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Evaluation of The Effect Of Apical Diameter On The Shaping Abilities of Four Different Rotary İnstrument Systems İn Curved Root Canals

Eğimli Kök Kanallarında Dört Farklı Döner Alet Sisteminin Şekillendirme Yeteneklerine Farklı Apikal Boyutların Etkisinin Değerlendirilmesi

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ABSTRACT

İntroduction: Mechanical preparation is an important step of root canal therapy. Apical enlargement is recommended for effective disinfection.The aim of this study is to compare the shaping ability of PTG, PTN, RS and BR rotary file systems in curved canals up to the apical file size to 40

Material and Method: Before root canal instrumentation, pre-instrumented CBCT images of 60 MB canals of mandıbular molar teeth were taken and canals curvature angles were calculated. The samples were randomly divided into four groups (n=15),and instrumented up to the apical size 40. Changes in canal curvatures were measured after each file used in post-instrumented images. Statistical analysis was performed with the significance level set at p=0.05.

Results: As the apical tip size increased root canals were straightened significantly. In the apical size 25;RS and BR(25/04) were found to straighten the canal curvatures less than PTG whereas, PTG caused less straightening than PTN and BR(25/06). In the apical size 30; RS caused less straightening whereas PTN was the most. In the apical size 40; PTG and RS caused less straightening than PTN and BR(40/02), BR(40/04) caused the most straightening.

Conclusions: While all of the treatments in this study straightened the root canals as the apical size increased, and PTG and RS showed promising outcomes, the results differed depending on the taper and tip size.

Anahtar Kelimeler: Canal straightening, Shaping abilities, ProTaper Gold

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ÖZET

Giriş: Mekanik şekillendirme kök kanal tedavisinin önemli bir basamağıdır. Etkili dezenfeksiyon amacıyla apikal genişletme önerilmektedir. Bu çalışmanın amacı, PTG, PTN, RS ve BR döner alet sistemlerinin 40 apikal uç boyutuna kadar olan eğelerinin eğimli kök kanallarındaki şekillendirme yeteneklerini incelemektir.

Materyal ve Metot: Çalışmada, mandibular molar dişe ait 60 adet MB kanalın mekanik şekillendirme işlemi öncesinde KIBT görüntüsü alındı ve kanal eğim açıları hesaplandı. Sonra örnekler açılarına göre, randomize olarak 4 gruba ayrıldı (n=15) ve 40 apikal uç boyutuna kadar şekillendirildi. Şekillendirme sırasında her eğeden sonra KIBT görüntüsü alındı ve kanalların başlangıç açılarına göre açısal değişimleri hesaplandı. İstatistiksel anlam düzeyi p=0.05 olarak belirlendi.

Bulgular: Apical uç boyutu arttıkça kök kanal eğimlerinde düzleşme gözlendi.25 apikal uç boyutundaki aletler karşılaştırıldığında; RS ve BR(25/04) kök kanallarında PTG'ye göre daha az oranda kök kanallarını düzleştirirken, PTN ve BR(25/06)'nın diğer sistemlerden daha fazla oranda düzleşmeye neden olduğu belirlendi. 30 apikal uç boyutundaki aletler karşılaştırıldığında; RS'nin en az, PTN'nin ise en çok düzleşmeye neden olduğu tespit edildi. 40 apikal uç boyutundaki aletler karşılaştırıldığında; PTG ve RS, PTN ve BR'den(40/02)daha az düzleşmeye neden olurken,BR(40/04)'nin en fazla düzleşmeye neden olan eğe olduğu belirlendi.

Sonuç: Bu çalışmada incelenen tüm sistemler, apikal boyut arttığında daha fazla düzleşmeye neden olmaktadır. PTG ve RS diğer sistemlere göre daha umut verici sonuçlar ortaya koyarken, sonuçların taper ve uç boyutuna göre değişiklik gösterdiği ifade edilebilir.

