

THE SHAPING ABILITY OF FIVE DIFFERENT NICKEL-TITANIUM ROTARY INSTRUMENTS IN SIMULATED ROOT CANALS#

SİMÜLE KÖK KANALLARINDA BEŞ FARKLI NİKEL-TİTANYUM DÖNER ALETİN ŞEKİLLENDİRME YETENEĞİ

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ÖZET

Purpose: The aim of this study was to compare the shaping ability of a recently introduced instrument (Revo-S) in comparison with the four current instruments (HeroShaper, Mtwo, ProTaper, RaCe) in simulated root canals.

Material and methods: Nickel-Titanium systems (n=15 resin in each case) were used to prepare 34-35° curved and S-shaped simulated root canals in clear resin blocks. The width of resin removal was measured by comparing the pre- and postoperative images under a stereomicroscope. The amount and direction of transportation, the centering ability and the total amount of resin removal were determined. Canal aberration incidence, preparation time, and instrument deformation were also recorded.

Results: In both canal types, the RaCe group prepared canals more rapidly (P < 0.05) and created no canal aberrations. The ProTaper Universal group was significantly slower than other groups (P < 0.05) for both canal types. The tapered canal form was obtained in the Mtwo, ProTaper Universal; and RaCe groups in 34-35° curved canals; and only the RaCe group in S-shaped canals. Some deformations but no instrument fractures were observed for HeroShaper, Mtwo, and Revo-S groups.

Conclusion: RaCe rotary Nickel-Titanium instruments, probably do to their triangular cross-sectional shape with alternating cutting edges and sequence encompassing a high number of instruments, exhibited a better centrally shaping and fewer canal aberrations.

Keywords: Nickel-Titanium Rotary Instruments, RaCe, Revo-S, S-Shaped Simulated Canal.

ABSTRACT

Amaç: Bu çalışmanın amacı dört adet güncel alet (HeroShaper, Mtwo, ProTaper, RaCe) ile yakın tarihte üretilmiş bir aletin (Revo-S) şekillendirme yeteneklerinin simüle kök kanallarında karşılaştırılmasıdır.

Gereç ve yöntem: Nikel-Titanyum sistemler S şekilli ve 34-35° eğimli şeffaf rezin blokların (her bir grup için n=15 rezin blok) genişletilmesinde kullanıldı. Kaldırılan rezin miktarı bir stereomikroskop altında işlem öncesi ve sonrası görüntüler karşılaştırılarak ölçüldü. Transportasyonun yönü ve miktarı, merkezde kalma yeteneği ve toplamda kaldırılan rezin miktarı tespit edildi. Kanaldan sapma insidansı, preparasyon zamanı ve alet deformasyonu kaydedildi.

Bulgular: RaCe grubu her iki kanal tipinde kanalları daha hızlı bir şekilde (P < 0.05) ve kanalda sapma oluşturmadan genişletti. ProTaper Universal grubu her iki kanal tipi için diğer gruplardan anlamlı şekilde yavaştı (P < 0.05). Gittikçe genişleyen kanal formu 34-35° eğimli kök kanallarında Mtwo, ProTaper Universal ve RaCe gruplarında, S şekilli kanallarda ise sadece RaCe grubunda gözlemlendi. HeroShaper, Mtwo ve Revo-S gruplarında hiç alet kırığı tespit edilmezken bazı eğelerde deformasyon gözlemlendi.

Sonuç: RaCe Nikel-Titanyum döner aletleri muhtemelen değişken kesici kenarlara sahip üçgen kesitleri ve çok sayıda aleti kapsayan eğe serisi nedeniyle daha az kanaldan sapma ve daha merkezi bir şekillendirme ortaya koydu.

