



## Comparison of Canal Transportation and Centering Ability of Wave One and SafeSider in Curved Root Canals Using Cone-Beam Computed Tomography

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### ABSTRACT

**Background and Aim:** Maintaining the original central canal path during cleaning and shaping of the root canal system plays an important role in the success of endodontic treatment. This study sought to compare canal transportation and centering ability of WaveOne and SafeSider rotary files using cone-beam computed tomography (CBCT).

**Materials and Methods:** This ex vivo experimental study was conducted on 40 mesiobuccal canals of extracted human mandibular first molars with 20° to 40° of curvature. The teeth were randomly divided into two groups (n=20) and mounted in putty. Next, preoperative CBCT scans were obtained. Root canals were prepared using primary file of WaveOne in group A and SafeSider system up to file #25/0.04 taper in group B. Postoperative CBCT scans were taken and cross-sectional images at 1, 3, and 7 mm distances from the anatomic apex were compared. Data were analyzed using t-test and two-way analysis of variance (ANOVA).

**Results:** WaveOne was significantly superior to SafeSider regarding the canal centering ability and caused significantly less canal transportation (P<0.001). The canal centering ability of both systems was higher at the coronal and middle thirds of the root compared to the apical region (P<0.05).

**Conclusion:** WaveOne, in contrast to SafeSider, has optimal canal centering ability and less transportation in curved root canals.

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## Introduction:

Efficient endodontic treatment requires the complete elimination of bacteria, debris, and necrotic tissues from the root canal system followed by proper shaping and irrigation and subsequent filling of the root canal.<sup>(1)</sup> In this process, it is important to shape the root canal in accordance with its original path. However, this is difficult to achieve in curved canals and may even result in procedural errors such as canal transportation, ledge formation or perforation.<sup>(2-4)</sup> These procedural errors occur for straight files tend to return to their straight shape in curved root canals.

Nickel-titanium (NiTi) rotary instruments were introduced to prevent the occurrence of procedural errors since these files have high flexibility and optimal canal centering ability.<sup>(1)</sup> They facilitate endodontic treatment and result in significantly less procedural errors, which further add to their popularity.<sup>(5)</sup> However, cyclic fatigue and fracture of these files have also been reported due to their overuse in curved and narrow root canals.<sup>(6,7)</sup>

Endodontic rotary instruments with reciprocating motion, such as WaveOne system, were later introduced with a lower risk of fracture in curved root canals.<sup>(8,9)</sup> However, the shaping ability and canal centering ability of recently introduced systems have not been well investigated.<sup>(10,11)</sup> In 2007, Yared described root canal preparation with a NiTi rotary file; although his emphasis was on the use of one single-file for root canal preparation, his study was unique in that he changed the movement of NiTi rotary files from a 360° rotational movement to back and forth motion.<sup>(12)</sup> In 2011, Dentsply Tulsa Specialties used Yared's idea and introduced WaveOne system into the market.<sup>(13)</sup> The difference between this system and the previous rotary systems was in its back and forth clockwise and counterclockwise motion. This file is made of NiTi M-wire and its high flexibility preserves the root structure and decreases the risk of zipping of the canal while expediting the root canal preparation.<sup>(14)</sup>

SafeSider system, produced by Essential Dental Systems Inc., has a flat-sided design, which decreases involvement with dentin. SafeSider

files have a high fracture resistance during root canal preparation. This system has eight stainless steel and three NiTi files, which are narrow and highly flexible due to their small cross-section and flat-sided design.<sup>(15)</sup>

Evaluation of the canal centering ability of rotary instruments is highly important to determine their efficacy and safety for use in curved root canals. Electron and light microscopy, micro-computed tomography, high resolution computed tomography and cone-beam computed tomography (CBCT) are used for the evaluation of the canal centering ability of files;<sup>(16,17)</sup> CBCT is a highly efficient imaging modality, which provides high-resolution, three-dimensional (3D) images, enabling evaluation of changes in the root canal system. Although CBCT has a lower spatial resolution than micro-computed tomography, it provides valuable information regarding the root canal morphology and fracture or changes in the root canal system with lower patient radiation dose than micro-computed tomography.<sup>(18,19)</sup>

Studies comparing canal centering ability of WaveOne and SafeSider in curved root canals are limited. Thus, this study sought to compare the canal centering ability of WaveOne and SafeSider in curved root canals using CBCT.