Keywords: Kök kanallarında düzleşme, Mekanik şekillendirme yeteneği, ProTaper Gold

1. Introduction

Mechanical preparation is an important step of non-surgical root canal therapy. Root canals are being recommended to shape in conical form (widening from apical to coronal) with enough apical enlargement for effective elimination of infection and obtaining disinfection [1]. In the literature "enough apical enlargement" is still a dilemma. Ensuring adequate balance between preserving root canal anatomy and apical disinfection is still a challenge in endodontics, especially in teeth with curved canals [2]. Enlarging the curved root canals creates risk factors for iatrogenic errors (canal straightening, transportation, zipping etc.) [3,4]. Various instruments, especially nickel-titanium (NiTi) ones, were described to overcome these clinical difficulties. These instruments present more flexibility and adequate cutting capacity. NiTi instruments respect root canal anatomy and reduce the risk for canal straightening or transportation [5]. From past today because of the phase of the alloy may found to have impact on the physical behaviors of the instrument, different heat-treated NiTi wires were described to produce novel rotary file systems with more flexibility and resiliency [6].

ProTaper Gold (PTG; Dentsply Tulsa Dental Specialties) is made with a novel gold-heat treated NiTi wire [7]. The manufacturing process starts with the traditional NiTi alloy, after the machined for grinding process the metal heat treated. Heat-treated turns the metal to gold color with more flexibility and resiliency for cyclic fatigue [6]. The files of the system have a convex triangular cross-section same as ProTaper Universal (PTU) with variable progressive taper and use with rotary action.

ProTaper Next (PTN; Dentsply Sirona, Ballaigues, Switzerland) is made with M-wire to improve flexibility and cyclic fatigue resistance. These instruments include a variable progressive and regressive taper design, unique offset mass of rotation, and rectangular cross section. According to the manufacturer these design reduce contact points with canal walls that cause less stress on the instrument during use [5,8].

Revo-S (RS; Micro-Mega, Besancon Cedex, France), is made with R-phased wire and has an asymmetric cross-section blade design to reduce the stress on the instrument and prevents canal penetration and directs the debris through the coronal [9]. This design cause more flexibility and adequate shaping ability.

BioRace (BR; FKG Dentaire, La Chaux-de-Fonds, Switzerland) is a rotary file system, whose instrument was electro-chemical surface treatment for reducing the corrosion and preventing the file to be broken. BioRace instruments has the same physical characteristics such as alternating cutting edges, non-cutting tips and triangular cross section as well-known NiTi rotary Race instruments. The only differences between these two system, BR has different instrument tapers, sizes, sequence and handle codes that allows biologically desirable apical sizes [10].

The use of cone beam computed tomographic (CBCT) imaging is widely accepted for studying the internal anatomy of the teeth. It is an accurate, non-destructive method commonly used to investigate changes in the root canal anatomy after instrumentation [11,12]. The CBCT is more available and cost-effective in contrast with micro-CT and also more trustable according to 2-dimension imaging procedures [13].

Many studies show the geometrical changes occurring in the root canals after mechanical instrumentation with various rotary file systems (different alloys, having different blade designs and working with different kinematics, etc). However, there are limited studies on the shaping abilities of various apical sizes' in curved canals.

The aim of this study is to compare the shaping ability on changing in canal curvatures of PTG, PTN, RS and BR rotary file systems in curved canals with the apical file size 25 to 40.

2. Material and Method

This study has been approved by Selçuk University, School of Dentistry, Non Clinical Research Ethical Committee (2014/3).

The experimental pre/posttest study design was preferred. A total of 60 mesio-buccal (MB) root canals of extracted (not related to this study) mandibular molars with fully formed apices were used. The patients signed an informed consent form that consisting to donate their extracted teeth for usage of researches after they were diagnosed for extraction. In the selection of the teeth, besides their morphological appearance, the radiographic images taken from the mesiodistal and buccocolingual directions are examined; teeth with MB-mesiolingual (ML) canals started, continued and ended separately were included; teeth with no comparable root length, root canal calcification or internal/external root resorption are excluded from study. Teeth were cleaned, disinfected and stored in 0.9% saline solution.

Standardized access cavities were made to the teeth using a standard diamond cylindrical bur with a 10 mm apical size using water-cooling. Canals were controlled using #10 K-files (Dentsply Maillefer, Ballaigues, Sweden).

Before root canal instrumentation, the teeth were fixed in a silicone impression (Zetaflow, Zhermack, Badia Polesine, Italy) in a plastic-platform with the reference point for specimens for providing constant procedure of CBCT location (Figure 1,2). Pre-instrumented, CBCT (NewTom/NT5G; Nevtom 5G®, QR, Verona, Italy) images were taken whereby the constant exposure parameters of 110kv tube potential and 0.02 mAs tube current and 12x15 cm field of view were preferred. Axial slice thickness was 0.15mm with a 0.15 mm pixel size. CBCT images were analyzed and reconstructed with Mimics 15.01 software (Materalise HQ, Levven, Belgium) (Figure 3).

