A Comparative Study Of ProTaper Universal And ProTaper Next Used By Undergraduate Students To Prepare Root Canals

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Abstract

Aim

To determine whether final-year undergraduate dental students achieved better shaping outcomes using the new ProTaper Next system (PTN) to prepare root canals for the first time compared with the existing ProTaper Universal system (PTU) on which they had trained. A secondary aim was to explore the attitudes and preferences of the students to both systems.

Materials and Methods

Forty students prepared one simulated S-shaped canal using PTN and another with PTU. Images of the canals were saved before and after preparation, and the outcomes assessed included the formation of aberrations and the amount of resin removed at specific points along the canal length. Student opinions relating to PTN and PTU were collected via a questionnaire completed immediately after using the systems. For statistical analysis, the McNemar test was used to compare the incidence of aberrations, and a paired *t*-test was used to analyse the width measurements. Responses to the questionnaire were analysed using frequencies. Thus, McNemar's test was used for paired binary data and the marginal homogeneity test for categorical data when more than two categories was used. Finally, the overall preferences (either PTN or PTU) were analyzed using the sign / binomial test, which is a standard statistical test that allows us to determine if the proportion preferring one or the other is equal or not.

Results

Canal ledges were formed in 30% of the canals prepared with PTU, whereas no ledges were formed with PTN ($P < 0.001$). A middle constriction, a form of canal aberration, was created by both systems, although it occurred significantly ($P = 0.006$) more often with PTN. The "number of files" was judged by students to be significantly higher ($P < 0.001$) for PTU compared to PTN. Even though using PTN for the first time, students were more likely to recommend the system to other students for preparing S-shaped canals than PTU ($P = 0.018$), and preferred to use PTN in the future ($P < 0.001$).

Conclusions

The students who had previous experience with the use of PTU were able to produce comparable shaping outcomes when they used PTN for the first time. For preparation of S-shaped canals, the students preferred PTN over PTU in terms of the number of files and would prefer to use it in future.

Key Words

Aberrations, canal transportation, middle constriction, ProTaper Next, ProTaper Universal, questionnaire, shaping ability, S-shaped canals, undergraduate students

Introduction

Outcome studies have revealed that root canal treatment is associated with success rates of over 80% when completed by specialists or graduate trainees (1-4), however, the estimated total success rates of primary root canal treatment performed by undergraduate students and general dentists were reported to be 68.4% and 64.4%, respectively (5). A 10-year longitudinal observational study on outcome and quality of root canal treatment performed by dentists in Denmark found that 42% of root filled teeth had apical periodontitis (6). The results also revealed that approximately 65% of teeth with root fillings of inadequate technical quality had apical periodontitis (6), and that inadequate root fillings were associated with decreased rates of tooth survival (6).

A comprehensive evaluation of the technical quality of root fillings provided by dentists with the use of hand files in England and Wales reported that these fillings did not comply with European guidelines (7). Poor technical quality of root fillings has also been reported in many studies that evaluated the performance of students when using hand files (8-11). Rafeek *et al.* (11) found that the percentage of "acceptable" root fillings was as low as 10.9%, which was close to the 13% reported previously (10).

NiTi rotary systems were introduced in the mid-1990s (12). When the first systems were tested in simulated canals, the results revealed that although minor canal transportation occurred (13), the overall postoperative shape was satisfactory (13-16). Furthermore, several laboratory studies reported the advantages of using NiTi rotary instruments over manual preparation with hand files both for experienced and inexperienced operators (17-19), however, other studies (20) reported that even with the use of NiTi instruments, the technical quality of root fillings performed by students was "poor" and that tooth type significantly affected the quality of root fillings. Preparation of curved root canals in molar teeth by students has been associated with procedural errors (21), and curvature of canals has been found to be one of the main factors linked with poor quality root fillings performed by students and dentists (21-23).

The European Society of Endodontology (ESE) has provided guidelines for the undergraduate curriculum in Endodontology in an attempt to improve standards of education and clinical training (24). Enhancing endodontic education in undergraduate programs is essential (25-27) and that includes incorporation of training on the use of newer instruments and techniques (28). Recently, the ProTaper Next (PTN) rotary system (Dentsply Sirona, Ballaigues, Switzerland) was marketed (29) and is one of the latest variations of the ProTaper (PT) rotary system. PTN is made of M-wire while the PTU system is made of conventional NiTi alloy. Furthermore, PTN has a cross-section of off-center rectangular design that is responsible for the "swaggering movement" of the file during rotation (29).