Anahtar kelimeler: Nikel-Titanyum döner aletler, RaCe, Revo-S, S-şekilli simüle kanal

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INTRODUCTION

Although perfect root canal treatment related to many factors, biomechanical root canal preparation is one of the most important stages. The aim of biomechanical root canal preparation is to remove microorganisms, canal contents, debris, and to shape a continuously tapered form with the smallest diameter at the apical foramen and the largest at the orifice to allow effective irrigation and filling without changing the initial canal shape.¹ Over the past 20 years, several instrument systems have been introduced to the field of endodontics such as EndoSequence (Savannah, Georgia, Brassler USA), ProFile (Dentsply/Maillefer, Ballagiques, Switzerland) ProTaper Universal (Dentsply/Maillefer), Mtwo (VDW, Munich, Germany), and RaCe (FKG, Dentaire, La Chaux-de-Fonds, Switzerland), Self-Adjusting File (SAF; ReDent-Nova, Ra'anana, Israel) along with several others. Previous studies have found that rotary Nickel –Titanium (Ni-Ti) instruments protected the original canal curvature better than stainless steel hand files.² Ni-Ti instruments' improved flexibility and shape memory permits the shaping of narrow, curved root canals.³ Moreover, root canal preparation is complex and time consuming when relatively non-tapered instruments are used to form "flaring" shapes.⁴ This difficulty is being eased with Ni-Ti rotary instruments.

Previous research on root canal morphology has reported that root canals not only have mesio-distal direction but also bucco-lingual curvature.^{5, 6} The preparation of this type canal is difficult with stainless steel instruments. Similarly Ni-Ti rotary instruments, owing to their shape memory properties and superelastic behavior protected the original canal curvature in extreme curved or S- shaped canals still remains a challenge.^{7, 8}

ProTaper (Dentsply Maillefer) instruments have a non-cutting, modified guiding tip, three cutting edges with a negative cutting angle, a convex triangular cross-sectional design, and a flute design that combines progressive tapers within the shaft.⁹

Reamers with Alternating Cutting Edges (RaCe, FKG) instruments have sharp cutting edges with triangular cross-sectional design, with the exception of the .02 taper size 15 and 20 files, which have a square

cross-section. Moreover, RaCe (FKG) files have noncutting tips and alternating cutting edges. According to the manufacturer, the combination of alternating cutting edges and triangular section with sharp edges ensures efficient evacuation of debris, enhances cutting efficiency, and eliminates screwing.¹⁰ In addition, the surfaces of RaCe (FKG) instruments are treated electrochemically to enhance cutting efficacy.¹¹

Mtwo instruments (VDW) have a non-cutting safety tip and an S-shaped cross-sectional design. These instruments have a positive rake angle with two cutting edges.¹²

HeroShaper (Micro-Mega, Besançon, France) instruments have triple helix cross-section and an inactive tip. These instruments have a pitch length that varies depending on the taper. The more tapered an instrument is, the longer is its pitch.¹³

Revo-S (Micro-Mega) instruments (SC1 and SU) have an asymmetric cross-section design with an inactive tip. Only the SC2 instrument has a symmetric cross-section design.¹⁴

The purpose of this study was to investigate the shaping ability of ProTaper, RaCe, HeroShaper, Mtwo, and Revo-S rotary nickel-titanium instruments in two different canal-shaped simulated canals.

MATERIALS AND METHODS

Simulated canals

Seventy-five 34-35° curved and 75 S-shaped simulated root canals in clear resin blocks (Endo Training Bloc; Dentsply Maillefer, Ballagiques, Switzerland) were randomly distributed among five groups of 15 canals each. The taper and the diameter of all simulated canals were equal to an ISO size 15. The 34-35° curved simulated root canals were 16.5 mm long. The S-shaped canals were 16 mm long, and had two curves. The curvature angles were 30° and 20° at the coronal and apical curves separately, which were measured with Cunningham's method.⁵

Preparation of simulated canals

The final apical preparation was set to a size 25 for all resin blocks canals. The apical end point of instrumentation was 0.5 mm short of the artificial apical foramen. Each instrument was used according to the manufacturers' instructions. All types of instruments were set into permanent rotation with a



6: 1 reduction hand piece powered by a torque-limited electric motor (VDW Gold, VDW GmbH, Munich, Germany). All instruments were used crown-down technique except for Mtwo, which used single-length technique. The instrumentation sequences and working lengths used in each system are presented in Table 1.

