

ORIGINAL ARTICLE

Comparison of single cone obturation performance of different novel nickel-titanium rotary systemsISMAIL DAVUT CAPAR¹, HÜSEYİN ERTAS¹, EVREN OK² & HAKAN ARSLAN¹¹Department of Endodontics, Faculty of Dentistry, İzmir Katip Çelebi University, İzmir, Turkey, and²Department of Endodontics, Faculty of Dentistry, Şifa University, İzmir, Turkey**Abstract**

Objectives. The purpose of this study was to compare several different single-cone obturations in the gutta-percha-filled areas (PGFA), sealer-filled areas (PSFA) and voids, also determining the volumetric characteristics of the tested cones. **Materials and methods.** Curved mesial roots of 120 mandibular molars were instrumented using several different systems (ProTaper Next, Twisted File Adaptive, OneShape, ProTaper Universal, WaveOne and Reciproc) and filled with corresponding single cones. The teeth were then sectioned horizontally at 2, 4, 6 and 8 mm from the apex. The area values of each section were calculated and converted to percentages (PGFA, PSFA and voids) of the total area. To determine volumetric characteristics of the tested cones, 20 gutta-percha points of each tested group were scanned with CBCT using the same parameters. **Results.** The ProTaper Next and WaveOne groups presented the most PGFA and least PSFA. The Twisted File Adaptive group presented the least PGFA and most PSFA ($p < 0.05$) and the least gutta-percha volume. **Conclusions.** The Twisted File Adaptive system matched cones had the least volume and the least PGFA in severely curved mesiobuccal canals of mandibular first molars. Single matched cones volume varied.

Key Words: CBCT, gutta-percha filled area, ProTaper Next, single-cone obturation, Twisted File Adaptive**Introduction**

Three-dimensional obturation of the root canal system is essential for success in endodontic treatment [1]. Root canal obturation has historically been successful using gutta-percha and a sealer. Gutta-percha is an inert material [2]; however, some endodontic sealers dissolve over time [3]. Therefore, the amount of sealer should be kept to a minimum for optimal results [4]. This can be achieved by adapting the gutta-percha to the root canal space as much as possible. Several techniques combining gutta-percha and sealers, such as thermoplasticized gutta-percha, cold lateral compaction of gutta-percha and single-cone gutta-percha have been recommended to achieve effective adaptability of the root canal filling [5].

Technological advancements in nickel-titanium (Ni-Ti) instruments have led to new concepts of root-canal shaping and obturation. The use of special single gutta-percha points corresponding to the rotary Ni-Ti instruments provides a 3-dimensional

obturation in less time than traditional obturation techniques [6,7]. Among these, the ProTaper Next file is a novel NiTi file system that has an off-centered asymmetric design, which generates a swaggering effect along its active portion. With the aid of this new design technology, the ProTaper Next files are capable of cutting a larger envelope of motion, compared to a similarly sized file with a symmetrical mass and axis of rotation. One recent study [8] has revealed that some single special cones produced different results, with regard to the percentage of gutta-percha-filled areas (PGFA). However, matched cones of the ProTaper Next, Twisted File Adaptive and OneShape systems have not yet been compared, with respect to PGFA.

Several investigations have also reported standardization problems, both in root canal instruments and gutta-percha cones [9–13]. Previous studies have primarily focused on the dimensional variability of gutta-percha cones in two dimensions [9–11,13]. To our knowledge, no studies evaluating volumetric

characteristics of the single corresponding cones have been published to date.

Preparation of a curved canal may cause canal transportation, and subsequently result in a root canal shape that does not match the corresponding gutta-percha cones [14–16]. This could result in voids on the outer wall of the curve. Thus, the recently introduced single-cones should be evaluated in curved root canals [17].

