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ORIGINAL ARTICLE

Shaping ability of WaveOne Gold reciprocating file with and without glidepath in artificial S-shaped canals

ABSTRACT

Aim: *Most authors have recognized that coronal pre-flaring has several advantages and it provides accordance with the objectives of endodontic treatment. Together with glidepath, it constitutes the most appropriate work sequence for the success of canal shaping. The purpose of this study was to compare the influence of glidepath on canal transportation and centring ability, using the WaveOne Gold with and without glidepath.*

Methodology: *40 standard clear resin "S" shaped Endo Training Blocks* (Dentsply, Maillefer, Switzerland) *divided into two groups of 20 blocks were used in this study. The first group was prepared using WaveOne Gold Glider and WaveOne Gold while the second group was prepared with WaveOne Gold only. After the preparation, the amount of canal transportation, centring ratio, angle and radius of curvature, were measured on superimposed photos taken with an optical microscope. The two groups were statistically compared with analysis of variance, Kolmogorov-Smirnov and Student significant difference test. The level of significance was set at* $P<0.05$.

Results: *Less transportation and better centring ability occurred when using glidepath before root canal preparation (*$P<.0001$*). In these two groups there was a significant variation in the angles and radius of curvature compared to the initial values and this variation was found to be reduced when using glidepath.*

Conclusions: *Canal modifications seem to be significantly reduced when previous glide path was performed before using the WaveOne Gold. The use of glidepath reduced significantly the root canal transportation, minimized the curvatures straightening after the preparation and revealed a better centring ability.*

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Introduction

The objectives of root canal treatment are the elimination of irritants from the canal system, multidimensional obturation in order to block the entry and the exit doors of bacteria and to promote bacterial entombing after canal disinfection, prevention of the recontamination of the canal systems and preservation of the initial canal trajectory (1). Canal transportation is a common error to all canal preparation techniques. It is directly related to canal curvature as well as variations in the centre of gravity (2). According to the AAE (American Association of Endodontics), canal transportation is the concept according to which the instruments tend to regain their initial shape at the level of the external curvature of the apical third, and this by eliminating the canal wall (3). Centring ability preserves the initial canal trajectory and reduces the risk of canal transportation, thus minimizing errors such as ledges, straightening of curvatures and apical enlargement (4).
According to West 2010 (5), canal preparation consists of three stages: the initial canal negotiation, therefore scouting and pre-flaring which is always necessary when the canal is not wide enough, the creation of glidepath and finally canal shaping. The glidepath is a smooth canal tunnel from the orifice of the canal to the foraminal constriction. The glidepath must be discovered if it is already present in the canal anatomy or it must be prepared if it is not. The original canal anatomy can influence the glide path creation (5). Coronal pre-flaring and glidepath minimize errors during canal preparation, since they prevent taper lock, broken instruments and aberrations.
The introduction of nickel-titanium (NiTi) instruments' super elastic alloy which provides great flexibility for shaping the root canal, improved the effectiveness of endodontic treatment, thus reducing preparation time and iatrogenic errors (6). These instruments are associated with lower canal transportation than manual stainless steel files because of their ability to maintain the original curvature of the canal and because of their memory shape (7). However, the resistance of these instruments when it comes to fracturing, is lower and remains disadvantageous compared to manual files (8). The reciprocating movement could reduce the continuous fatigue caused by the rotation of the NiTi instruments, relatively to the continuous motion. The WaveOne Gold which is a unique instrumentation system, introduced by Dentsply Maillefer, is composed of four single-use files: Small (ISO 20 tip and 7% cone) for fine root canals; primary (ISO 25 tip and 7% tapered) for most of the canals; and large (ISO 35 and 6% cone-ISO 45 and 5% cone) for large canals. The files are made of Gold-Wire NiTi alloy. The WaveOne Gold glider (ISO 15 tip and 2 to 6% tapered), introduced by Dentsply Maillefer also, is a single instrument that works in reciprocating motion and is made of gold-Wire, designed in order to be used before the WaveOne Gold system.
The aim of the study was to compare the shaping ability of WaveOne Gold and its impact on the modification of the canal curvature and axis in artificial resin blocks, with and without glidepath.