MB canals curvature angles were calculated according to Estrela et al (2008)(Figure 4) [14]. The MB canals with the curvature of 20° to 45° (mean 29,63°) were selected for the study.

For the selection of samples, the samples were randomly divided into four groups and placed into plastic molds. Randomization were occurred when the samples were placement as you see in the Figure 1. In all sample groups there were 20 teeth (as a precaution for any complication). After the access cavities were performed and the initial CBCT images were taken, the first measurements of angles were determined. And all 20 teeth were evaluated. After this process, 15 of appropriate samples (similar angular measurement values) were selected for the study and also, the canal curvatures were analyzed according to groups to check whether it makes a statistical difference. After it was shown that there was not a significantly differences among groups according to initial canal curvatures, the shaping procedures were continued. So it can be claimed that the groups were distributed according to their angles (n=15). Working length was determined by inserting #10K file to the root canal terminus and subtracting 1 mm from this measurement. With a #15 K file (Dentsply Maillefer, Ballaigues, Sweden), a glide path was made. Root canal instrumentation was completed according to the manufacturer recommendation's in four group (PTG,PN,RS,BR) up to the apical size 40 with flushing using 2 ml 2.5% sodium hypochlorite solution after each instrument change. The apical size and apical taper of the files of each system is shown in Table1. Each instrument of all systems was used in only 3 canals. Instrumentation was completed by an expert with a low-torque motor (X smart plus; Denstply Maillefer Chemin du Verger, Ballaigues, Switzerland). In each group according to the rotary systems, the instruments have been used in the appropriate order with the manufacturers' recommendation for especially curved root canals. Accordingly, Sx,S1,S2,F1,F2,F3,F4 in Group 1; X1,X2,X3,X4 in Group 2; Sc1,Sc2,SU,As30,As35,As40 in Group 3 and BR0,BR1,BR2,BR3,BR4c,BR5c,BR5 were used in Group 4 respectively. And after apical size of 25, CBCT images were taken after each file used, up to apical size 40. By this way, post instrumented images has been achieved at the apical size of 25, 30, 35 (if files were existed) and 40 as each of this apical sizes would be a final tip. While the taper was variable according to groups, the root canals were shaped up to apical size 40 in all four rotary systems.

The changing in root canal curvatures were determined by CBCT imaging was used in all groups using the same position and parameters for comparing pre and post images. Curvature angles was determined according to Estrela et al (2008) as mentioned before [14]. Changing in root canal curvatures were calculated as the formula; Initial measurement(pre-instrumented) – Post instrumented measurement(after the files from 25 to 40 was used). The positive values presenting the straightening the root canals.

Statistical analysis was performed using the IBM Statistics SPSS 20.01 program. The Kolmogorov-Smirnov test was used for normality distributions of the values. The data was analyzed according to intra and inter group for changes in canal curvatures. One-way Anova and post hoc Duncan tests were used for evaluating changes based on the rotary systems and the file sizes. Because of there is only two rotary systems in group 3 and 4 (BR and RS) in the apical size 35, an independent t test were used. The significance level was set at *p=0.05.*

Table 1: The tapers and apical sizes of the finishing files used in root canal

Systems	Finishing File name	Apical size	Apical Taper
Group 1, ProTaper Next[15]	X2	25	6
	X3	30	7
	X4	40	6
Group 2, ProTaper Gold[16]	F2	25	8
	F3	30	9
	F4	40	6
Group 3, Revo-S[17]	SU	25	6
	As30	30	6
	As35	35	6
	As40	40	6
Group 4, BioRace[18]	BR2	25	4
	BR3	25	6
	BR4c	35	2
	BR5c	40	2
	BR5	40	4

Figure 1: Fixing the teeth in the plastic mold with silicone impression material.

Figure 2: Fixing the prepared plastic molds to the rubber imaging cube with two hangers.