Therefore, we had two aims; (1) to compare different single-cone obturations (ProTaper Next, Twisted File Adaptive, OneShape, ProTaper Universal, WaveOne, and Reciproc) with respect to the PGFA, sealer-filled areas (PSFA), and voids in severely curved mesiobuccal canals of extracted mandibular first molars, and (2) to determine the volumetric characteristics of the tested cones, which had a #25 tip diameter and a taper of 0.06. Our null hypotheses were that (1) there are no difference in different single-cone obturations, with respect to the PGFA, PSFA, and voids and (2) there is no difference between the volumetric characteristics of the tested cones.

Materials and methods

Curved mesial roots of mandibular molars, which were extracted for reasons unrelated to this study, were used. Radiographs of teeth in both buccolingual and mesiodistal directions were taken to select the samples. Only teeth with two separated mesial canals, no significant calcifications and an angle of curvature ranging from 20–40° were included.

One hundred and twenty teeth were fixed in a silicone impression material and scanned for morphometric evaluation of the pre-instrumented root canals by using cone-beam computed tomography (CBCT; NewTom 5G[®]; QR, Verona, Italy). 8 × 8 cm field of view was preferred with high resolution denture scan mode, using a 36 s scanning time and 5.4 s exposure time. Tube potential and tube current were automatically determined from scout views by the CBCT machine. Axial slice thickness was 0.075 mm, with a pixel size of 0.075 mm.

CBCT images of the samples were analyzed with NNT software using a Dell Precision T5400 workstation (Dell, Round Rock, TX). Mesiobuccal canal curvature angles of the teeth were measured according to Estrela et al. [18]. The specimens were allocated to one of six groups ($n = 20$), on the basis of canal curvature angle and radius.

Before instrumentation, mesiobuccal canals of each specimen were traced and the total volume was measured. Volumetric measurements were obtained by using Simplant Pro15 software (Materialise Dental n.v., Leuven, Belgium). The distribution of teeth among the six groups for pre-instrumentation canal curvature, radius and volume was assessed by using

analysis of variance (ANOVA). Statistical analysis revealed that there was no statistically significant difference between the groups, with regard to the canal curvature ($p = 1.000$), radius ($p = 0.989$) and volume ($p = 0.083$).

Teeth were accessed with a diamond bur and the working length determination of mesiobuccal canals was determined by inserting a size 10 K-type file into the root canal terminus and subtracting 1 mm from this measurement. A glide path was performed via a size 15 K-type file. RC-Prep (Premier Dental Products, Plymouth Meeting, PA) was used in all canal preparations and the root canal was irrigated with 2 mL of 2.5% NaOCl solution after each instrument change. Each instrument was used in four canals. Apical preparation was completed with a size #25 instrument using the instrument order as specified by the manufacturer. With the exception of the Twisted File Adaptive groups, all instruments were operated with a low-torque motor (VDW Silver; VDW, Munich, Germany). TFA groups were operated with their own motor (Elements Motor; Sybron Endo, Orange, CA). The preparation sequences were as follows.

We used the individual rotational speed and torque limit programmed in the file library of the motor for each ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) file. The sequence of files was as follows: SX, S1, S2, F1 and F2 (size 25). The first three shaping files were used with a brushing motion away from the root concavities before light resistance was encountered and the last two finishing files were used with a non-brushing action until the working length was reached.

- *OneShape* (MicroMega, Besancon, France) file having a taper of 0.06 and size of #25 was used with in-and-out movements without pressure at a rotational speed of 400 rpm and 400 g/cm torque.
- *Reciproc R25* (VDW, Munich, Germany) file was used with the Reciproc program of the motor. The file was used in a slow in-and-out pecking motion.
- *ProTaper Next* (Dentsply Maillefer) files were used with the sequence PU SX, PN X1 and X2 at a rotational speed of 300 rpm and 200 g/cm torque. Each file was used with a brushing motion similar to the PU files.
- *Twisted File Adaptive* (Sybron Endo, Orange, CA) instruments were used with the Twisted File Adaptive program of their motor in a sequence of SM1 and SM2. The file was advanced to the canal with a single controlled motion until it engaged dentin.
- *WaveOne primary* (Dentsply Tulsa Dental Specialties, Tulsa, OK) file was used similar to the Reciproc group with the WaveOne program of the motor.