Materials and Methods

The protocol was approved by the Ethics Committee of Saint Joseph University on March 20.
Forty ISO 15,0.02 taper S-shaped Endo Training Blocks (Dentsply, Maillefer. Ballaigues, Switzerland) were used. Green ink (Pelikan, Hannover, Germany) was injected with a syringe into each of the blocks. Holders were made with putty (ZETAPLUS, Zhermax) and ice cube tray for each of the blocks (Figure 1) in order to organize the blocks during work. Each block was photographed with an optical microscope (Olympus, E330-ADU1 2X, Japan) at 1.25x/0.04/FN 26.5 magnification preoperatively and postoperatively while maintaining the same photography conditions in order to superimpose the photos during the analysis (Figure 2). An opaque slide was chosen to improve the brightness of the photo and therefore increase the accu-

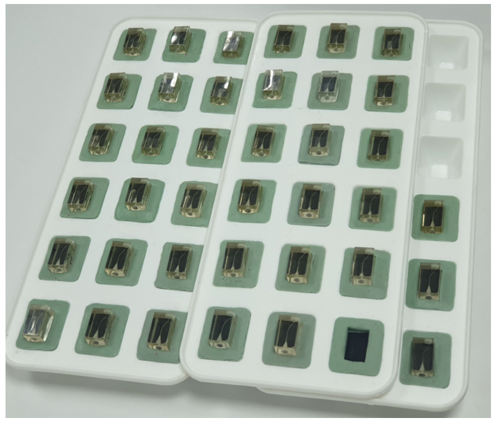


Figure 1
Preparation of the blocks in holders made with putty and ice cube tray.

Figure 2
Olympus optical microscope at 1.25x/0.04/FN 26.5 magnification.

racy of the analysis. Distilled water was used to remove the ink and the blocks were randomly divided into two groups (n=20).

Group A: Catheterization with K file #10 (Dentsply, Sirona) and determination of the working length (WL) and mechanical glidepath using WaveOne Gold Glider (Dentsply, Sirona, Ballaigues, Swizerland). The system consists of a single file with a parallelogram shaped cross-section, 1 size glider 15, and variable taper 2% to 6, used in reciprocating motion with WaveOne Gold settings. The glider was used at the WL. Each canal was shaped with the WaveOne Gold Primary (Dentsply, Sirona, Ballaigues, Swizerland) according to the sequence of pecking motion with parietal support and vertical back and forth to allow the progression of the instrument apically with a light pressure, use of the instrument about three times in average in this group, cleaning of the instrument with a compress soaked in sodium hypochlorite (NaOCl, 2.5%) after each movement, irrigation using half a syringe 3cc of distilled water and permeabilization using K file #10, brushing motion for the elimination of coronary interference and finally, arrival of the instrument at the WL.

Group B: Catheterization with K file #10 (Dentsply, Sirona) and determination of the working length, no glidepath performed and final shaping with the WaveOne Gold Primary (Dentsply, Sirona) using the same sequence as group A. For both groups, the motor used was the E-Connect PRO Endo Motor (Eighteeth medical) in mode: Fwd 30° and Rev 150° according to the manufacturer's recommendations. All procedure was done by the same operator.

Measurements

Pre and post-operative images were overlaid using CS4 extended Adobe Photoshop Program software (San Jose, CA, USA) (Figure 3). The width and angle measurements were made using AutoCAD software (Autodesk Inc, San Rafael, California). Twelve defined measurement points were traced over the entire length of each block and perpendicular to the axis of the root canal.

