

# Canal Transportation and Centering Ability in Long Oval Canals: A Multidimensional Analysis

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## ABSTRACT

**Introduction:** The purpose of this study was to evaluate and compare the centering ability and canal transportation of the ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) and Self-adjusting File (SAF; ReDent-Nova, Ra'anana, Israel) systems in long oval root canals using cone-beam computed tomography imaging. **Methods:** Fifty-six fully formed single-rooted mandibular premolars were selected with a buccolingual canal size 2 to 2.5 times the mesiodistal size at 5 mm from the apex, ranging from a 0°–10° canal curvature with a 5- to 6-mm radius. The teeth were divided into 2 groups ( $n = 28$ ) and prepared with PTN or SAF according to the manufacturers' instructions. Cone-beam computed tomographic images were taken in the same position before and after instrumentation using modeling wax. The centering ability and canal transportation were calculated at 3, 6, and 9 mm from the apex in both mesiodistal and buccolingual directions. The mean and standard deviation were calculated, and the Student  $t$  test was used for comparative analysis. **Results:** significant difference for canal transportation was observed mesiodistally at 9 mm from the apex ( $P < .05$ ) where the PTN shaved more dentin in 1 direction. A significant difference for the centering ability was observed at 6 mm buccolingually from the apex ( $P < .05$ ) where the PTN was less centered in the canal compared with the SAF. **Conclusions:** Both SAF and PTN were shown to be safe for being used in long oval canals. SAF resulted in less transportation at the coronal third in the mesiodistal direction and more centered at the middle third in the buccolingual direction compared with PTN. (*J Endod* 2019; ■:1–6.)

## KEY WORDS

Centering ability; cone-beam computed tomography; oval canal; ProTaper Next; Self-adjusting File; transportation

The primary aim of root canal treatment is to eliminate bacteria and dentinal debris and adequately prepare canals through mechanical instrumentation, disinfection, and adequate filling of the root canal system<sup>1</sup>. Maintaining the original root canal configuration is 1 of the main technical goals that should be achieved during the treatment<sup>2</sup>.

Although complete debridement of the root canal is essential to guarantee a successful outcome<sup>3,4</sup>, none of the available instruments can adequately prepare the anatomic variations of the root canal system, especially oval root canals<sup>5,6</sup>. Studies suggest that oval root canals are frequently present in the apical third of the tooth<sup>7–9</sup>. They are estimated to account for about 25% in the apical 5 mm of human teeth, of which more than 50% are reported to be in the maxillary second premolars and the mandibular incisors and 25%–30% in the distal root of the mandibular molars<sup>5</sup>.

These anatomic variations represent a great challenge for clinicians during chemomechanical preparation of the root canal system because uninstrumented recesses and debris might be left within the canal, leading to a higher risk of root canal treatment failure<sup>9–12</sup>. Many studies have shown that the Self-adjusting File (SAF; ReDent-Nova, Ra'anana, Israel) system can safely and effectively prepare oval canals<sup>6,13</sup>. SAF, designed like a coronary stent of a slim nickel-titanium (NiTi) framework, hollow from the inside and rough from the outside, enables extreme compression<sup>1</sup>. The file is operated with a special

## SIGNIFICANCE

Mechanical preparation of long oval canals with both PTN and SAF results in canal transportation in mesiodistal and buccolingual directions. However, the resulting canal transportation is not clinically relevant. A safe preparation of oval root canals can be achieved with both file systems.

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RDT3 (ReDent-Nova) handpiece head and an irrigation pump, previously known as the VATEA system (ReDent-Nova), which allows the irrigant delivery throughout the hollow framework of the file while it prepares the root canal space<sup>1</sup>. It expands into the oval canals by adjusting to its anatomy and preparing the maximum surface by its unique movement and simultaneous irrigation<sup>6</sup>.

Continuous rotary systems have been used for the last 25 years. ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) belongs to the fifth-generation rotary shaping file systems. It is designed with an offset center of mass and rotation<sup>14</sup> and produces a mechanical wave of motion. According to the manufacturer, PTN produces less transportation than previous rotary NiTi instruments. M-Wire technology-based instruments apparently have increased flexibility and improved cyclic fatigue<sup>15</sup>. PTN instruments have an asymmetric design and include some advantages such as removal of debris coronally and a high resistance to cyclic fatigue<sup>16,17</sup>. PTN has been associated with less debris extrusion and less canal transportation when compared with other file systems, such as WaveOne (Dentsply Maillefer) BT-Race (FKG, La Chaux-de-Fonds, Switzerland), and ProTaper Universal (Dentsply Maillefer)<sup>18–21</sup>.