Although most of the available evidence on the shaping ability of PTN might support the superiority of PTN over PTU, this evidence is not generalized to students since all the studies that tested PTN involved a single experienced operator who performed the canal preparations (30-32). To date, no study has assessed either the performance of these systems or the preferences of students relating to the use of PTN to prepare curved root canals. Thus, the present study aimed to investigate the performance of students (final year) using PTN for the first time in comparison with the existing PTU system, which the students had used during their training. The study evaluated changes in canal shape and the incidence of aberrations, and it also obtained feedback from students on the perceived usefulness and preferences of using both rotary systems during preparation of simulated S-shaped canals. The null hypothesis is there is no significant difference between PTU and PTN in the shaping ability of S-shaped simulated canals and no significant difference in student feedback on the use of both systems.

Materials and Methods

This study was approved by the Research Ethics Committee of the School of Dentistry, Cardiff University, Cardiff, UK. It was designed in two parts (canal preparation and a questionnaire) that were conducted synchronously. Forty or approximately 60% of the final year Bachelor of Dental Surgery (BDS) students at Cardiff University (2015-2016 intake) were included. Each student prepared two simulated S-shaped canals contained within endodontic training blocks (Dentsply Sirona) with an apical diameter of 0.15 mm and a 0.02 taper. The first simulated block used by each student was prepared by either the PTN or the PTU system and the second simulated block was prepared by the other system. Thus, 80 identical simulated blocks were used in total.

Practical sessions

Laboratory sessions commenced with a slide presentation that included information on the purpose of the study, on how to prepare the canals, and on the use of the systems based on the manufacturers' instructions.

Rotational speed and torque were set according to the manufacturers' recommendations. Alcohol was used for canal irrigation and SlickGel ES (Kerr endodontics, Bioggio, Switzerland) was used as a lubricant. Canals were negotiated, and glide paths were confirmed using size 10 K-files to a working length of 16.5 mm. Preparation with PTU was completed up to F2 (size 25, 0.08 taper) while preparation with PTN was performed up to X2 (size 25, 0.06 taper). Stopwatches were given to each participant in order to record the preparation time.

Preoperative, intraoperative, and postoperative images of the canals were acquired using a video camera imaging system and standard set-up conditions (Panasonic F10 CCD, Osaka, Japan). For PTU, four images were taken: preoperative, intraoperative 1 after S2, intraoperative 2 after F1, and postoperative after F2. For PTN three images were taken, preoperative, intraoperative after X1 and postoperative after X2. All images were stored in a computer, and composite images were created using software (Image-Pro Plus, Media Cybernetics, Silver Springs, MD, USA).

Measurements

Image-Pro Plus software was used to measure the amount of resin removed 1 mm from the preparation end-point toward the outer side of the apical curvature (AR-1mm) (Fig. 1). Measurements were taken of the maximum amount of resin removed on the inner side of the apical curvature (Max-AC) and of the entire canal width at this level. Finally, measurements were taken of the minimum canal width between the two curvatures (Min-W).

Aberrations

An assessment was made of the presence and location of canal aberrations in the postoperative composite images. If a canal aberration was noted, its occurrence was traced back through the previous intraoperative composite images. If the canal width at Max-AC was found to be greater than the Min-W then this was taken to be an indication of the presence of a preparation error, which was termed a "middle constriction" (Figs. 1 and 2).

Questionnaire

The questionnaire included rating the systems for controllability, simplicity, effectiveness, cutting efficiency, sequence designation, and general personal opinions (Table 1) and these questions were asked separately for PTN and then PTU.

Data management and statistical analysis

Intra-class correlation coefficients were conducted on measurements to assess the intra-rater reliability, that is the variation in measuring canal widths at different points in time. Outcomes for the presence of aberrations were binary, and they were "paired" because each subject used either the PTN first and then PTU or (order reversed) PTU first and then PTN. McNemar's test is used in situations where the data is both paired and binary, where $P \geq 0.05$ indicated that the proportion of aberrations was the same for PTU as for PTN and $P < 0.05$ indicated that they were significantly different. Measurements and preparation time were also found for PTU and PTN for each subject, and data for these variables were also "paired". The differences in these paired measurements were normally distributed, and the paired *t*-test was used to detect significant differences between the two systems. The effect of system order was adjusted for by using mixed ANOVA.