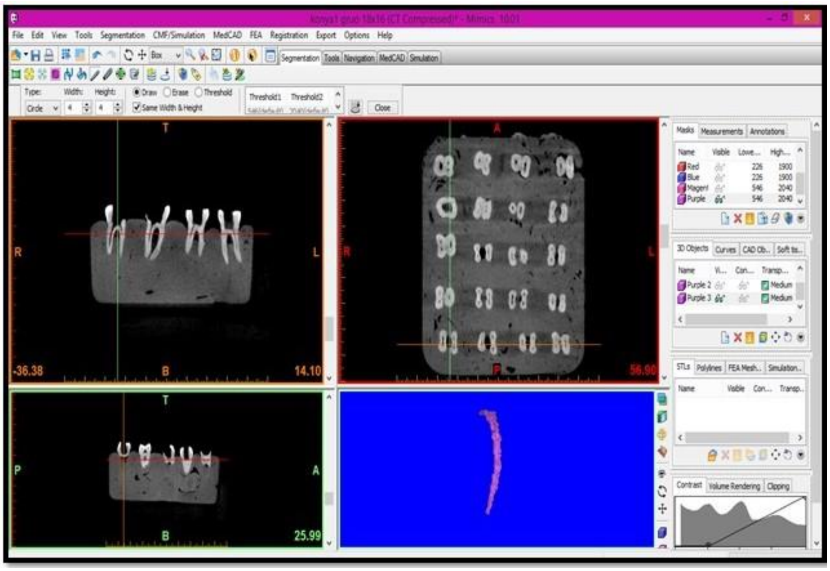

Figure 3: 3D modeling of mesiobuccal root from CBCT images before shaping.

Figure 4: Calculation of the root canal curvatures.

3. Results

In this study no fracture occurred and none of the working length was lost.

The initial root canal curvatures according to the groups is shown in Table 2 and no significant difference was found based on the groups.

Table 2: Initial root canal curvatures according to groups

	Root Canal Curvatures (º)
Systems	Mean ˚ ±SD ˚(Min- Max)˚
Group 1 PTN	30,3±6,5(21-45)
Group 2 PTG	29,8±5,7(21-42)
Group 3 RS	30,6±6,1(20-43)
Group 4 BR	29,6±5,8(22-44)
P value	0.104

*One-Way ANOVA p value

In intra-group evaluations; the file's of each system were compared with each others. Canal straightening were occurred in all systems with the apical size increased.So, It has been determined that each file causes canal straightening at a higher rate than the previous file. There have been two files for the apical size 25 (BR2 and BR3) and 40 (BR5c and BR5) in the group 4, it was shown that more tapered files caused more straightening in this systems (Table 3).

Table 3. Intra-group comparisons of the canal straightening according to the rotary file systems

Straightening (º) of root canal curvatures accordıng to different systems

ProTaper Next		ProTaper Gold		Revo-S		BioRace	
Systems	**Mean±SD (Min- Max)**	**Systems**	**Mean±SD (Min- Max)**	**Systems**	**Mean±SD (Min- Max)**	**Systems**	**Mean±SD (Min- Max)**
PTN X2	2.83±1.15^{A} (1.10-4.60)	PTG F2	2.18±0.52^{A} (1.09-3.08)	RS SU	1.29±0.27^{A} (1.02-1.95)	BR2	1.51±0.35^{A} (1.09-2.13)
PTN X3	3.96±1.19^{B} (2.24-5.94)	PTG F3	3.29±0.50^{B} (2.43-4.20)	RSAs30	2.21±0.54^{B} (1.44-3.15)	BR3	2.73±0.43^{B} (2.09-3.62)
PTN X4	5.09±1.00^{C} (3.68-6.55)	PTG F4	4.26±0.57^{C} (3.17-5.07)	RSAs35	3.34±0.67^{C} (1.00-4.87)	BR4	3.83±0.70^{C} (1.17-4.72)
				RSAs40	4.45±0.82^{D} (3.37-5.82)	BR5c	5.20±0.48^{D} (4.18-5.85)
						BR5	6.13±0.49^{E} (5.40-6.93)

In inter-group evaluations; results according to the various systems in the same apical sizes were compared with each others. In comparing the files in the apical size 25; RS and BR with BR3 were found to straightened the canal curvatures less than PTG whereas, PTG caused less straightening than PTN and BR with BR2 (p=.00) (Table 3). There has been only three systems with the files in the apical size 30. RS caused less straightening whereas PTN was found to be most (p=.00) (Table 4). Only RS and BR has the files in the apical size 35 and there was no statistical difference in root canal curvatures change (p=.887). In comparing the files in the apical size 40. RS and PTG caused less straightening than PTN and BR with BR5c (40/02), however, BR with BR5 caused the most straightening (p=.00) (Table 4).