## Materials and Methods

This ex-vivo, experimental study was conducted on 40 mandibular first molars. The teeth had been extracted for periodontal reasons and had closed apices with no canal calcification, no internal/external root resorption or root caries. Two samples as controls were subjected to primary CBCT scans in this study. They did not undergo root canal preparation and were subjected to postoperative CBCT scans with no manipulation. A special jig made using putty impression material was used to ensure the fixed position, reproducibility, and repeatability of testing and comparability of preoperative and postoperative images. All teeth had separate mesial canals such that a #10 K-file could pass through their apical foramen while a #15 K-file could not pass through their apices. Only teeth with root curvature between 20° to 40° and radius of curvature

less than 5 cm were included. The sample size was calculated to be 40 teeth, according to a previous study.<sup>(20)</sup>

After collection, the teeth were sectioned at the cemento-enamel junction (CEJ) to provide a root length of  $16 \pm 1$  mm and immersed in 5.25% sodium hypochlorite solution for one hour for disinfection. Debris and tissue residues were removed using a scaler and a sterile gauze, and the teeth were stored in saline.

Impressions were taken of teeth using putty impression material (Speedex; Coltene, Altstätten, Switzerland) with their roots completely embedded in putty.<sup>(21)</sup>

Care was taken not to introduce any file into the canal prior to taking preoperative CBCT scans to maintain the original canal anatomy. Also, metal restorations were removed (if present) to prevent metal artifacts.

Next, the teeth underwent CBCT (Rotograph Evo 3D; Villa Sistemi Medicali, Buccinasco MI, Italy) at 60 peak kilovoltage (kVp), 6 milliamperes (mA), and 11.2 seconds time with 0.5-mm slice thickness (0.166-mm voxel size). The CBCT unit used had 0.01-mm accuracy. Using OnDemand software (Cybermed Inc., Seoul, South Korea), sections were made at 1, 3, and 7 mm distances from the apex perpendicular to the longitudinal axis of the canal. All preoperative CBCT scans were obtained by one oral and maxillofacial radiologist. After taking preoperative CBCT scans, a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the root canals until its tip was visible at the apex. Working length was determined 0.5 mm short of this length.

The teeth were then randomly divided into two groups (n=13) and their mesiobuccal root canals were prepared with WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) in group A and SafeSider (Essential Dental Systems Inc., NJ, USA) in group B with the speed and torque recommended by the manufacturer.

In group A, root canals were shaped using WaveOne system with crown-down technique using a low-speed handpiece. Only one primary file (#25, 0.08 taper) was used at 250 rpm (revolutions per minute) and a 2.8-Ncm torque. The file was introduced into the canal passively with a gentle in-and-out motion until reaching the working length.

In group B, SafeSider system was used for root canal preparation, and #15 to #35 (0.02 taper) stainless steel files and then a #25 NiTi file (0.06 taper) were consecutively used in an Endo-Express handpiece at 2500 rpm. The files were used passively with gentle motion as recommended by the manufacturer.

In both groups, root canal patency was checked after using each rotary file with a #10 K-file. Each file was replaced with a new one after five canal preparations. After using each file, the canal was rinsed with 2 ml of 2.5% sodium hypochlorite solution with a 27-gauge needle. Samples were then stored in saline. To take postoperative CBCT scans, the teeth were placed in their respective putty impressions, and postoperative images were taken with the same exposure settings and conditions as for the preoperative scans.

Preoperative and postoperative cross-sectional images at 1, 3, and 7 mm distances from the apex were evaluated in the two groups using a software program. The distance between the root canal wall and external root surface was measured at the mesial and distal aspects on both preoperative and postoperative radiographs at 1, 3, and 7 mm distances from the apex (Figure 1).

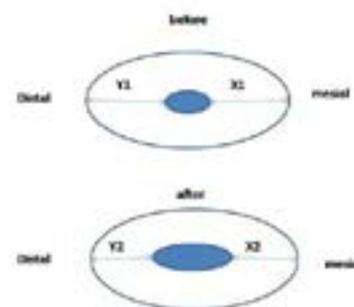


Figure 1. Schematic representation of the distance between the internal canal wall and external root surface before and after canal preparation.

Measurements were made by two observers, and the mean of the values measured by the two observers was calculated and placed in the centering formula below:

$$\frac{(y1-y2)}{(x1-x2)} \text{ or } \frac{(x1-x2)}{(y1-y2)}$$

Canal transportation was also determined using the formula  $(x2-x1)-(y2-y1)$ , (22) where  $x1$  is the shortest distance from the root surface to the root canal wall at the mesial aspect before preparation,  $x2$  is the same distance after preparation,  $y1$  is the shortest distance from the root surface to the root canal wall at the distal aspect before preparation, and  $y2$  is the same distance after preparation. The canal centering ratio was also calculated using t-test. If the obtained value was 1, it indicated that the file was capable of perfectly maintaining the central canal path. The greater the deviations of this value from 1, the higher the deviation from the central canal path. The closer the transportation value to zero, the smaller the canal transportation.<sup>(23)</sup> Canal transportation and centering ability of the two systems were compared using t-test. Also, the mean duration of canal preparation at 1, 3, and 7 mm by each system was calculated, and the results were compared using t-test and repeated measures analysis of variance (ANOVA).