Following instrumentation each canal was flushed with 10 mL of 17% EDTA and 10 mL of NaOCl and then dried with paper points. The matched gutta-

percha points of each system were used for obturation, with the exception of the OneShape system. The OneShape system did not have a matched gutta-percha cone. Therefore, in the OneShape group, a group size of #25 and 0.06 tapered cones (Micro-Mega) that were a similar shape to the OneShape instruments were used. Before obturation small amounts of sealer were applied to the canal by using a K-file size #25 in a counter-clockwise rotation. In all groups, AH Plus (Dentsply De-Trey, Konstanz, Germany) was mixed according to the manufacturer's instructions, single cones were coated with sealer and placed into the root canal to the working length.

After completion of obturation procedures, a heated plugger was used to remove the coronal excess gutta-percha, with no further vertical compaction. The teeth were then kept at 37°C with 100% humidity for 7 days to allow the sealer to set.

The teeth were sectioned horizontally with a low-speed saw (Isomet, Buehler Ltd, Lake Bluff, IL) under water cooling at 2, 4, 6 and 8 mm from the apex (Figure 1). Digital images at 40× magnification were obtained using a stereomicroscope (Olympus BX43, Olympus Co., Tokyo, Japan) attached to a digital camera and were transferred to the computer. On these digital images, the total area of each canal segment, of gutta-percha, sealer and voids were measured. Measurements were repeated twice for each section and the means were calculated. The average area values of each section were converted to percentages (PGFA, PSFA and voids) of the total area. The average data of each tooth were also evaluated using the values of four segments.

To determine the volumetric characteristics of the tested cones, 20 gutta-percha points from each tested group were scanned with CBCT using the same parameters. Each specimen was traced 8, 16 and 25 mm from the apical tip and the volumes were measured (Figure 2).

PGFA, PSFA and volumetric data showed a parametric distribution; thus, ANOVA and the Tukey test were used to make comparisons among groups. The data of percentage of voids were non-parametric; thus, the Kruskal–Wallis test was used to compare the groups. The significance level was set at $p = 0.05$. Statistical analysis was performed with SPSS Statistics Version 20 for Windows (IBM, Chicago, IL).



Figure 1. Representative images of single cone obturations at 2, 4, 6 and 8 mm from the apex (WaveOne Group).

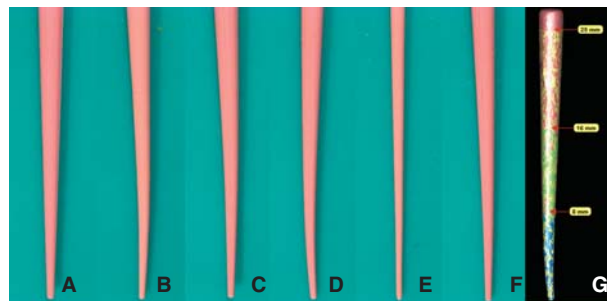


Figure 2. Stereomicroscopic images of the tested gutta percha cones at 10× magnification for (A) ProTaper Universal, (B) OneShape, (C) Reciproc, (D) ProTaper Next, (E) Twisted File Adaptive and (F) WaveOne groups. (G) Representative image for volumetric measurements of gutta percha cone at 8, 16 and 25 mm from the apical tip.

Results

The results for PGFA, PSFA and voids are shown in Table I. At all levels, no significant differences were found among groups regarding percentage of voids ($p > 0.05$). Most of the samples did not show any voids at all levels.