Table 4. Statistical Analysis of Straightening of Canal curvatures (o) at the different apical sizes (#25, #30, #35, #40) via the different systems

Straightening (o) at Different Apical Sizes							
#25		**#30**		**#35**		**#40**	
Systems	**Mean±SD (Min- Max)**	**Systems**	**Mean±SD (Min- Max)**	**System**	**Mean±SD (Min- Max)**	**Systems**	**Mean±SD (Min- Max)**
PTN X2	2.83±1.15^{B} (1.10-4.60)	PTN X3	3.96±1.19^{A} (2.24-5.94)	RS As35	3.34±0.67 (1.00-4.87)	PTN X4	5.09±1.00^{B} (3.68-6.55)
PTG F2	2.18±0.52^{A} (1.09-3.08)	PTG F3	3.29±0.50^{B} (2.43-4.20)	BR 4	3.83±0.70 (1.17-4.72)	PTG F4	4.26±0.57^{C} (3.17-5.07)
RS SU	1.29±0.27^{C} (1.02-1.95)	RS As30	2.21±0.54^{C} (1.44-3.15)			RS As40	4.45±0.82^{C} (3.37-5.82)
BR2	1.51±0.35^{C} (1.09-2.13)					BR5c	5.20±0.48^{B} (4.18-5.85)
BR3	2.73±0.43^{B} (2.09-3.62)					BR5	6.13±0.49^{A} (5.40-6.93)
<0.001*		**<0.001***		**0.087****		**<0.001***	

*****One-Way ANOVA p value
**Independent Sample t test
***Upper letters shows post hoc Duncan test

4. Discussion and Conclusion

The aim of this study is to compare the shaping ability on changing in canal curvatures of PTG, PTN, RS and BR rotary file systems in curved canals with the apical file size up to 40. The current study showed that root canal curvatures is straightened with the apical enlargement. And also it was shown that more tapered files caused more canal straightening in BR systems.

Deciding the enough apical enlargement is still a major topic of discussions [19]. Minimally invasive procedure concepts suggest to preserve the original shapes of root canals and remain as much hard tissue as possible. In addition, enlarging the curved root canals is increased the risk factors for iatrogenic errors like canal straightening, transportation, zipping, perforation etc. On the other hand especially in devital teeth, in order to eliminate microorganisms or microbial products, moreover enlargement is recommended [19]**Error! Bookmark not defined.**. Although usually the studies evaluated the shaping abilities of the different rotary systems in the apical size up to 30 [20,21], there are some samples of which root canals were shaped up to 40 [22]. Because of the 98.2% of the microbial products/microorganism was shown to eliminated with shaping root canals up to apical size to 40 and even in curved canals, the devital teeth were recommended to shape up to apical size of 40 [23]. Thereby, it was preferred to shape the root canals up to apical size 40 to show a wide spectrum for clinicians in this study.

The diversity and deviations of root canal morphology should effect the effectiveness of the shaping process and consequently the success of the root canal treatment. As an important risk factor, it is recommended to determine the root canal curvatures before the treatment [24]. With this context, various of measuring methods were described. The first mentioned and the most common way is using Schneider’s method. This method was defined to measure the canal curvatures on 2-dimensional(2D) images like radiographs or photos. Root canal anatomy is more complex to evaluate with 2D and in addition to this superposition’s of the images caused misunderstanding [25]. Although the Schneider’s method can still use for simulated canals that the only variable is canal curvature, it is essential to use 3D imaging methods that provide an understanding of complex anatomy. CT, CBCT and micro-Ct are the preferred methods for describing anatomical structures 3D in endodontics treatments [26]. CT has poor spatial resolution and inadequate slice thickness [25]. Micro-CT has high resolution images and is an effective method for evaluating the more detail variables like internal structures of root canal anatomy, pre/post instrumented changing, amount of untouchable areas and etc [6,7,25,27]. Because of the only variable is changing in canal curvatures in this study, CBCT imaging were preferred as an cost-effective way [28]. CBCT is also a proven method for providing a certain and reproducible 3D images [11]. Estrela et al. (2008) described an easy and reproducible method for measuring canal curvatures via CBCT [14]. The curvature of root canals ranged between 20° to 45° (mean 29,63°) to ensure moderate or extreme curvatures according to American Association of Endodontics [24] similarly with the studies published before [6,21].