All items in the questionnaire were analyzed using frequencies. Thus, McNemar's test was used for paired binary data or the marginal homogeneity test for categorical data when more than two categories was used. Finally, the overall preferences (PTN or PTU) were analyzed using the sign / binomial test, where $P \geq 0.05$ indicated that equal numbers of students preferred PTU compared to PTN (and vice versa) and $P < 0.05$ indicated that significantly more students preferred PTU compared to PTN (or vice versa). The sign / binomial test gives an exact *P*-value by using the binomial distribution and so it may be used even for very small sample sizes, in principle. All calculations were carried out using SPSS V20.

Results

Measurements

The intraclass correlation for single measures of the canal measurements was 0.975 (95% CI = 0.954 to 0.987), and for average measures was 0.988 (95% CI = 0.976 to 0.993). The estimate of the error between repeated measurements, approximate 5%, could be safely ignored.

Results for the width measurements at all points are shown in Table 2. The order (PTN first and then PTU or PTU first and then PTN) did not lead to significant effects in most cases. The amount of resin removed at Max-AC was significantly larger with PTN than with PTU ($P < 0.001$). The Min-W values were significantly larger for PTU compared to PTN ($P = 0.001$).

For the amount of resin removed 1 mm from the preparation end-point toward the outer side of the apical curvature (AR-1mm), all of the canals without ledges were prepared beyond the pre-determined preparation end-point, i.e. they were over-prepared. Canal transportation as an apical zip occurred at the preparation end-point toward the outer side of the apical curvature in 5 canals with PTU (out of 28; ≈ 18%) and 8 canals with PTN (out of 40; ≈ 20%).

Preparation time

The mean preparation time of PTU was 12 minutes and 52 seconds, which was significantly longer than the mean preparation time with PTN, 8 minutes and 6 seconds ($P < 0.001$) (Table 2).

Aberrations

Ledges occurred with PTU in 12 canals, but no ledges were formed with PTN. The McNemar's test indicated that there were significantly more ledges created using the PTU compared to the PTN ($P < 0.001$). The intraoperative composite images revealed that ledges in 11 of the 12 canals were formed with F2 files. In just one canal was the ledge formed with F1 files.

The creation of the middle constriction (Fig. 2) occurred in 29 out of 40 canals (i.e. 73%) for PTN and in 18 out of 40 (i.e. 45%) canals for PTU. The McNemar's test indicated that significantly more middle constrictions were created using PTN when compared to PTU ($P = 0.006$). In all of the canals prepared with PTN, the middle constriction was created first with X1 and continued with X2.

Other types of aberrations, such as perforation, apical blockage, and outer widening were not found. No instrument fractures occurred.

Questionnaire

Table 1 demonstrates the questionnaire results. The students perceived that the number of files of the PTU system was significantly higher than that of PTN ($P < 0.001$). The students reported they would recommend to other students the PTN system over the use of PTU in preparation of S-shaped canals ($P = 0.018$), and they also preferred to use PTN in the future ($P < 0.001$).

Discussion

The aim of this study was to determine whether the first use of PTN by final year Bachelor of Dental Surgery (BDS) students to prepare simulated canals achieved better shaping outcomes than the system that the students had been trained to use (PTU). In addition, the questionnaire was designed to determine which system they preferred.

The study was divided into two parts that were conducted synchronously. The first part assessed the shaping ability using simulated S-shaped canals. The results revealed that ledges were formed in 30% of the canals prepared with PTU whereas no ledges were formed with PTN ($P < 0.001$). A middle constriction was created by both systems, however, it occurred significantly more often with PTN than PTU ($P = 0.006$).

In the second part of the study, immediate feedback from the students was collected through a questionnaire. The results revealed that students preferred the number of files of PTN compared to PTU ($P < 0.001$)and were more likely to recommend PTN to other students for preparing S-shaped canals ($P = 0.018$), furthermore, they also preferred to use PTN in the future ($P < 0.001$).

Overall, the results of the study indicate that the null hypothesis was partially rejected in its two parts (subjectively and objectively), however, the students' feedback was in favor of the PTN files in most of the parameters.

S-shaped canals were used because they have a high degree of technical difficulty during treatment according to the case difficulty assessment as described by the AAE (33). This canal form represents one reason for the increased incidence of canal blockages and instrument fracture during canal preparation (34).