Pre- and postoperative images of the simulated canals were taken under standardized manners using a stereomicroscope (Leica MZ 12.5, Heerbrugg, Germany). A specially designed contrivance was prepared that allowed the pre- and postoperative images of the canals to be taken in a standardized condition. The graph paper was fixed base of set-up to provide calibration of measurements. Before preparation, red dye (Focuspoint, White board marker refill ink, Taiwan) was injected into the canal, and a preoperative image was obtained. Then distilled water was used to remove the dye. After the last instrument, black dye (Focuspoint, Taiwan) was injected, and postoperative image was obtained using the same previously described method.

The pre- and postoperative images were superimposed into a composite image using a computer software program (Adobe Photoshop Elements 2.0; Adobe Systems Incorporated, San Jose, CA). The amount of resin removed from both the outer and inner sides of the canal in 1 mm steps were measured one dimensionally using the NetCAD (NetCAD 5.0 GIS for Windows, AK Engineering Computer Co. Ltd, Ankara, Turkey) program with an accuracy level of 0.01 mm. The first measuring point was 1 mm away from the artificial apical foramen, and the last measuring point was 10 mm from the apical end, resulting in 10 measuring points on the inner and outer sides of the canal, for a total of 20 measuring

points¹³ (Figure 1). According to these measuring points in 34-35° curved canals, the curved part is 1 to 6 mm from the apex, and the straight part of the canal is 7 to 10 mm from the apex. In S-shaped canals, there is apical curvature 1 to 3 mm from the apex, coronal curvature 4 to 7 mm from the apex, and the straight part of the canal is 8 to 10 mm from the apex.

All instruments were used to enlarge three canals only. Instruments were examined after every use; if an instrument was deformed or fractured during use, it was substituted for a new one and data were recorded. Glyde (Dentsply Maillefer) was used as a lubricant before each instrument was utilized. At each instrument change, 10 mL of distilled water was used to irrigate the canal. Ten mL of distilled water was used for final flush. All canals were prepared by one operator experienced in preparation with all instruments. Measurement of the canals was carried out by a second examiner who was blind to experimental groups.

The centering ability was calculated by subtracting the amount of resin removed from the inner wall from that removed from the outer wall. According to this calculation, values closer to "0" indicate better centering ability. The direction of transportation was determined by the wider width of resin removal from the two walls of the canal. The total amount of resin removed was assessed by adding the amount of resin removed from the inner wall and that removed from the outer wall. Canal aberrations (apical zip associated with elbow and ledge) were assessed using superimposed images. The time for canal preparation was recorded excluding file changes and irrigation.

Table 1. The instruments sequence for each system. Working length in mm (for 34-35° curved canals) and {for S-shaped canals}.

HeroShaper			Mtwo			ProTaper Universal			RaCe			Revo-S		
.06/20	{10.5}	{10}	.04/10	{16}	{15.5}	S1	{13}	{13}	.10/40	{9}	{9}	SC1	{10.5}	{10}
.04/20	{16}	{15.5}	.05/15	{16}	{15.5}	SX	{10}	{10}	.08/35	{10}	{10}	SC2	{16}	{10.5}
.04/25	{16}	{15.5}	.06/20	{16}	{15.5}	S1	{16}	{15.5}	.06/25	{13}	{13}	SU	{16}	{10.5}
			.06/25	{16}	{15.5}	S2	{16}	{15.5}	.04/25	{14}	{14}			
						F1	{16}	{15.5}	.02/25	{16}	{15.5}			
						F2	{16}	{15.5}	.04/25	{16}	{15.5}			
									.06/25	{16}	{15.5}			
300rpm			300rpm			300rpm			500rpm			300rpm		



Statistical analysis

Data were analyzed by means of ANOVA, Kruskal–Wallis, and Mann–Whitney U-tests with the Bonferroni correction.

RESULTS

Preparation time

The mean preparation time and relative standard deviation (SD) is presented in Table 2. The active instrumentation time was significantly shorter in the RaCe group ($P < 0.05$) whereas there was no significant difference among the HeroShaper, Mtwo, and Revo-S groups for 34-35° curved canals ($P > 0.05$). The RaCe and Revo-S groups were significantly faster than the Mtwo and ProTaper Universal groups for S-shaped canals ($P < 0.05$). The ProTaper Universal group was significantly slower than other groups ($P < 0.05$) for both canal types.

