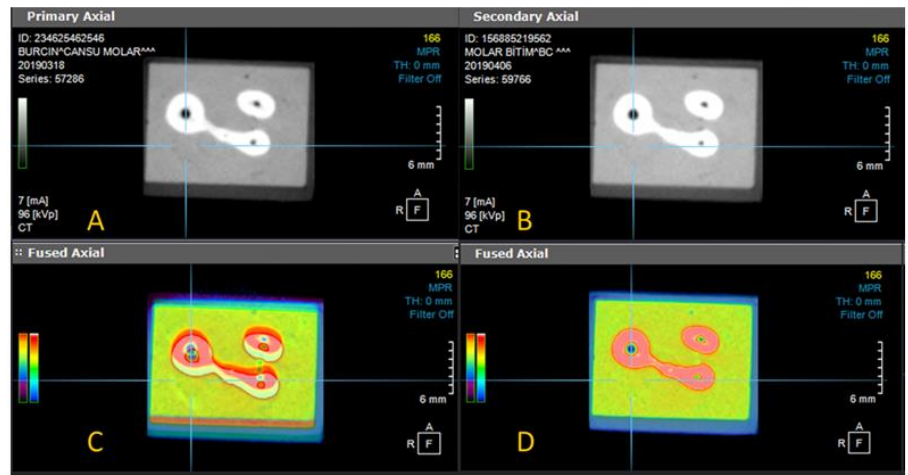


Figure 2: Axial slices of prepared area (mm²) (A) and prepared outline (mm) (B).

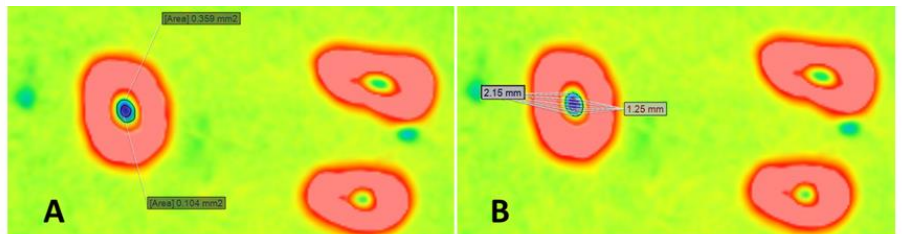
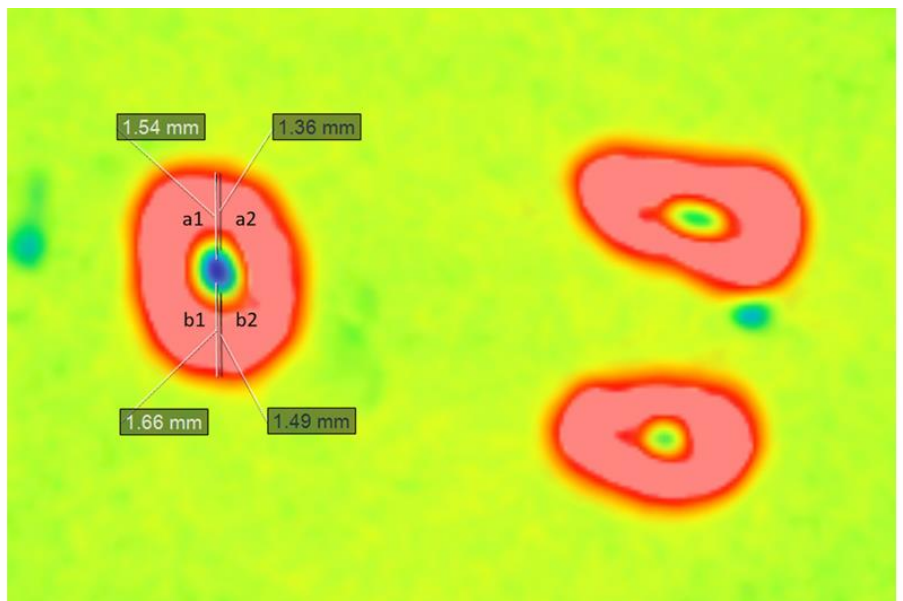


Figure 3: Schematic presentation of the transportation (a₁-a₂) - (b₁-b₂) and centering ability (a₁-a₂) / (b₁-b₂) or (b₁-b₂) / (a₁-a₂)



randomly selected 15 teeth was reexamined in all parameters after three weeks by the same operator. The intra-observer agreement was assessed by the intraclass correlation coefficient (ICC) rate.

Statistical analysis

MiniTab 18 Software was used for all statistical analyses. The gathered data were first tested for normality with the Ryan-Joiner test. Then, the One-Way Anova test was used to compare the groups that showed the normal distribution. Tukey test was applied to analyze the groups that caused the difference. For the groups that did not follow the normal distribution, the Kruskal-Wallis test was used for the comparison analysis. Finally, Dunn’s test was applied to identify the difference between groups. Significance level established at $P < 0.05$.