The order of canal preparation using the systems was reversed in the two groups of participants to eliminate 'experience' as a factor. There was very little if any, difference when the systems were used either first or second, and consequently, the results for each system were combined to give a total of 40 specimens per group.

Ledges occurred in 30% of the canals prepared with PTU whereas no ledges were formed with PTN. This difference is likely to be related to instrument flexibility. PTN is made of M-wire, which is more flexible whereas, PTU is made from traditional NiTi wire. The two systems are also different in their design with the PTU having a convex triangular cross-sectional design while the PTN is rectangular. The F2 instrument of the PTU has a fixed taper from D1 to D3 (0.08) whereas the X2 of the PTN is described as having an apical taper of 0.06 (29). In summary, the greater taper of the F1 and F2 instruments of the PTU system, combined with its alloy composition and its cross-sectional shape results in a stiffer instrument that is more prone to creating ledges (35).

An elbow-like aberration or *"middle constriction"* was also observed and recorded as a preparation error (Figure 2). It could have resulted from the tendency of instruments to straighten within the curved root canals, as they do in zip and elbow formation (36), however, it cannot be described as a zip and elbow where the elbow is a narrow portion at the point of maximum curvature of the root canal (37). In the present study the term *"middle constriction"* was used to refer to the canal region with reduced width (Min-W) between the apical and the coronal curvatures in comparison with the canal width at the apical curvature (canal width at Max-AC). This portion had a diameter less than the canal diameter at the apical curvature.

The results indicate that the creation of the middle constriction was significantly higher with PTN than PTU (P = 0.006). The results also revealed that PTN removed significantly more resin at Max-apical than PTU (P <0.001), and the Min-W values were significantly larger for PTU compared to PTN (P=0.001), which can explain the increased incidence of middle constrictions in canals prepared with PTN. Wu *et al.* (2015) reported that PTN and PTU straightened the apical curvature of the S-shaped simulated canals with no significant difference, however, the authors reported that PTN produced more transportation in the straight portion of L-shaped canals compared with PTU.

The more frequent creation of this error with PTN (72% of the canals) might be related to the difference in taper between the two systems, especially the last instrument used (X2 0.06; F2 0.08). Another possible explanation is the effect of the off-center cross-sectional design on PTN movement during canal preparation, especially at the second curvature of the S-shaped canals where the *"swaggering movement"* may become exaggerated. The overall flexibility and movement of PTN may have an unfavorable impact on the preparation outcome especially in S-shaped canals, however, studies on natural teeth found that the PTN produced significantly less canal transportation compared with PTU (38,39).

Student perceptions of the PTN and PTU systems were explored in the questionnaire and results are shown in Table 1. In response to Q1 “which part of the canal was difficult to prepare?” noticeably, 17 (42.5%) of students responded that no part of the canal was difficult to prepare for PTN, whereas only 5 (12.5%) responded in the same way for PTU. Responses were broadly similar for the PTN and PTU for Q2: “Which stage of the canal preparation was easy to perform?” Nine or 22.5% responded that no stage was difficult to prepare for PTN, whereas, no students responded that any part of the canal was difficult to prepare for PTU. This indicates a higher level of perceived difficulty when using PTU compared to PTN, although responses to these questions were not significantly different (Q1 (P=0.138), Q2 ($P = 0.098$)).

The results revealed that students preferred the number of files of PTN compared to PTU ($P < 0.00$), and there was a trend for more students rating PTN as safer than PTU.

Interestingly, a greater percentage of the students selected PTN as the system that they would use in the future (34 students, 85%) compared to the only 5 (12.5%) students who selected PTU. The difference between the two systems was significant ($P < 0.001$), and the main reasons for selection of PTN were technical reasons such as preparation time and number of files.

Conclusion

- Canal ledges were formed in 30% of the canals prepared with PTU whereas no ledges were formed with PTN.
- A middle constriction was formed with both systems, however, it occurred significantly more often with PTN.
- There was no significant difference reported by the students in perceived difficulty when using PTU and PTN.
- The students reported significantly more acceptance for the number of files with PTN than PTU.
- The students recommended the use of PTN to other students for preparation of S-shaped canals significantly more often than the use of PTU.
- The students preferred to use PTN in the future significantly more than PTU.