At the 2-mm level, the Twisted File Adaptive and Reciproc groups demonstrated the least PGFA and most PSFA of all the groups ($p < 0.05$). However, there were no statistically significant differences between the Twisted File Adaptive and Reciproc groups ($p > 0.05$). There were also no statistically significant differences between the ProTaper, OneShape, ProTaper Next and WaveOne groups ($p > 0.05$).

At the 4-mm level, OneShape, ProTaper Next and WaveOne showed higher PGFA and lower PSFA than all other groups ($p < 0.05$), but there were no significant differences between them ($p > 0.05$). The ProTaper group showed significantly higher PGFA and lower PSFA than the Twisted File Adaptive group ($p = 0.005$ for PGFA and $p = 0.002$ for PSFA).

At the 6-mm level, the ProTaper Next and WaveOne groups demonstrated the highest PGFA and lowest PSFA of all the groups ($p < 0.05$), with no significant differences between them ($p > 0.05$). The Twisted File Adaptive group presented the least PGFA and highest PSFA among the groups. The other groups did not show any significant differences (Figure 3).

At the 8-mm level, the Twisted File Adaptive group showed the least PGFA ($p < 0.001$) and the most PSFA of all the groups ($p < 0.001$). The remaining groups did not show any significant differences ($p > 0.05$).

With respect to average data of four segments, the ProTaper Next and WaveOne groups showed the most PGFA and the least PSFA among the groups ($p < 0.05$) and these two groups demonstrated similar PGFA and PSFA to the OneShape group ($p > 0.05$). The ProTaper and OneShape groups showed higher PGFA and lower PSFA than the Reciproc and

Table I. Mean and standard deviation of the different groups with regard to the percentage of gutta-percha-filled areas (GP), sealer and voids.

		Protaper	OneShape	Reciproc	Protaper Next	TFA	Wave One	p-value
2 mm	GP	82.1 ± 10.6 ^a	82.6 ± 6.0 ^a	71.8 ± 8.0 ^b	86.7 ± 4.1 ^a	75.5 ± 5.6 ^b	85.2 ± 5.9 ^a	0.000
	Sealer	17.1 ± 11.2 ^{ab}	16.1 ± 8.5 ^{ab}	26 ± 7.7 ^c	12.3 ± 4.3 ^a	22.7 ± 7.6 ^{bc}	14.1 ± 5.6 ^a	0.000
	Voids	0.9 ± 2.2	1.3 ± 4.9	2.2 ± 5.7	1.0 ± 3.2	1.8 ± 3.7	0.7 ± 1.5	0.888
4 mm	GP	78.4 ± 7.7 ^{ad}	85.7 ± 7.8 ^b	71.4 ± 9.1 ^{ac}	87.8 ± 4.0 ^b	69.2 ± 9.2 ^c	84.7 ± 8.6 ^{bd}	0.000
	Sealer	21 ± 7.9 ^{ac}	13.9 ± 7.7 ^{ab}	27 ± 7.7 ^{cd}	11.4 ± 4.3 ^b	29.9 ± 9.5 ^d	15 ± 8.4 ^{ab}	0.000
	Voids	0.6 ± 1.4	0.3 ± 1.1	1.6 ± 3.4	0.9 ± 3.0	0.9 ± 2.8	0.4 ± 0.9	0.744
6 mm	GP	78.6 ± 8.7 ^a	83.4 ± 5.5 ^{ab}	78.8 ± 8.2 ^a	85.9 ± 3.3 ^b	63.4 ± 4.5 ^c	87.7 ± 5.3 ^b	0.000
	Sealer	21 ± 8.6 ^a	16.3 ± 5.5 ^{ab}	20.9 ± 8.3 ^a	13.4 ± 4.4 ^b	35.7 ± 4.2 ^c	11.1 ± 5.0 ^b	0.000
	Voids	0.4 ± 1.4	0.3 ± 0.7	0.3 ± 0.9	0.7 ± 2.8	0.8 ± 1.3	1.3 ± 1.9	0.140
8 mm	GP	85.2 ± 8.3 ^{ab}	83.8 ± 5.2 ^{ab}	82.8 ± 7.7 ^a	88.1 ± 4.2 ^{ab}	52.4 ± 7.2 ^c	89.5 ± 5.7 ^b	0.000
	Sealer	14.3 ± 7.8 ^{ab}	16 ± 5.1 ^{ab}	16.3 ± 8.0 ^b	11.4 ± 4.3 ^{ab}	47 ± 7.5 ^c	9.9 ± 5.9 ^a	0.000
	Voids	0.5 ± 1.8	0.2 ± 0.5	0.9 ± 1.8	0.5 ± 1.4	0.6 ± 2.1	0.6 ± 1.2	0.780
Total	GP	81.1 ± 6.3 ^a	83.9 ± 3.6 ^{ac}	76.2 ± 5.5 ^b	87.1 ± 1.9 ^c	65.2 ± 4.9 ^d	86.8 ± 4.6 ^c	0.000
	Sealer	18.4 ± 6.5 ^a	15.7 ± 3.4 ^{ac}	22.5 ± 4.7 ^b	12.1 ± 2.8 ^c	33.9 ± 4.7 ^d	12.5 ± 4.1 ^c	0.000
	Voids	0.6 ± 1.0	0.4 ± 0.5	1.3 ± 1.7	0.8 ± 2.0	1.0 ± 1.5	0.7 ± 0.7	0.219