Previous studies have also shown a similar bacterial reduction between SAF and PTN in oval canals<sup>22</sup>. However, there appears to be no studies comparing PTN with SAF for canal centering ability and transportation. Consequently, the aim of the present study was to evaluate and compare canal transportation and the centering ability of PTN and SAF using cone-beam computed tomographic (CBCT) imaging in long oval root canals. The null hypothesis was that both systems resulted in the same canal centering ability and canal transportation.

## MATERIALS AND METHODS

Ninety-four extracted human mandibular premolars with fully developed roots were collected and then cleaned with ultrasonic scaling tips (Universal Tip No. 1, Satelec SAS, Acteon, France) for external calcifications and soft tissue remnants. A 10% buffered formalin solution was used to store the single-rooted teeth, which were handled according to the guidelines of the Occupational Safety and Health Administration and the Centers for Disease Control and Prevention.

Two preoperative radiographs were taken buccolingually and mesiodistally (RVG 5200; Carestream Dental LLC, Atlanta, GA). Only teeth with no previous endodontic treatment or caries and with a buccolingual

canal size of 2 to 2.5 times the mesiodistal canal size at 5 mm from the apex, measured with an inbuilt measuring tool (Kodak Dental Imaging Software v6.14.0; Carestream Dental LLC), were selected. Moreover, the selected teeth had a similar length ( $19 \pm 2$  mm) with an angle of curvature ranging from  $0^\circ$ – $10^\circ$  and a radius of curvature no less than 5–6 mm measured according to the Pruett method<sup>23</sup>. The final sample size was 56 teeth ( $N = 56$ ).

The access cavity was performed with a #4 round bur and an Endo-Z bur (Dentsply Maillefer). Patency was confirmed with a #10 K-file (Mani, Inc, Shioya, Japan). The cusps of the crowns were reduced with a straight diamond disc to standardize the working length of 12 mm with all samples. The working length (WL) was established and confirmed radiographically by inserting a #10 K-file up to the apical foramen and then subtracting 1 mm from that measurement. All the teeth were then randomly divided into 2 groups of 28 each. The teeth were first mounted on modeling wax (Prodent, Ratnagiri, India) to facilitate positioning, and then preoperative CBCT scans were taken (Kodak CS 9000 3D, Carestream Dental LLC) at 90 kV, 10 mA with a 5 cm  $\times$  5 cm field of view, 90- $\mu$ m resolution, and an exposure time of 18.6 seconds using CS 3D Imaging Software 3.3.9 (Carestream Dental LLC).

## Root Canal Preparation

A #15 K hand file (Mani, Inc) was used to prepare all the root canals to the determined WL.

SAF Group ( $n = 28$ ): The samples were prepared with SAF according to the manufacturer's instructions. Each sample was prepared with a 21-mm/1.5-mm file used once for each tooth. The glide path was achieved by inserting the SAF manually up to the WL, and, after confirmation, the samples were prepared using the EndoStation endodontic motor (ReDent-Nova) with an RDT3 handpiece at an operating frequency of 5000 oscillations/min. Small pecking motions were performed for 4 minutes at an irrigant flow rate of 4 mL/min with 4.25% sodium hypochlorite.

PTN Group ( $n = 28$ ): Samples were prepared using PTN (21 mm/X1, X2, and X3) and a torque control endodontic motor (X-Smart, Dentsply Maillefer) at 300 rpm and 3.2 Ncm. Three to 4 pecking motions were performed until the file reached the WL. After each pecking motion, the samples were irrigated with 4.25% sodium hypochlorite, and the file flutes were cleaned with a gauze soaked in 96% alcohol. Five milliliters of irrigant was used for each consecutive file to mimic the VATEA system flow rate.