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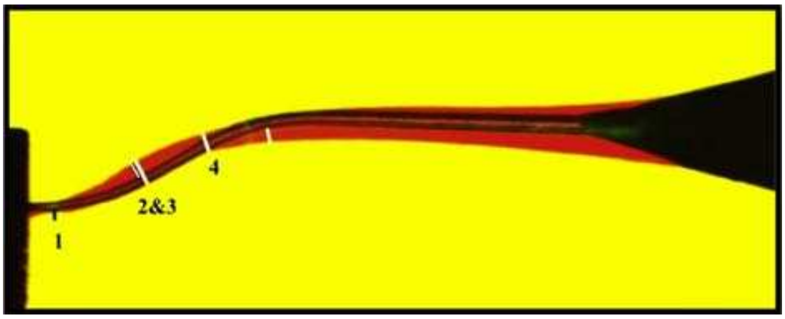

Figure 1: The measuring points: (1) 1 mm from the preparation end point toward the outer side of the apical curvature, (2) Max-AC, (3) the entire canal width at Max-AC, and (4) Min-W.

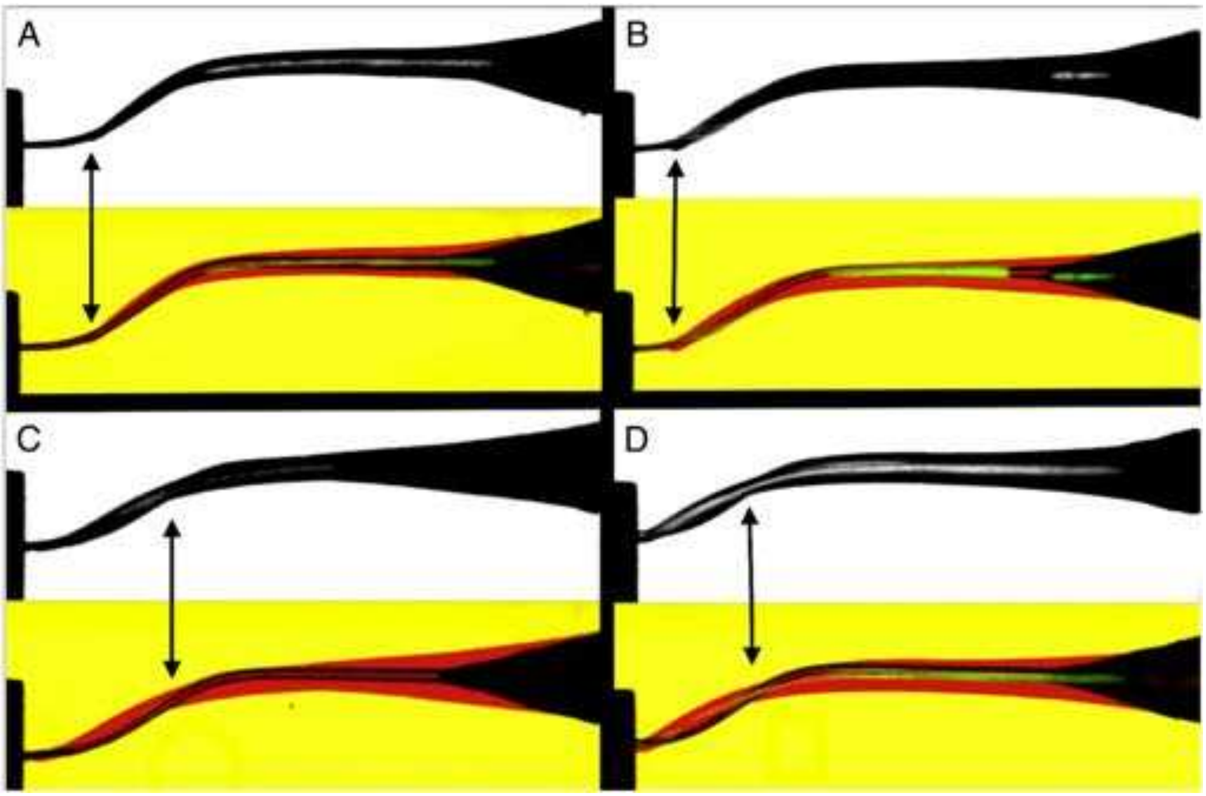

Figure 2: Postoperative images (black and white), preoperative-postoperative composite image (colored). The red color represents the amount of resin removed. Two degrees of ledge formation (A) and (B), the black arrows indicate the ledge positions. (C) and (D) are showing the position of the middle constriction (minimum canal width).