Table 2. Preparation time (s). Values are means \pm SD.

	34-35° curved	S-shaped
HeroShaper	103.32 \pm 8.95 B	72.40 \pm 5.55 B
Mtwo	101.64 \pm 9.53 B	106.85 \pm 5.71 C
ProTaper Universal	139.03 \pm 10.34 C	122.12 \pm 12.42 D
RaCe	85.07 \pm 5.87 A	64.19 \pm 6.77 A
Revo-S	104.98 \pm 10.79 B	70.55 \pm 4.54 A, B

Groups identified by different characters are significantly different at the same measuring points ($P < 0.05$). Groups identified by the same characters are not significantly different ($P > 0.05$).

Canal aberrations

The results of canal aberrations are summarized in Table 3. In 34-35° curved canals, the RaCe and Mtwo groups created no canal aberrations. More canal aberrations were observed in the HeroShaper group (3 zips and 1 ledge). In S-shaped canals no canal aberrations were observed for the RaCe group. The HeroShaper (3 zips) and Revo-S (3 zips) groups created more canal aberrations in S-shaped canals.

Table 3. The incidences of canal aberrations

	34-35° curved		S-shaped	
	Zip and elbow	Ledge	Zip and elbow	Ledge
HeroShaper	3	1	3	-
Mtwo	-	-	1	-
ProTaper Universal	-	2	-	2
RaCe	-	-	-	-
Revo-S	2	1	3	-

Instrument deformation

In 34-35° curved canals, plastic deformation was observed only one HeroShaper (.04/25) instrument. No deformations or fractures were observed in any of the other groups. In S-shaped canals, one HeroShaper instrument (.06/20), one Mtwo instrument (.04/10), and four Revo-S instruments (2 SC1, 2 SC2) deformed. No instrument fractures were seen in any of the groups.

Centering ability

The centering ability of all of the Ni-Ti systems for 34-35° curved canals is shown in Table 4. In the 34- 35° curved canals, when the centering ability of all groups at all measurement points was evaluated; there was a statistical difference, except for 10 mm from the apex. In regard to centering ability 1 to 3 mm from the apex, the RaCe group had significantly the best value in comparison with all other groups except for the Mtwo group. The HeroShaper group created centered enlargements 5 to 7 mm from the apex. However, there were no significant differences between the HeroShaper and RaCe groups 6 and 7 mm from the apex. The ProTaper Universal group created centered enlargements 4, 9, and 10 mm from the apex.

S-shaped canals, the difference was not significant for all groups 3, 9, and 10 mm from the apex (Table 5). The RaCe group created centered enlargements at 1 to 4 mm from the apex. The ProTaper Universal group showed larger values of transportation 1 to 8 mm from the apex. The HeroShaper group gave best centering values at 5 to 8 mm from the apex.



Table 4. Centering ability for 34-35° curved canals. Values are means ± SD.

	Measuring point from the apex (mm)									
	1	2	3	4	5	6	7	8	9	10
HeroShaper	-0.25±0.05 C	-0.31±0.15 C	-0.30±0.10 C	0.11±0.10 B	0.08±0.12 A	0.25±0.07 A	0.09±0.06 A	0.01±0.06 A, B	0.07±0.06 B	-0.08±0.07 A
Mtwo	-0.06±0.01 A	-0.11±0.04 A	-0.11±0.04 A	0.01±0.05 A	0.21±0.06 B	0.35±0.05 B	0.16±0.07 A, B	0.08±0.05 C	0.01±0.04 A	-0.04±0.07 A
ProTaper Universal	-0.09±0.03 A	-0.20±0.07 B	-0.21±0.05 B	0.00±0.05 A	0.32±0.05 C	0.43±0.05 C	0.21±0.07 B	0.06±0.08 A, C	0.00±0.05 A	-0.02±0.06 A
RaCe	-0.05±0.03 A	-0.06±0.04 A	-0.06±0.03 A	0.01±0.04 A	0.20±0.08 B	0.29±0.09 A, B	0.12±0.09 A	0.00±0.07 A	0.08±0.06 B	-0.07±0.07 A
Revo-S	-0.18±0.05 B	-0.31±0.07 C	-0.32±0.06 C	0.15±0.05 B	0.18±0.06 B	0.31±0.05 A, B	0.16±0.05 A, B	0.02±0.06 A, B, C	0.02±0.08 A, B	-0.03±0.10 A

Groups identified by different characters are significantly different at the same measuring points ($P < 0.05$). Groups identified by the same characters are not significantly different ($P > 0.05$).