After root canal preparation, postoperative CBCT scans were obtained

using the same parameters as those for the preoperative CBCT scans. Each tooth was placed in the same position before and after instrumentation. Images of the cross-sectional planes at 3, 6, and 9 mm from the apical end of the root before and after instrumentation were then analyzed for apical transportation and centering ability.

## Canal Transportation

Canal transportation was calculated by measuring the smallest distance from the margin of the uninstrumented samples to the border of the root and then comparing these lengths with the parameters obtained from the instrumented sample scans<sup>24</sup>. According to this formula, besides measuring the mesiodistal direction, the canal transportation was also measured for the buccolingual direction<sup>25</sup>.

1.  $(a_1 - a_2) - (b_1 - b_2)$
2.  $(c_1 - c_2) - (d_1 - d_2)$  (Fig. 1)

$a_1$ ,  $b_1$ ,  $c_1$ , and  $d_1$  are the shortest distances from the mesial, distal, buccal, and lingual edges of the root, respectively, to the related edges of the uninstrumented canal (Fig. 1), whereas  $a_2$ ,  $b_2$ ,  $c_2$ , and  $d_2$  are the shortest distances from the mesial, distal, buccal and lingual edges of the root, respectively, to the related edges of the instrumented canal (Fig. 1).

According to this formula, 0 indicates that no transportation occurred in the canal,<sup>24,26</sup> whereas positive and negative values show mesial or buccal and distal or lingual transportation, respectively<sup>25</sup>.

## Centering Ability

According to Gambill et al<sup>26</sup>, the mean centering ratio indicates the ability of the instrument to stay centered in the canal. Therefore, each section was calculated using the following ratios:

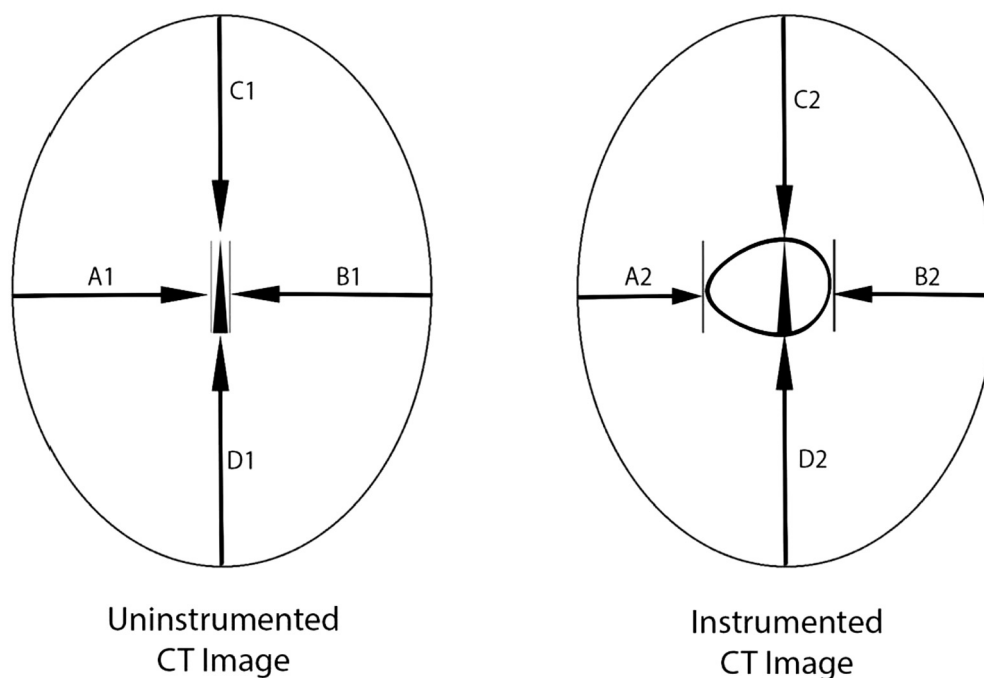
1.  $(a_1 - a_2)/(b_1 - b_2)$  or  $(b_1 - b_2)/(a_1 - a_2)$
2.  $(c_1 - c_2)/(d_1 - d_2)$  or  $(d_1 - d_2)/(c_1 - c_2)$

In the formulas shown, the value of 1 indicates complete centering, whereas any other value denotes changes in the canal pathway<sup>27</sup>. The mean and standard deviation were calculated for both groups separately in the mesiodistal and buccolingual directions and at 3 different levels from the apex (3, 6, and 9 mm).