These levels were designed according to the method described by Madureira et al. (9) (Figure 4): level 1 at the beginning of the root canal and level 3 at the end of the coronal zone before the first curvature, level 2 in the middle between level 1 and level 3 while level 12 is at the apex. In addition, seven more equidistant levels were drawn between levels 3 and 12 and numbered 4, 5, 6, 7, 8, 9 and 10. Level 11 was halfway between 10 and 12. Finally, the images were evaluated in three areas: coronal area (CZ) of level 1-3, area of first curvature of level 4-7 (FCZ) and area of second curvature or apical curvature (AZ) of level 8-12 (Figure 5).

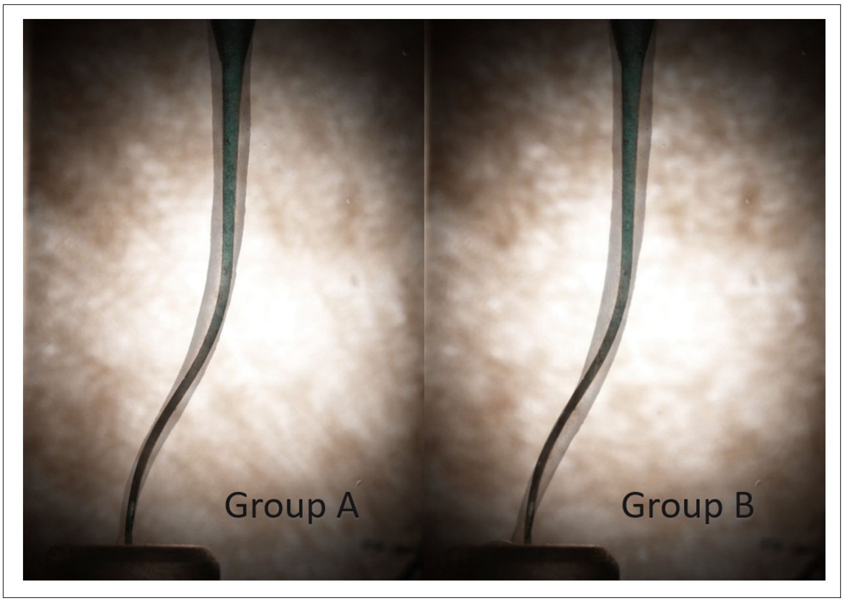
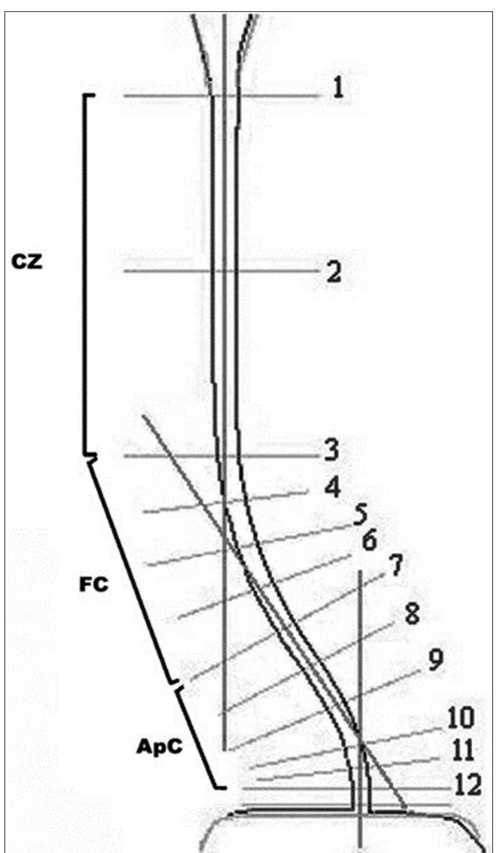


Figure 3
Pre- and post-operative images of resin blocks with (Group A) and without glidepath (Group B).

The comparison between the two groups in pre and post-operative was obtained according to the following factors: the quantification of the canal transport, the quantity of resin eliminated, the centring ratio, the variation of the angles of curvature and the variation of the radius of curvature. The canal was divided into two sides: the first defined as the external aspect of the apical curvature and the internal aspect of the coronal curvature while the second side defined by the opposite (10). To facilitate the measurements and their analysis, the first side was designated by the letter R and the second by the letter L indicating the right and left sides (Figure 6).