Table 5. Centering ability for S-shaped canals. Values are means ± SD.

	Measuring point from the apex (mm)									
	1	2	3	4	5	6	7	8	9	10
HeroShaper	0.09±0.08 A, B	0.24±0.09 A, B	0.15±0.04 A	0.05±0.04 A, B	0.17±0.06 A	0.19±0.06 A	0.09±0.04 A	0.00±0.03 A	0.03±0.03 A	0.05±0.02 A
Mtwo	0.07±0.04 A, B	0.23±0.05 A, B	0.15±0.09 A	0.07±0.07 A, B	0.29±0.06 B, C	0.31±0.07 C	0.16±0.08 C	0.05±0.08 A, B	0.00±0.07 A	0.02±0.07 A
ProTaper Universal	0.11±0.07 B	0.28±0.04 B	0.16±0.08 A	0.13±0.09 B	0.34±0.05 C	0.37±0.06 C, D	0.22±0.06 C, D	0.08±0.05 B	0.00±0.07 A	0.03±0.09 A
RaCe	0.02±0.03 A	0.18±0.03 A	0.12±0.05 A	0.06±0.05 A, B	0.24±0.02 B	0.25±0.05 A, B, C	0.13±0.05 A, B, C	0.02±0.04 A	0.03±0.03 A	0.06±0.04 A
Revo-S	0.05±0.11 A, B	0.24±0.07 A, B	0.22±0.11 A	0.00±0.13 A	0.18±0.09 A, B	0.25±0.06 A, B, C	0.17±0.12 A, B, C, D	0.07±0.12 A, B	0.00±0.08 A	0.03±0.07 A

Groups identified by different characters are significantly different at the same measuring points ($P < 0.05$). Groups identified by the same characters are not significantly different ($P > 0.05$).

Amount and direction of transportation

In 34-35° curved canals, all groups created transportation towards the outer wall 1 to 4 mm from the apex, whereas transportation was created towards the inner wall 5 to 8 mm from the apex. A central preparation was formed 9 and 10 mm from the apex (Figure 2). In the S-shaped canals, all groups created transportation towards the inner wall 1 to 3 mm, and the outer wall 5 to 7 mm from the apex respectively. At 4, 8, to 10 mm from the apex, a centered enlargement were created (Figure 3).

Total amount of resin removed

In the 34-35° curved canals, the HeroShaper and Revo-S groups removed more resin than the other groups 1 to 4 mm from the apex. The ProTaper Universal group removed more resin than the other groups 5 to 10 mm from the apex (Figure 4).

In S-shaped canals, the Revo-S group removed more resin 1 to 4 mm from the apex than the other groups. The ProTaper Universal group removed significantly more resin 5 to 10 mm from the apex than the other groups (Figure 5).



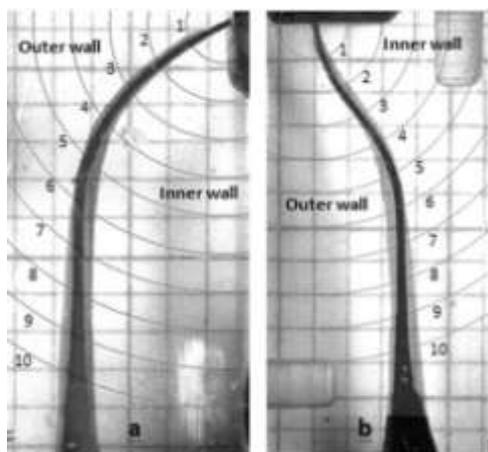


Figure 1. Composite image of canal pre- and post-operative images of resin blocks. (a: 34-35° curved canal; b: S-shaped canal)