## Statistical Methods

The 2 parameters, canal transportation and centering ability, were obtained for each tooth based on CBCT scan measurements. The statistical parameters, such as the mean and standard deviation of canal transportation and centering ability, were obtained for the 2

## Measurement for Image Cross Sections



**FIGURE 1** – A schematic representation of measurements of image cross sections.

groups. Statistical analysis was performed with SPSS software 12.0 (SPSS Inc, Chicago, IL). Because the Kolmogorov-Smirnov test did not reveal a normal distribution of results, the significance of difference of the mean canal transportation and centering ability between the 2 groups, in both directions at each distance, was tested statistically using the Mann-Whitney *U* test; the level of statistical significance was set at  $P < .05$ .

## RESULTS

### Canal Transportation

The mean values and standard deviation of canal transportation at the 3 different levels from the apex (3, 6, and 9 mm) of the SAF and PTN groups are shown in Table 1. The mean canal transportation values for the SAF group varied from  $-0.01$  to  $0.02$  mesiodistally and

$-0.01$  to  $0.00$  buccolingually. The mean values for the PTN group varied from  $-0.06$  to  $0.04$  mesiodistally and from  $-0.01$  to  $0.03$  buccolingually.

### Centering Ability

Table 2 shows the values of centering ability for both groups at the 3 different levels evaluated. The mean centering ability values for the SAF group varied from  $0.73$ – $0.79$  mesiodistally and  $0.68$ – $0.76$  buccolingually. Comparatively, the mean centering ability values for the PTN group varied from  $0.63$ – $0.73$  mesiodistally and  $0.53$ – $0.61$  buccolingually.

### Comparative Evaluation

According to the canal transportation (Table 1), a significant difference was observed mesiodistally at 9 mm from the apex ( $P < .05$ ). Both the files showed no significant differences

in the rest of the measurements performed. According to the centering ability (Table 2), a statistically significant difference was observed at 6 mm from the apex in the buccolingual direction ( $P < .05$ ).

## DISCUSSION

The main technical objective during root canal preparation is the development of a shape tapering from the apical to the coronal part while still maintaining the canal's original anatomic configuration<sup>27</sup>. The study aimed to evaluate the centering ability and canal transportation in long oval canals using the SAF and PTN file systems. The flatness of oval canals has been widely described in the literature to range from 25%–50%<sup>28</sup>. Unfortunately, because of the flatness of these oval canals, usually

**TABLE 1** - Means and Standard Deviation (mm) of Canal Transportation with *P* Values of the *t* Test for the Tested Groups

Distance from apex and direction	3 mm		6 mm		9 mm	
	BL	MD	BL	MD	BL	MD
SAF group	$-0.01 \pm 0.09$	$0.00 \pm 0.08$	$0.01 \pm 0.08$	$0.02 \pm 0.05$	$0.00 \pm 0.09$	$-0.01 \pm 0.09$
PTN group	$0.01 \pm 0.08$	$-0.06 \pm 0.08$	$0.03 \pm 0.11$	$0.04 \pm 0.10$	$0.01 \pm 0.12$	$-0.05 \pm 0.11$
<i>P</i> value	.46	.65	.37	.60	.78	.03*

BL, buccolingual; MD, mesiodistal; PTN, ProTaper Next; SAF, Self-adjusting File.

\*Significant at  $P < .05$ .

**TABLE 2** - Means and Standard Deviation (mm) of Centering Ability with *P* Values of the *t* Test for the Tested Groups

Distance from apex and direction	3 mm		6 mm		9 mm	
	BL	MD	BL	MD	BL	MD
SAF group	0.68 ± 0.19	0.73 ± 0.16	0.76 ± 0.19	0.79 ± 0.18	0.71 ± 0.26	0.75 ± 0.16
PTN group	0.56 ± 0.28	0.68 ± 0.22	0.53 ± 0.27	0.73 ± 0.20	0.61 ± 0.21	0.63 ± 0.22
<i>P</i> value	.12	.54	.00*	.28	.06	.66

BL, buccolingual; MD, mesiodistal; PTN, ProTaper Next; SAF, Self-adjusting File.