RESULTS

The ICC consistency was rated at 93% between two analysis of the radiographs. Therefore no significant difference was observed between the evaluations ($P > 0.05$). The mean increase in PA and PO are summarized in Table 1. PA and PO increased in all apical size groups at each experimental level. In this study, in all apical sizes and all three levels (2 mm, 3 mm and 4 mm from the apex), there was a significant difference in the mean increase in PO ($P < 0.05$). At both 3 mm and 4 mm levels the maximum PO and PA were achieved in apical size 35, while at 2 mm level the maximum values were obtained in apical size 40. At 2 mm level from the apex, there was no significant difference

between size 40 and size 50 groups in the mean increase in PO ($P > 0.05$).

Table 2 and Table 3 shows the statistical analysis of CR and CT values at the 3 studied levels for each apical size groups. The difference in transportation amounts and centering ability in 3 apical size groups were statistically significant at all levels except the 2 mm level ($P < 0.05$). Size 35 group had lower CR values at both 3 mm and 4 mm from the apex. There was not any significant difference between size 40 and size 50 groups in CT and CR at 2 mm and 4 mm level ($P > 0.05$). However, size 50 group had statistically better CR and lower mean CT values than size 40 group at 3 mm level ($P < 0.05$).

DISCUSSION

The purpose of this study was to evaluate the shaping ability of XPS in

created large and curved root canals with different sizes of apices. It is an open secret that simulating clinical conditions is almost impossible in *in-vitro* studies. The major problem in the present study was the difficulty of creating large canals with minimum damage to the root canal anatomy. BioRace Ni-Ti instrument system was chosen for the initial shaping of the root canals because of its non-cutting safety tip and alternating cutting edges that avoid self-threading.⁹ By this way, we aimed to protect the original root canal anatomy. When taking into consideration the canal shapes and anatomies, palatal root canals of maxillary molars are large, single, and moderately curved canals in its nature. For this purpose, palatal root canals of extracted human maxillary molars with moderate curvature and short radii were chosen. To prove its canal anatomy, initial bucco-lingual and mesio-distal

Table 1: The mean increase (%) in prepared area and prepared outline at different apical sizes and 3 distance levels from the apex.

Level	% increase	Apical Size 35		Apical Size 40		Apical Size 50		P value
		Mean	SUM (95% CI)	Mean	SUM (95% CI)	Mean	SUM (95% CI)	
2mm	PA	94.96	(85.80; 104.12)	107.76	(102.55; 112.98)	98.30	(94.46; 102.13)	*
	PO	38.17	(34.11; 42.23)	52.03	(47.98; 56.09)	46.08	(42.02; 50.14)	*
3mm	PA	115.62	(110.94; 120.30)	105.80	(101.12; 110.48)	110.12	(105.13; 115.11)	*
	PO	47.61	(44.75; 50.46)	47.38	(44.53; 50.23)	42.08	(39.23; 44.93)	*
4mm	PA	124.97	(119.98; 129.96)	110.12	(105.13; 115.11)	85.58	(80.59; 90.57)	*
	PO	55.63	(52.42; 58.84)	48.21	(45.00; 51.42)	37.43	(34.23; 40.64)	*
P value	PA	*	*	**	**	*	*	
	PO	*	*	**	**	*	*	

PA: Prepared area, PO: Prepared outline, * $p < 0.05$, ** $p > 0.05$, CI: Confidence interval

Table 2: Statistical analysis of canal transportation values for tested apical sizes

Level	2 mm Median (Sum %95 CI)	3 mm Median (Sum %95 CI)	4 mm Median (Sum %95 CI)	P_Value
Size 35#	0.02 (0.01; 0.02)	0.04 (0.03; 0.05)	0.03 (0.03; 0.04)	0,000
Size 40#	0.02 (0.01; 0.03)	0.02 (0.02; 0.0362649)	0.02 (0.01; 0.0262649)	0,121
Size 50#	0.02 (0.01; 0.02)	0.01 (0.01; 0.02)	0.02 (0.01; 0.0262649)	0,597
P_Value	0,685	0,000	0,001	

Table 3: Statistical analysis of centering ratio values for tested apical sizes

Level	2 mm Mean (Sum %95 CI)	3 mm Mean (Sum %95 CI)	4 mm Mean (Sum %95 CI)	P_Value
Size 35#	0.8451 (0.8112; 0.8790)	0.7567 (0.7258; 0.7875)	0.8159 (0.7873; 0.8444)	0,001
Size 40#	0.8107 (0.7767; 0.8446)	0.8220 (0.7912; 0.8528)	0.8853 (0.8568; 0.9139)	0,004
Size 50#	0.8340 (0.8001; 0.8679)	0.8807 (0.8498; 0.9115)	0.8700 (0.8415; 0.8985)	0,079
P_Value	0,344	0,000	0,003	

periapical radiographs were taken and the angle of the curvature was calculated according to the Schneider method.⁷

Both simulated canals and extracted teeth have been widely used in shaping ability studies.¹⁰⁻¹² Resin block has several advantages likewise ease of use; reproducibility of experimental conditions, the standardization of the degree, location and working length of the root canals, apical diameter of the root canal, and radius of the root canal curvature.¹³ However, heat generation caused by the rotation movement of the rotary instruments may soften the resin material.¹⁴ Beside this, low microhardness and large particle size of resin blocks may negatively affect the shaping ability of the experimental files.^{10,15} For this reason, extracted human teeth were preferred to mimic clinic conditions. It was not easy to standardize the teeth which have naturally large root canals. Therefore, a full-sequence rotary NiTi instrument was used to create standard large root canals.