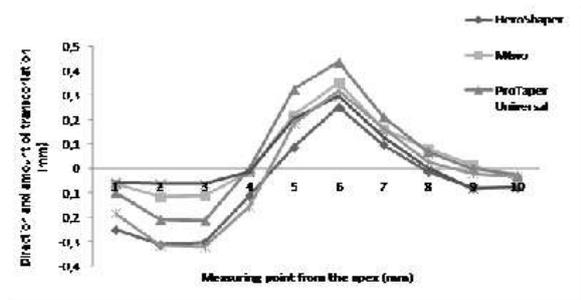


Figure 2. The amount and direction of transportation of root canal wall measured from original canal shape in 34-35° curved canals. Negative values refer to the outer canal wall and positive values refer to the inner canal wall. Values close to "0 mm" indicate to the better centering ability.

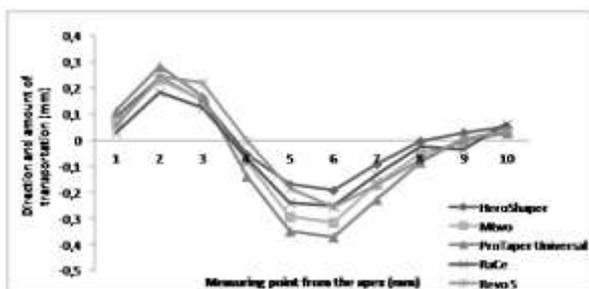


Figure 3. The amount and direction of transportation of root canal wall measured from original canal shape in S-shaped canals. Positive values refer to the inner canal wall and negative values refer to the outer canal wall. Values close to "0 mm" indicate to the better centering ability.

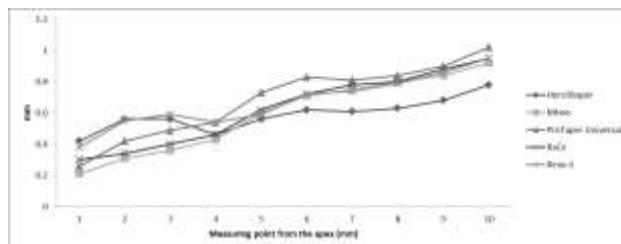


Figure 4. Total amount of resin removed in 34-35° curved canals. Steeper line corresponds to better tapered root canal form.

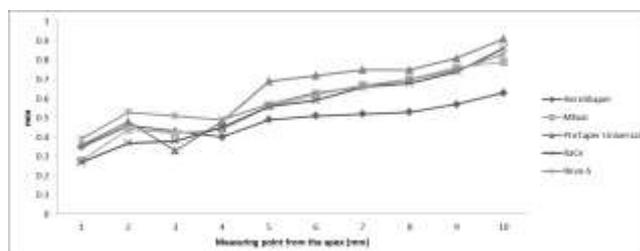


Figure 5. Total amount of resin removed in S-shaped canals. Steeper line corresponds to better tapered root canal form.

DISCUSSION

Resin blocks and real teeth are typically used to investigate the shaping ability of instruments. Both materials have their own disadvantages and advantages. The root canal curve angle, length, and diameter of resin blocks are standard thus; it is possible to obtain identical samples.¹⁶ However, the microhardness of resin-based materials is different from that of natural teeth.¹⁷ The Knoop hardness number was reported 36 for resin blocks, and between 40 and 72 for dentine.¹⁸ Resin may be softened by heat created with rotary instruments, and resin material does not cut in the same manner as dentine.¹⁹ At the same time, resin blocks allow different instruments' shaping ability to be directly compared, and studies using extracted teeth have fully approved the results obtained from resin blocks.²⁰

Rangel et al.²¹ reported that instrument changes and irrigation time are operator-dependent and difficult to control. Therefore, in this study, these processing times were not included in the preparation time. The total number of files used during the preparation of each 34-35° curved and S-shaped canal was 7 for RaCe, 6 for ProTaper Universal, 4 for Mtwo, 3 for HeroShaper, and 3 for Revo-S. The RaCe group

was faster than the other groups in both canal types. Schirrmeister et al.²², and Schafer and Vlassis¹⁰ obtained similar results. The reason for these results may be related to electrochemical treatment, and be used 500rpm for RaCe instruments.