The widths of resin removed was calculated at each of the 12 levels divided according to the technique of Madureira described above. The amount of canal transportation is the difference between the widths of resin removed from both sides of the canal while resin removal was calculated by summing the widths of resin removed from both sides of the canal and the centring ratio was calculated by dividing the narrowest width of resin removal by the widest at each sides (11).

<u>For the measurement of the angles of curvature</u> a line A along the axis of the coro-



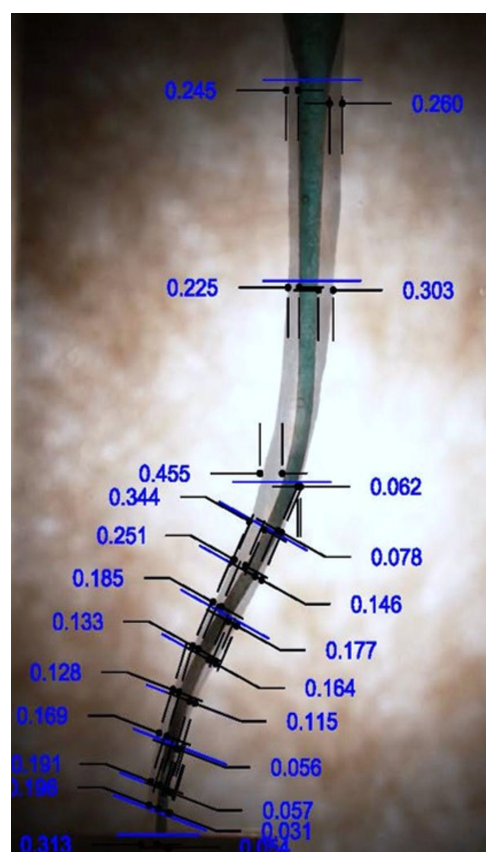
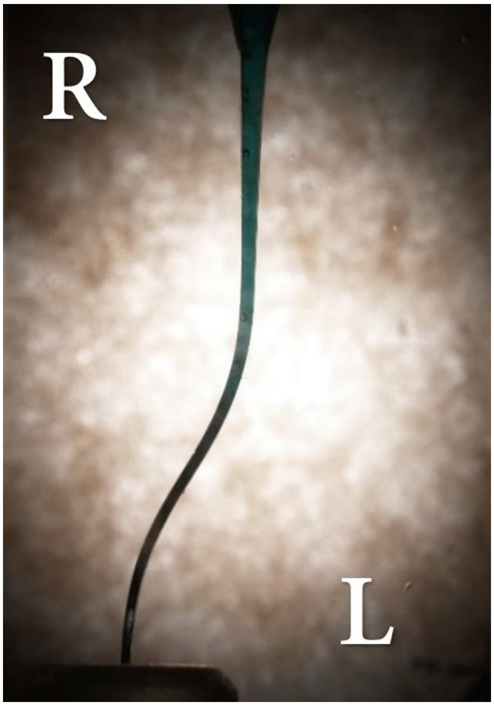


Figure 4
Madureira's technique to divide the entire canal into 12 sections perpendicular to the axix of the root canal.

Figure 5
Measurements of the widths of resin removed from both sides of the canal.



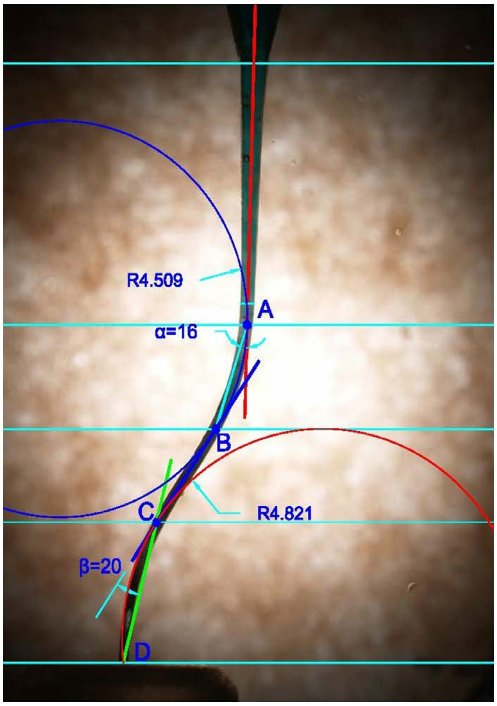


Figure 6
Right and left sides of the canal.