*Different superscript letters indicate a significant difference between groups.

Twisted File Adaptive groups, with no significant differences between them ($p > 0.05$). The Twisted File Adaptive group demonstrated the least PGFA ($p < 0.001$) and most PSFA among the groups ($p < 0.001$).

The results for gutta-percha volume are shown in Table II. The Twisted File Adaptive group showed the least gutta-percha volume at all levels (Figure 2).

Discussion

The present study showed that the volume of matched gutta-percha cones of Twisted File Adaptive SM 2 instruments was lower than Micromega's similarly sized and tapered cones (size #25 and 0.06 taper), as well as those of other tested systems at all levels

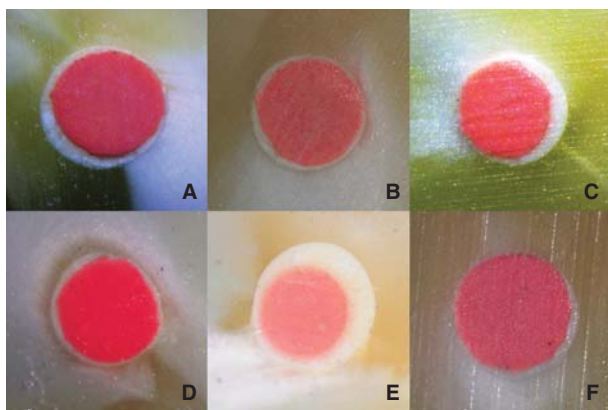


Figure 3. Cross-section of root canal obturation with different single cones at 6 mm from the apex for (A) ProTaper Universal, (B) OneShape, (C) Reciproc, (D) ProTaper Next, (E) Twisted File Adaptive and (F) WaveOne groups.

(Figure 2). In accordance with this, the Twisted File Adaptive group showed the least PGFA among all groups (Figure 3). Therefore, we can reject the null hypothesis that there is no difference in different single-cone obturations, with respect to the PGFA, PSFA and voids. The results revealed that the Reciproc group demonstrated the second-lowest PGFA, with respect to the average data of four segments. However, the volume of the Reciproc systems matched cones was not particularly low at 8 mm, as the Twisted File systems matched the cones. This might be due to the cross-sectional design of the Reciproc file, which possesses a double-cutting edge S-shaped geometry that provides high cutting efficacy.