Clinicians are generally struggling with anatomically hard cases. Although large root canals caused by resorption, trauma, or infections sound like easy to handle, irregularities and large diameter of the root canal make it difficult to eliminate all microorganisms from dentin walls. However, there are not enough studies on this topic in the literature. In the present study, shaping ability of XPS in large root canals with different apical diameters was evaluated at 1 mm intervals at the apical third of the root canals. The parameters of “prepared area” and “prepared outline” in axial slices of CBCT images were used for this purpose. In the present study, XPS was found to be able to remove dentin at all experimental levels, even in 50/.04 apical

diameter. From this point of view, it could be said that XPS expands more than .04 taper in the large and curved root canals.

It was reported that the apical canal transportation smaller than 0.3 mm would have a minimum impact on the prognosis of endodontically treated teeth.¹⁶ Poly et al. compared the canal transportation and centering ratio of XPS and WaveOne Gold using micro-CT at apical, middle and coronal thirds of the mandibular molars. According to that study, the mean transportation values of XPS were also smaller than 0.3 mm but larger than the present study's values.¹¹ The possible reason for this result could be the tooth selection and experimental levels that were evaluated. In the present study, only the apical part with 1 mm intervals was assessed. Based on the present study's result, the transportation value of XPS was found less than 0.3 mm at all experimental levels which were in correlation with Reham et al¹² and Poly et al.¹¹ Beside this, according to our knowledge, there is not any study that evaluated the shaping ability of XPS at 2 mm, 3 mm and 4 mm from the apex. Studies have generally focused on examining the apical, middle, and coronal third of the root canals.^{10-12,13,15,17} But it is noteworthy that the apical third which is the most challenging part of the root canal should also be specifically researched in shaping ability studies.

XPS is a novel instrument with its MaxWire alloy and snake shape nature that has been frequently subjected to endodontic researches. Until today several properties of this instrument have been studied such as; cyclic fatigue resistance¹⁸, shaping ability¹¹, retreatment efficiency¹⁹ and

dentinal micro-crack events.²⁰ The common trait of all these researches is unique directions for using this instrument. XPS needs body temperature to expand and adapt root canal morphology.⁶ For this reason, the most crucial step to be considered in XPS studies is to create an experimental environment where the body temperature can be achieved. For this purpose all shaping procedures performed at 37°C inside a cabinet in this study. Also before the instrumentation, NaOCl was kept in the root canal up to 10 sec to equalize the temperature of both root canals and the cabinet. By this way, the proper experimental settings were provided for MaxWire technology. The speed of this instrument was also evaluated in several researches and was tested at 800 rpm to 3000 rpm.^{18, 19, 21} In the present study, we followed the manufacturer's instructions and used the instrument at 1000 rpm. In addition, observing the shaping limits of the instrument in large and curved root canals was our primary goal. In the light of the results of our study, we can say that although XPS is a single file system, it can maintain the shaping efficiency in large and curved root canals by respecting root canal anatomy thanks to its unique alloy. Because of being the only instrument made with MaxWire alloy on the market, it was not possible to compare the efficiency of XPS with any other rotary instruments.

Despite the fact that micro-CT is a new popular tool in experimental endodontics, CBCT still provides better imaging solutions because of reasonable clinical outcomes as a consequence of its use on human subjects. In a study of Domark's conducted in cadaver maxillary molars to understand tooth anatomy in endodontic therapies, it was

shown that there was no significant difference between the voxel sizes of 76 μm at CBCT and 20 μm at micro-CT.²² On the other hand, there is still no certain consensus about the voxel size of CBCT imaging before and after the preparations of root canals in the literature.¹⁷ It's well-known that for obtaining the highest accuracy on analysis and interpretation of the 3D volume on CBCT, both spatial and contrast resolutions should be optimum.²³ Considering technical specifications, the small voxel sizes lead to a higher spatial resolution in CBCT imaging. Further, larger FOV size leads to a poor spatial resolution because the cone-beam angulation becomes greater in the edges of the volume.²⁴ To obtain the most accurate result in the measurements and decrease the limitations of this study, the smallest FOV (5 X 5.7 cm) and the smallest voxel size that is possible with CBCT (75 μm) was selected.

CONCLUSION

The terminology of "large and curved root canals" was used in the literature for the first time with this study. Under the limitations of this study, it was shown that XPS could easily adapt root canal morphology through its unique technology. It can continue its shaping efficiency even in 50/.04 apical diameter and can be said that expand more than .04 taper in large and curved palatal roots of maxillary molars. On the other hand, it was assumed that small FOV and small voxel size of CBCT could be used in shaping ability studies in endodontics. However, further studies conducted with micro-CT or at different speeds are needed to provide more

specific data to confirm all this assumptions.

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CONFLICT OF INTEREST

The authors deny any conflicts of interest related to this study.

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