Figure 7
Measurements of the angles and radius of curvatures.

nary part of the canal was drawn passing through the canal entrance and by point A marking the end of the straight coronal part and the beginning of the first curvature. A point B at the start of the deviation of the first curvature and thus forming the first point of inflection. Point C at the beginning of the second curvature and therefore forming the second point of inflection, Point D at the apex.
The inflection points were the exact locations of the change of the direction of the canal. Lines joining A to B, B to C and C to D were also drawn. The angle α of the first curvature represented the intersection of line A with the line AB with vertex the point A. The angle β of the second curvature the intersection of lines BC and CD with the vertex the point C. The measurement of these angles was carried out preoperatively by obtaining: α is 16˚ and β is 20˚. Post-operative measurements were performed on each of the canals of the two study groups (Figure 7).
For the measurement of the radius of curvature the hypothetical circle of centre O of the first curvature represents the circle passing through the points A and B and whose radius is: Radius 1=AB/2sinα. Whereas the hypothetical circle of centre O' of the second curvature is the circle passing through points C and D and whose radius is: Radius 2=CD/2sinβ.
It should be noted that the more the amount of the initial angle decreases and the more the radius of curvature increases, the more the curvature is straightened. The variation of the distances between points A and B, C and D plays an essential role in the variation of the radius of curvature and it must be taken into consideration (Figure 7).

Statistical analyses
The IBM SPSS Statistics (version 25.0) was used for statistical analyses. The level of significance was set at $p \leq 0.05$. Repeated-measure analyses of variance with one between-subjects factor (with or without glidepath) and one within-subjects factor (coronal, first and second curvature zones) were used to compare the canal transportation, resin removal and centring ratio between groups; they were followed by univariates analyses and Bonferroni multiple comparisons tests.
Student t-tests were also used to compare the mean angle and radius of curvature variations between groups (with and without glidepath). One Sample t-tests were

used to compare the mean angles and radius variations with the theoretical values which indicate the absence of a significant variation.

Results

Canal transportation
The mean canal transportation was significantly smaller when using glidepath ($p<0.001$). Without glidepath, the mean canal transportation was significantly smaller at the coronal zone ($p=0.002$), and the difference was not significant between the first and the second curvature zone ($p=0.243$). However, with glidepath, the canal transportation was not significantly different within levels ($p=0.504$) (Table 1).

Centring Ratio
The mean centring ratio was significantly greater with glidepath at the apical level ($p<0.001$). The centring ratio was significantly smaller on the apical zone, intermediate on the middle zone and elevated on the coronal zone for specimen shaped with ($p<0.001$) or without glidepath ($p<0.001$) (Table 1).

Resin removal
The mean resin removal was significantly greater on specimen shaped without glidepath ($p<0.001$). Moreover, the amount removed was smaller on the apical zone and greater on the coronal or middle zone ($p<0.001$) (Table 1).

Angles and radius curvature variations
The variation of alpha and beta angles, the variation of distances and radius curvature were significantly greater in group shaped without glidepath ($p<0.001$).