\*Significant at *P* < .05.

oriented in a buccolingual direction, they are frequently missed in 2-dimensional radiographs<sup>29</sup>. Chemomechanical preparation of such anatomy poses a great challenge to the clinician<sup>5</sup>. Therefore, long oval single mandibular canals were selected with a buccolingual size 2 to 2.5 times larger than the mesiodistal canal 5 mm from the apex.

CBCT imaging features a 3-dimensional radiographic technology that allows viewing of a tooth in all 3 planes of space rather than a predetermined "default" view<sup>30</sup>. The operator can choose slices of volumetric data, a requirement for measurements at 3 different levels; which, in this study, was used to view the tooth in all the orthogonal and nonorthogonal planes<sup>30</sup>. Images produced by a CBCT imaging system are geometrically accurate, and image measurements, in any plane, are made free from distortion<sup>30</sup>. This feature allows a nondestructive analysis of variables, like volume, surface area, cross-sectional outline, and taper of the root canal system<sup>31</sup>. Several studies have also used CBCT imaging as a measurement tool to evaluate the effect of different root canal preparation and instrumentation techniques<sup>25,32,33</sup>.

Simulated root canal resin blocks have been used in several studies to show the shaping ability of instruments and techniques of preparation of the canal space<sup>4,34–36</sup>. Nevertheless, the significance of the results of these studies is a concern because the hardness of dentin and resin is not the same<sup>37</sup>. In this study, the use of extracted human teeth may be considered as an advantage for the reproduction of the clinical setting<sup>4</sup>. For reproducibility and better comparison, PTN X3 was used in this study because its apical

diameter (#30) was similar to the apical diameter prepared by SAF 1.5 mm after 4 minutes (#30–#35)<sup>38</sup>.

In the present study, PTN produced more transportation than SAF only mesiodistally at 9 mm from the apex, which is not in concordance with the study of Shah et al<sup>29</sup>, who found less transportation at all 3 levels studied (3, 6, and 9 mm) with SAF when compared with the continuous rotation ProTaper Universal system. Rotary instruments with a solid metal core tend to prepare the canal in a rounded shape irrespective of the canal anatomy<sup>39,40</sup>. In oval canals, these instruments result in a round-shaped preparation, either in the center or toward 1 pole of the canal<sup>41</sup>.

In most of the published literature, canal transportation and centering ability have been evaluated in the mesiodistal direction only. However, the main goal of our study was to evaluate these measurements in multiple dimensions, mesiodistal as well as buccolingual<sup>42</sup>, in order to take full advantage of the CBCT 3-dimensional imaging technology.

The studied tolerable amount of canal transportation by any instrument in the apical third is in the range of 0.15–0.30 mm<sup>24,43,44</sup>. Both the file systems did not eliminate excess dentin in any direction and at any given levels mentioned in the present study. Nevertheless, a statistically significant difference was observed at 9 mm mesiodistally where PTN shaved more dentin distally compared with SAF.

The secondary objective of this study was to evaluate and compare the centering ability of both the file systems. An ideal instrumentation system should remove an equal amount of dentin from the canal walls,

offering effectiveness in cleaning and shaping and evading undesired overpreparation of the dentinal structure<sup>44,45</sup>. In the present study, instrumentation with SAF resulted in a more centered preparation only at 6 mm from the apex in the buccolingual direction compared with PTN (*P* < .05). This is in accordance with the study of Serefoglu and Piskin<sup>46</sup> in which no difference was found when preparing distal canals between a continuous rotation instrument and SAF. However, they also found that the uninstrumented area was higher after preparation with SAF<sup>46</sup>.

Both file systems were able to maintain the original canal shape without deviating from the acceptable range; the SAF appears to have adjusted to the shape of the root canal, whereas the PTN, being a rigid, robust, and circular file, might be the reason for shaving more dentin in 1 direction.

## CONCLUSION

Canal transportation and the centering ability of both instruments resulted in similar results; SAF resulted in less transportation only at the 9-mm level in the mesiodistal direction and more centered preparation at the 6-mm level in the buccolingual direction when compared with PTN. Both SAF and PTN were shown to be safe for being used in long oval canals. Further research is required in this field because there are numerous other file systems to be evaluated and compared.

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