## Results:

Table 1 shows changes in the central canal path at 1, 3, and 7 mm from the apex following the use of WaveOne and SafeSider systems. As shown in Table 1, at 1, 3, and 7 mm from the apex, according to repeated measures ANOVA, the centering value in WaveOne group was greater than that in SafeSider system, and the difference was statistically significant ( $P=0.0012$ ).

In WaveOne system, canal centering ability was greater at the coronal and middle thirds compared to the apical region, and this difference was statistically significant ( $P=0.01$ ). The same was true for SafeSider ( $P=0.002$ ).

Table 2 shows the root canal transportation at 1, 3, and 7 mm distances from the apex in WaveOne and SafeSider groups. As seen in Table 2, at 1, 3, and 7 mm from the apex, the magnitude of transportation in SafeSider group was greater than the value in WaveOne group, and the difference was statistically significant ( $P=0.001$ ,  $P=0.001$ , and  $P<0.001$ , respectively). Apical transportation was significantly greater at the middle and apical thirds compared to the coronal third in SafeSider system. However, apical transport in WaveOne system was significantly greater at the apical third compared to the middle and coronal thirds.

**Table 1. The centering ratios of SafeSider and WaveOne at different levels from the apex**

Levels	At 1 mm from apex		At 3 mm from apex		At 7 mm from apex		P-value (ANOVA)
	Mean±SD	n	Mean±SD	n	Mean±SD	n	
Centering ratio							
SafeSider	0.19±0.09	60	0.36±0.07	40	0.49±0.08	31	P=0.002
WaveOne	0.74±0.09	12	0.81±0.06	8	0.85±0.06	8	P=0.01
P-value (t-test)	P=0.0012		P=0.0012		P=0.0012		-

SD=Standard Deviation

The mean duration of root canal preparation was 69±29.30 seconds in SafeSider and 47.09±16.54 seconds in WaveOne group.

According to t-test, root canal preparation was significantly faster with WaveOne compared to SafeSider system (P<0.05).

**Table 2. Amount of canal transportation in use of SafeSider and WaveOne at different levels from the apex**

Levels	At 1 mm from apex	At 3 mm from apex	At 7 mm from apex	P-value
System/Canal transportation	mean±SD(mm)	mean±SD(mm)	mean±SD(mm)	(ANOVA)
SafeSider	0.47±0.05	0.31±0.03	0.16±0.03	P<0.002
WaveOne	0.23±0.04	0.03±0.018	0.02±0.014	P<0.001
P-value (t-test)	P=0.001	P=0.001	P<0.001	-

SD=Standard Deviation

### Discussion

This study compared the canal transportation and centering ability of WaveOne and SafeSider in curved mesiobuccal root canals of mandibular molars at 1, 3, and 7 mm from the apex.

Root canal preparation is performed to eliminate debris and microorganisms from the root canal system;<sup>(1)</sup> however, deviation from the original central canal path, especially in the apical region, interferes with adequate cleaning, shaping, and filling of root canal and can result in treatment failure.<sup>(2)</sup>

Several rotary NiTi files have been introduced to overcome the limitations of stainless steel hand files in curved root canals. NiTi rotary instruments facilitate root canal preparation and decrease procedural errors. However, they may undergo cyclic fatigue and break in curved canals.<sup>(3)</sup> Reciprocating systems were recently introduced to overcome the shortcomings of NiTi systems. However, information about their root canal shaping efficacy is limited.<sup>(3)</sup> WaveOne and SafeSider reciprocating systems were compared in terms of canal centering ability in this study.