Table 1
Canal transportation, centring ratio and resin removal of the groups

	Canal transportation (mm)			
	Coronal zone	**First curvature**	**Second curvature**	**p**
With glidepath	0.1374±0.0302	0.1362±0.0257	0.1236±0.0277	0.504
Without glidepath	0.1725±0.0430[a]	0.2343±0.0743[b]	0.2077±0.0505[b]	0.002
p	0.005	<0.001	<0.001	
	Centring Ratio			
	Coronal zone	**First curvature**	**Second curvature**	**p**
With glidepath	0.6147±0.0817[c]	0.4952±0.0752[b]	0.4007±0.0748[a]	<0.001
Without glidepath	0.6276±0.0681[c]	0.4343±0.1200[b]	0.2994±0.0717[a]	<0.001
p	0.591	0.062	<0.001	
	Resin Removal (mm)			
	Coronal zone	**First curvature**	**Second curvature**	**p**
With glidepath	0.535±0.0508[b]	0.503±0.0250[b]	0.435±0.0617[a]	<0.001
Without glidepath	0.669±0.0504[b]	0.713±0.0679[b]	0.575±0.0962[a]	<0.001
p	<0.001	<0.001	<0.001	

a, b, c: different letters indicate the presence of a significant difference according to Bonferroni multiple comparisons.

Table 2
Angle curvature (degree), radius curvature (mm) and distance (mm) in different groups

Reference values	With glidepath	Without glidepath	p
Angle alpha=16 degrees	14.725±0.2918 -1.275 degrees	13.965±0.3573 -2.035 degrees	<0.001
Angle Beta=20 degrees	13.535±0.4771 -6.465 degrees	11.990±0.4327 -8.01 degrees	<0.001
Distance AB=2.486 mm	3.764±0.2096 +1.278 mm	4.424±0.4813 +1.938 mm	<0.001
Distance CD=3.298 mm	3.38± 0.1208 + 0.086 mm	3.583±0.2757 0.285 mm	0.005
Radius 1=4.509 mm	7.403±0.3678 +2.894 mm	9.175±1.0569 +4.666 mm	<0.001
Radius 2=4.821 mm	7.241±0.4094 +2.42 mm	8.627±0.6231 +3.806 mm	<0.001

All these measurements were different significantly compared to the reference values ($p<0.001$) (Table 2).

Discussion

A technique advocated by Pr. G. Yared used a single instrument without the glidepath only by using a K-file 08 for the canal scouting (12). Therefore, this technique encourages shaping without the preliminary creation of a manual or rotary glidepath, an idea subject to several controversies (13).
However, studies have shown that when the tip of an instrument faces a part of the canal that is smaller than its diameter, it locks up and quickly reaches a high torque. If the latter reaches a very high level, the instrument will cause structural deformations (14). Therefore, according to a study by Berutti and Pasqualini in 2004, it is necessary and crucial to carry out a pre-flaring in order to reduce the friction forces and the damage on the instruments (15). Berutti et al also demonstrated in 2009 that the use of Pathfiles to secure the path of the shaping instruments is an essential condition (14). Peter et al in 2003 (16) and Patino et al. in 2005 (17) demonstrated that the canal must be widened with a K 15 lime at least before any use of rotary instruments, regardless of what technique they used.
The main goal of this experimental research was to demonstrate the impact of glidepath on the shaping ability of WaveOne Gold and compliance with the initial canal trajectory. An instrument specially designed with the properties as the WaveOne Gold was used: the WaveOne Gold Glider. This instrument works in reciprocating motion and is made of gold-Wire, it is designed by the same company specially to assist the WaveOne Gold system. In fact, it has been shown that an ideal endodontic treatment begins with a coronal pre-flaring, followed by the realization of a glidepath, preferably rotary and in reciprocating motion, to finally move on to shaping (6,18). In our study, we ensured these conditions in order to be able to compare as accurately as possible the two groups A and B.
We have chosen to use simulated curved S-shaped canals to compare the shaping

ability of this system based on the technique of superimposing the contours of the pre- and post-operative root canals, which allowed a direct visual comparison of the changes. However, the blocks were photographed using an optical microscope in order to make sure of the precision of its overlay, unlike several other studies which have used digital photography, including the studies of Yilmaz et al. (11), Keskin et al. (18), Nazarimoghadam et al. (19).