Simulated canals or resin blocks are recommended to use the instruments before clinical usage. The studies also have beneficial effect for guessing the instrumental behaviors [29]. If there is a need of standardization before instrumentation this way is again preferable. Simulated canals differ in micro hardness compared to root dentine, and the effects of heat generation during instrumentation is questionable [26]. The real anatomy is never like a fabricated simulate canal so for simulation of clinical conditions in the methodology of the current study extracted teeth were used and the analyses was concluded with median values of pre/post instrumentation.

The tendency of the files to return the initial straight position causes root canals straightening so, novel instruments with advanced NiTi alloy (more flexible, shape-memory etc.) were developed to prevent this phenomena [8]. In present study, four different rotary file systems with different NiTi alloys and the apical size of these systems from 25 to 40 were evaluated according to the changing in canal curvatures.

Even the instruments were made of NiTi alloy or stainless steel apical enlargement resulted more straightening [26,30]. Similarly, the root canal straightening amount was significantly increased when comparing to the initial form in the present study. In addition, although there were some confounding factors like blade design, alloy differences etc. in experiement groups, we had a chance to evaluate the effect of taper in the group of BR files in the apical sizes of 25 and 40. By this evaluation, the current study showed that more tapered instruments caused more straightening. With the apical instrumentation size of #25 and #40, BR files with lower tapers respected the canal curvatures better than more tapered

BR files. Although this results were similar with some studies published before [29], there was also other studies in contrast of our findings [20,27,30].

In accordance with the literature, PTG and RS shows better shaping ability than PTN and BR in the experiments that all system can be evaluated. In accordance with this, as PTU was caused more straigtening than PTU [31], and PTU caused similar straightening with PTN in curved canals with the apical instrumentation diameter of #25 in a previous study [31]. As reported before, PTG's heat treated NiTi alloy (CM-wire like), should allow the file to be more flexible than PTU and PTN [32] thus it respects canal curvatures better. M-Wire is also a novel heat treated NiTi alloy, that allows instrument to be more flexible [9,22]. Although PTN was made of M-wire, it was found that RS, with R-phased NiTi alloy, was more flexible than PTN with the differences in blade-design [33] and the CM-wire like NiTi alloy of PTG was found more flexible than M-Wire. RS caused the lowest straightening in root canals in all apical sizes as the previous studies, the results should be related to the its asymmetric cross-sectional geometry of the instruments that was intended to facilitate canal penetration by a snake-like movement and leading to uniform removal of dentin as claimed by the manufacturer [34].

Although in the other apical sizes (25,30,40) RS was shown to respect the root canal curvatures better than BR, in the apical diameter of #35, BR and RS have similar effects. This can be explained by the differences in tapers cause, there was an extreme difference in tapers like 0.02 to 0.06 between two experiment group, so it can be stated that in the same apical size less tapered files can be preferable even they were made of more conventional alloy. In accordance with the literature PTN and BR were found to have similar effects on root canal shaping when BR's taper was 0.04 and BR caused the most straightening in canal curvatures with the more tapered files [35]. The differences in tapers may be changed the results.

The limitation of this study is to evaluate the shaping abilities of the instruments in *in vitro* conditions. The results were limited with the teeth undertaken in this study. And another important limitation point is to evaluate the instruments with very different properties like blade design, tapers, alloys etc. This could cause lots of variables that should affect the results however, for simulating the clinical conditions this confounding factors should be accepted prior to study. So in this study, many assumptions supported with the literature were required to accept to interpret the results. Further researches is necessary to investigate the differences with the constant variables.

Conclusion

As conclusion, (i)changing in root canal curvature was occurred in all systems when the apical size increased. Within the limitation of this in vitro study, (ii)clinicians should be aware of more tapered files can cause more straigtening. And while the apical tip size various to clinical conditions PTG or RS can be preferable than PTN or BR in the apical size 40. Further research may be achieved to evaluate different variables such blade design, taper or alloy etc. effects on root canal straightening of different systems or clinical importance of the amount of straightening.

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Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with, and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

This study has been approved by Selçuk University, School of Dentistry, Non Clinical Research Ethical Committee (2014/3).

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