Apical transportation may lead to zipping and elbow formation, which allows a limited number of accessory gutta-percha cones to be placed when curved canals are obturated with lateral compaction. This may lead to root canal treatment failure.²³ In the present study, apical transportation 1 mm from the apex, greater HeroShaper, Revo-S, ProTaper Universal, Mtwo, and RaCe, respectively. The HeroShaper and Revo-S showed greater apical transportation than the other groups in 34-35° curved canals. These systems don't have more tapered instruments for coronal enlargement and this factor may have influenced their shaping outcome. Moreover, these systems have three instruments to approach the apex. This might have also led to the much apical transportation. Thus, both systems created more canal aberrations in both canal types. The ProTaper Universal group created a relatively large number of ledge formations, which is consistent with previous research.²⁴ This group has a modified guiding tip, whereas all other groups have non-cutting tips, which may explain the results. The use of greater taper instruments in a crown-down technique appears to be beneficial and is recommended.²⁵ In this study, the HeroShaper (.06/20) and Revo-S (.06/15) groups had smaller taper instruments than the RaCe (.10/40) and ProTaper Universal (SX= .035-.19/19) groups; thus, the Revo-S and HeroShaper groups exhibit more instrument deformation. The Mtwo system had no coronal enlargement file; and used its full working length. Only one Mtwo instrument (.04/10) deformed in S-shaped canals. Mtwo instruments have an S-shaped cross-sectional design and an increasing pitch length (blade camber) from the tip to the shaft. These features might have influenced their deformation outcome.

As shown in this study, RaCe system was showed to maintain original canal shape in single curved resin canals^{21, 26} and, S-shaped resin canals with very few aberrations in the previous researchs.⁷ It was also found to be effective and safe in shaping the curved root canals of real teeth.²⁷ The alternating cutting edges of the RaCe instruments might be most

distinctive feature of other instruments. This design seems to prevent the blocking effect or threading and might be maintaining canal shape well and creating no canal aberrations.²⁸

The ProTaper Universal finishing files have a greater taper at the apical part of the instrument (F1, .07 and F2, .08), leading to increased stiffness or rigidity.²⁹ Furthermore, previous studies have reported that flexibility decreases with increasing thickness of rotary instruments.^{30, 31} For these reasons, in this study the ProTaper Universal group created transportation toward the outer side of 34-35° curved canals. Similarly, Yoshimine et al. researched the shaping ability of RaCe, ProTaper, and K3 systems in S-shaped resin blocks and showed that the ProTaper instruments have a tendency to straighten both curved parts of the canal.⁷

The Mtwo group created centered preparation 1 to 4 mm from the apex in both canal types. The reason for the centered preparation seems to be the gradually smaller amount of material removed from the canal walls. For the same reason, the Mtwo group created only one canal aberration in this study. In fact, the Mtwo group maintained the original canal shape with very few aberrations in single curved resin blocks¹²; it has also; been proven to be safe and effective in shaping curved root canals of real teeth.^{26, 32} Similarly, the HeroShaper and Revo-S groups showed a better centering ability than the other groups 5 to 10 mm from the apex in both canal types. One possible reason for this is the sets of HeroShaper and Revo-S don't have more tapered instruments for used in the coronal part. On the other hand, these two groups exhibited larger transportation values 1 to 4 mm from the apex in 34-35° curved canals. In contrast with the results of this study, Hashem et al. reported that the Revo-S group created significantly less transportation than ProTaper.¹⁵ However, the results of our study cannot be compared directly with those of Hashem et al. because of the different materials used. Hashem et al.¹⁵ examined real teeth, whereas the present study used resin blocks.

A further aim of root canal shaping is to create a tapered root canal form. The Mtwo, ProTaper Universal, and RaCe groups obtained this form in 34-35° curved canals, and the RaCe group only obtained it in S-shaped canals when the total amount of resin removed was investigated. In addition, the ProTaper

Universal group removed more resin in both canal types. This might be attributed to the sharp cutting edges and the multiple tapers along the cutting surface of the files.^{15, 33}

In conclusion, it can be said that the RaCe instruments avoided transportation and had a superior centering ability and fewer canal aberrations. Moreover, the RaCe group prepared curved canals rapidly in both canal types. Further studies are needed in extracted teeth and clinical studies.

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