For other authors, the evaluation criteria is mainly based on the quantification of canal transport, canal centring, the incidence of aberrations and the amount of resin removed (11, 18) who proved that glidepath promotes the maintenance of the initial canal trajectory, minimizes the modifications of the canal curvature as well as the occurrence of iatrogenic errors. However, the modification of canal trajectory is defined by the involuntary deviation of the path of the initial canal which generates the modification canal curvature, the decrease in angle of curvature, leading to the straightening of the canal base. In order to increase the precision of comparison, the straightening of the curvature must be added as an evaluation parameter. In this perspective, we have studied the variation of the angle of curvature as well as the radius of curvature, in addition to other criteria subjects present in several studies.

Our results confirm the initial problem and demonstrate that glidepath is an essential step which increases the success of canal preparation and promotes the maintenance of the initial canal trajectory. Indeed, there was a significant difference between the two groups of studies showing that glidepath reduced canal transportation and resin removal and increased the centring ratio especially at the apical third (p value<0.001). A considerable variation of the radius and the angle of curvature is found in the two groups of study. Glidepath reduced the amount of variation. In a study by Yilmaz (11) in which the shaping ability of WaveOne was evaluated with or without the use of Pathfiles, the results showed that no significant difference concerning canal transportation and resin removal between the two groups. Centring ratio has been shown to be better with the glidepath. Burklein et al. (20), in 2014, demonstrated that glidepath had no influence on transportation or canal centring. This difference may be explained by the experience of the operator which differs between studies, or by the use of a reciprocating glidepath instrument shown to be better compared to the continuous glidepath (18). Coelho et al. (21) and Vorster et al. (22) showed, as well, that glidepath did not reduce canal transportation. This difference can be explained by the use of extracted teeth instead of resin blocks.

Berutti et al. (23) studied the influence of glidepath on canal curvature and the modification of the axis using the WaveOne. They found a significantly greater alteration in canal curvature in the absence of glidepath, and the results of the present study were in agreement with these results. However, it should be noted that straightening was observed even with glidepath, and this was in agreement with the results of Berutti et al. (24) who reported a consequent reduction in the working length of curved root canals. A second check of the working length is recommended after the pre-flaring and before the preparation of the apical part in particular with the WaveOne system. Lim et al. (25) reported that the WaveOne and Reciproc systems remain more centred after the glidepath at the apical third, while Nazarimoghadam et al. (19) showed a significant reduction in canal transportation in the apical third in the presence of glidepath. Their results support the results of this study which showed significantly higher values for canal centring with glidepath.

However, in this study, resin simulators were used and it is well proved that resin differs from dentin in terms of hardness or surface texture (26), as it can be softened due to the heat of friction of mechanical instruments (23). The extracted teeth, on the other hand, reflect better the clinical conditions since two root canals are never identical to each other, they cannot be standardized anatomically, and they can include different variables which can influence the results of the study (27). For this reason, artificial resin canals were used in the present study in order to be able to standardize the sample and get accurate results. Further research on extracted teeth and using CBCT (Cone Beam Computerized Tomography) or Micro-CT (Microcomputed tomography) should be considered in order to increase the precision of the study parameters and reproduce the specific factors of teeth including the variation of the canal anatomy and the dentin properties.

Conclusions

Under the conditions of our study and within its limitations, the canal preparations with the WaveOne Gold enabled better compliance with the canal trajectory in the apical, middle and coronary areas of the double curvature canals with the use of the reciprocating file, WaveOne Gold glider. The use of the mechanical reciprocating glidepath seems to increase the shaping ability of WaveOne Gold by reducing modifications in canal curvature and trajectory. This concept, studied by many authors, remains subject to several controversies influenced by factors that should probably be better explored.

Clinical Relevance

Highlights of the study: Glidepath reduces canal transportation and resin removal and increases centring ratio while reduces canal straightening. Angles of curvatures have higher values in the presence of glidepath and radius of curvature are smaller.

Conflict of interest

The authors deny any conflict of interest.

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