In contrast with our findings, Schafer et al. [8] reported that use of single-cone techniques that used constant tapered gutta-percha resulted in higher PGFA than use of variable tapered gutta-percha

Table II. Mean and standard deviation of the different groups with respect to volumetric characteristics (mm^3) of the gutta-percha cones at 8 mm, 16 mm and 25 mm from the tip.

	8 mm	16 mm	25 mm
Protaper	2 ± 0.07 ^a	7.1 ± 0.24 ^a	17.3 ± 0.74 ^a
OneShape	1.8 ± 0.10 ^b	6.5 ± 0.28 ^{bc}	16.9 ± 0.43 ^{ad}
Reciproc	1.8 ± 0.08 ^b	6.5 ± 0.12 ^{cd}	16.9 ± 0.14 ^{ad}
Protaper Next	1.8 ± 0.04 ^b	6.3 ± 0.22 ^d	15.3 ± 0.32 ^b
TFA	1.2 ± 0.02 ^c	3.7 ± 0.06 ^e	8.18 ± 0.29 ^c
WaveOne	1.9 ± 0.03 ^a	6.7 ± 0.16 ^b	16.5 ± 0.57 ^d

*Different superscript letters indicate a significant difference between groups.

cones. This can be explained by the experimental design of the studies. The authors used mandibular central incisors with straight root canals and did not use instruments of the same size. In contrast, we used curved mesial roots of mandibular molars and used the same size of instruments.

We showed that matched cones of ProTaper Next files resulted in the most PGFA and least PSFA among the groups. This indicates that the matched cone of ProTaper Next is suitable, with its file that makes a swaggering motion.

In the present study, we found no significant differences between the different single cones, with regard to percentage of voids at all levels. This is corroborated by previous research [19], which showed that the apical leakage of matched single cone techniques was similar. The percentage of voids for all groups was very low, which was similar to the results of a study by Hammad et al. [20], who used micro-computed tomography. However; the method we used might cause unobserved smearing of the obturation during sectioning of the teeth, which may have influenced accurate measurement of small void areas [21]. Previously, the sectioning procedures were made under water cooling to reduce smearing of the obturation [2,22]. In the present study, the sectioning was performed under water cooling.

In the present study, all canals were instrumented to the same apical size. However, the taper of each system was varied. Two of these systems have constant tapered single cones (Twisted File Adaptive and OneShape); the others have variable tapered single cones. Reciproc R25, WaveOne primary and ProTaper Universal F2 files have a taper of 0.08 at the first 3 mm of apical tip. The other part of these files has tapers of decreasing percentage. However, the ProTaper Next X2 file has a taper of 0.06 at the first 3 mm of apical tip, and the other parts of the file have both increasing and decreasing percentage tapers. Previous studies have documented wide variability for the manufacturer's stated gutta-percha cone diameter and taper [9,10]. In the present study the Twisted File Adaptive group showed the least PGFA among all the groups studied. This could have originated from the difference in the volumetric sizes of the gutta-percha cones. Therefore, we also aimed to determine the volumetric characteristics of the tested cones, which had a size #25 tip diameter and a taper of 0.06. Our results showed that the Twisted File Adaptive group demonstrated the lowest gutta-percha volume at all levels. Therefore, we can reject the null hypothesis that there were no differences between the volumetric characteristics of the tested cones.

The use of matched gutta-percha cones relies on the original canal shape and the capacity to create a tapered circular preparation. The use of the matched cones would commonly be suitable for the cases of mesial and distal roots of maxillary molars that are

small in diameter, and the mesial roots of mandibular molars. However, oval-shaped and root canals with larger diameters are not suitable for matched single cones, which require excessive preparation with thick and more tapered instruments to fit the cones to the root canal [6].

Conclusion

The volume of single matched cones, which were of the same size and had constant or variable tapered cones, was varied. The matched cones of the Twisted File Adaptive system had the least volume and the least PGFA in severely curved mesiobuccal canals of mandibular first molars. There was no significant difference among the tested cones with respect to percentage of voids.

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Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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