TABLE 1. Results of the Questionnaire (Marginal Homogeneity Test [Exact, 2-tailed], McNemar Test [Exact, 2-tailed], and Exact Binomial/Sign Test Comparing Number Responding ProTaper Universal [PTU] against Number Responding ProTaper Next [PTN])

Which part of the canal was difficult to prepare?

	Coronal	Apical	None	Both Apical & Coronal	
PTU	3 (7.5%)	30 (75%)	5 (12.5%)	2 (5%)	*P* = 0.138
PTN	2 (5%)	21 (52.5%)	17 (42.5%)	0 (0%)	

Which stage of the canal preparation was easy to perform?

	Shaping	Finishing	None	Both shaping & finishing	
PTU	13 (32.5%)	14 (35%)	9 (22.5%)	4 (10%)	*P* = 0.098
PTN	10 (25%)	15 (37.5%)	0 (0%)	15 (37.5%)	

Number of files

	Highly acceptable	Acceptable	Many	Too many	Missing	
PTU	2 (5%)	24 (60%)	9 (22.5%)	5 (12.5%)	0 (0%)	$P < 0.001$
PTN	34 (85%)	5 (12.5%)	0 (0%)	0 (0%)	1 (2.5%)	

Rate from 1 to 4 according to its safe cutting

	Extremely unsafe	Unsafe	Safe	Extremely safe	Missing
PTU: S1	15 (37.5%)	10 (25%)	5 (12.%)	9 (22.%)	1 (2.5%)
PTU: S2	8 (20%)	17 (42.5%)	9 (22.5%)	5 (12.5%)	1 (2.5%)
PTU: F1	13 (32.5%)	16 (40%)	8 (20%)	2 (5%)	1 (2.5%)
PTU: F2	17 (42.5%)	9 (22.5%)	7 (17.5%)	6 (15%)	1 (2.5%)
PTN: X1	18 (45%)	16 (40%)	4 (10%)	0 (0%)	2 (5%)
PTN: X2	23 (57.5%)	15 (37.5%)	0 (0%)	0 (0%)	2 (5%)

Are you generally satisfied with the use of this system?

	Yes	No	
PTU	34 (85%)	6 (15%)	*P* = 0.164
PTN	37 (92.5%)	3 (7.5%)	

Do you recommend that other students use this system when preparing S-shaped canals?

	Yes	No	
PTU	27 (67.5%)	13 (32.5%)	*P* = 0.018
PTN	36 (90%)	4 (10%)	

Which system do you recommend for the students to use during their training?

PTU	PTN	Both	
16 (40%)	20 (50%)	4 (10%)	*P* = 0.618

Which system do you prefer to use in the future?

PTU	PTN	Missing	
5 (12.5%)	34 (85%)	1 (2.5%)	$P < 0.001$

TABLE 2. Results for the Measurements Made in Images of S-shaped Canals (n = 40 for All Cases)

	PTU		PTN		PTU – PTN			*P* =	
	Mean	SD	Mean	SD	Diff.	95% LCI	95% UCI	Paired *t*-test	ANOVA
AR-1mm (mm)	0.059	0.040	0.071	0.083	-0.001	-0.013	0.010	0.795	0.781
Max-AC (mm)	0.227	0.079	0.300	0.106	-0.073	-0.109	-0.037	< 0.001	< 0.001
The entire canal width at Max-AC (mm)	0.497	0.073	0.570	0.103	-0.073	-0.110	-0.036	< 0.001	< 0.001
Min-W (mm)	0.520	0.049	0.493	0.036	0.027	0.013	0.042	0.001	0.001
Preparation time (seconds)	772.300	314.569	486.575	265.034	285.725	204.389	367.061	< 0.001	< 0.001

ANOVA, analysis of variance; AR-1 mm, 1 mm from the preparation end point toward the outer side of the apical curvature; LCI, lower confidence interval; Max-AC, the maximum amount of resin removed on the inner side of the apical curvature; Min-W, the minimum canal width between the 2 curvatures; PTN, ProTaper Next; PTU, ProTaper Universal; SD, standard deviation; UCI, upper confidence interval. Results of the paired t test and results for the equivalent repeated measures factor via mixed analysis of variance are also given.