The efficacy of NiTi files in maintaining the central canal path can be evaluated by several methods, including radiographic comparison,<sup>(13)</sup> sectioning according to the Bramante's method,<sup>(24)</sup> clearing of teeth,<sup>(25)</sup> high-resolution computed tomography,<sup>(16,26,27)</sup> microtomography,<sup>(22)</sup> and CBCT;<sup>(14)</sup> CBCT enables high-resolution, reproducible, and accurate 3D assessment of the root canal system without damaging the samples.<sup>(28)</sup>

Canal transportation can be assessed by two methods. Some researchers superimposed preoperative and postoperative images to assess changes in the canal path caused by root canal preparation.<sup>(29)</sup> Some others measured the distance from the external root surface to the internal root canal wall at the mesial and distal aspects on preoperative and postoperative images at three levels from the apex.<sup>(23,30)</sup> This method was also used in our study. Measurements were made at 1, 3, and 7 mm distances from the apex to evaluate changes at the apical and middle thirds of the root caused by preparation because the risk of procedural errors is higher at the apical and middle thirds of the root canal. Also, teeth with 20° to 40° of root curvatures were chosen for this study because they are at higher risks of procedural errors such as ledge formation, transportation, and perforation.<sup>(31)</sup> The results showed that both systems caused canal transportation, but the magnitude of canal transportation was significantly greater in SafeSider group, especially at 1 mm from the apex, and SafeSider had a poorer canal centering ability than WaveOne. Observing no transportation in the control samples confirmed the high accuracy of the imaging. The curvature of root canals was measured using Schneider's method which is commonly used for this purpose.<sup>(11,32-34)</sup> Our results showed that SafeSider caused greater canal transportation at the apical region compared to WaveOne. Also, SafeSider had a poor canal centering ability. The flat sides of SafeSider files are responsible for improved flexibility of

stainless steel files.<sup>(11)</sup> Moreover, it is expected that the back and forth motion of these files creates a balanced force when inserted into the canal.<sup>(11)</sup> However, several studies have reported a significant canal transportation following the use of stainless steel files with back and forth motion.<sup>(33,34)</sup> Rhodes et al reported that SafeSider caused greater canal transportation compared to Vortex 06.<sup>(10)</sup> Also, many studies have supported the superiority of NiTi files to stainless steel instruments in maintaining root canal curvature.<sup>(33,35)</sup> Our current results also confirmed that WaveOne was superior to SafeSider in maintaining the original central path of the canal and preventing apical transportation. This finding is in accordance with the result of a study by Abu-Al Shawareb et al, in which WaveOne showed a lower percentage of danger zones and coronal narrowing incidence compared to SafeSider and K-files because larger sized stainless steel files in SafeSider system have more rigidity which increases canal straightening.<sup>(36)</sup>

Ceyhanli et al reported that canal transportation by SafeSider was greater than that of NiTi instrumentation system.<sup>(4)</sup> Also, in their study, SafeSider had lower canal centering ability. WaveOne operates with a back and forth motion to enhance root canal preparation.<sup>(9)</sup> Furthermore, only one file is required for root canal preparation to achieve adequate size and taper. Reciprocating motion applies balanced force to canal walls.<sup>(37)</sup> This motion decreases stress, fatigue, and locking of the file in canal walls and increases the ability to maintain the original root canal anatomy.<sup>(38,39)</sup> Previous studies have shown that use of one file with reciprocating motion results in a cleaning and shaping as effective as that obtained by the use of a complete series of rotary files.<sup>(40,41)</sup>

In our study, in both groups, canal transportation at 1 mm from the apex was significantly greater than that at 3 mm and 7 mm distances from the apex. Also, canal centering ability of both systems was lower at 1 mm from the apex compared to 3 mm and 7 mm levels; these findings were in agreement with those of Ceyhanli et al.<sup>(4)</sup> They also showed that SafeSider and WaveOne caused greater canal transportation at

1 mm from the apex, and canal transportation caused by SafeSider was greater than that caused by WaveOne.

Wu et al reported that apical transportation greater than 0.3 mm decreased the quality of the apical seal.<sup>(42)</sup> Our results are in accordance with those reported by Delgoshayi et al, showing that SafeSider system exceeded this critical threshold.<sup>(43)</sup> This highlights the need for further studies on this system. However, our results confirmed the results reported by Berutti et al, indicating that WaveOne did not exceed the critical threshold.<sup>(22)</sup>

The preparation time with WaveOne in our study was significantly shorter than that with SafeSider. The reason is the higher number of files used in SafeSider system. Future studies with larger sample sizes are required to evaluate the performance of SafeSider in terms of dentin removal and frequency of crack formation and file fracture. Also, WaveOne should be compared with other reciprocating files available in the market.

## Conclusion

Based on the results, WaveOne, in contrast to SafeSider, is suitable for use in curved and narrow root canals since it has optimal canal centering ability and causes minimal canal transportation. Also, WaveOne was significantly faster than SafeSider for canal preparation, which further adds to the efficacy of WaveOne.

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