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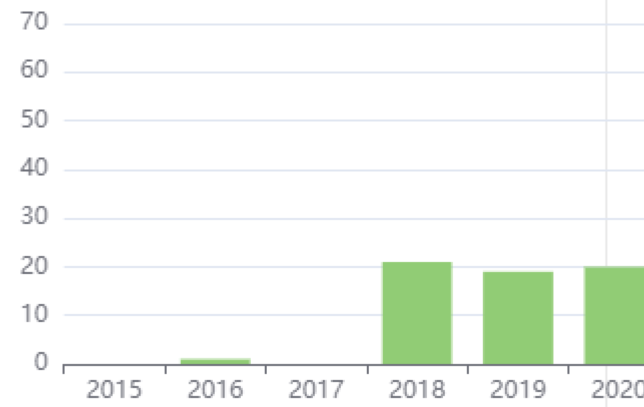

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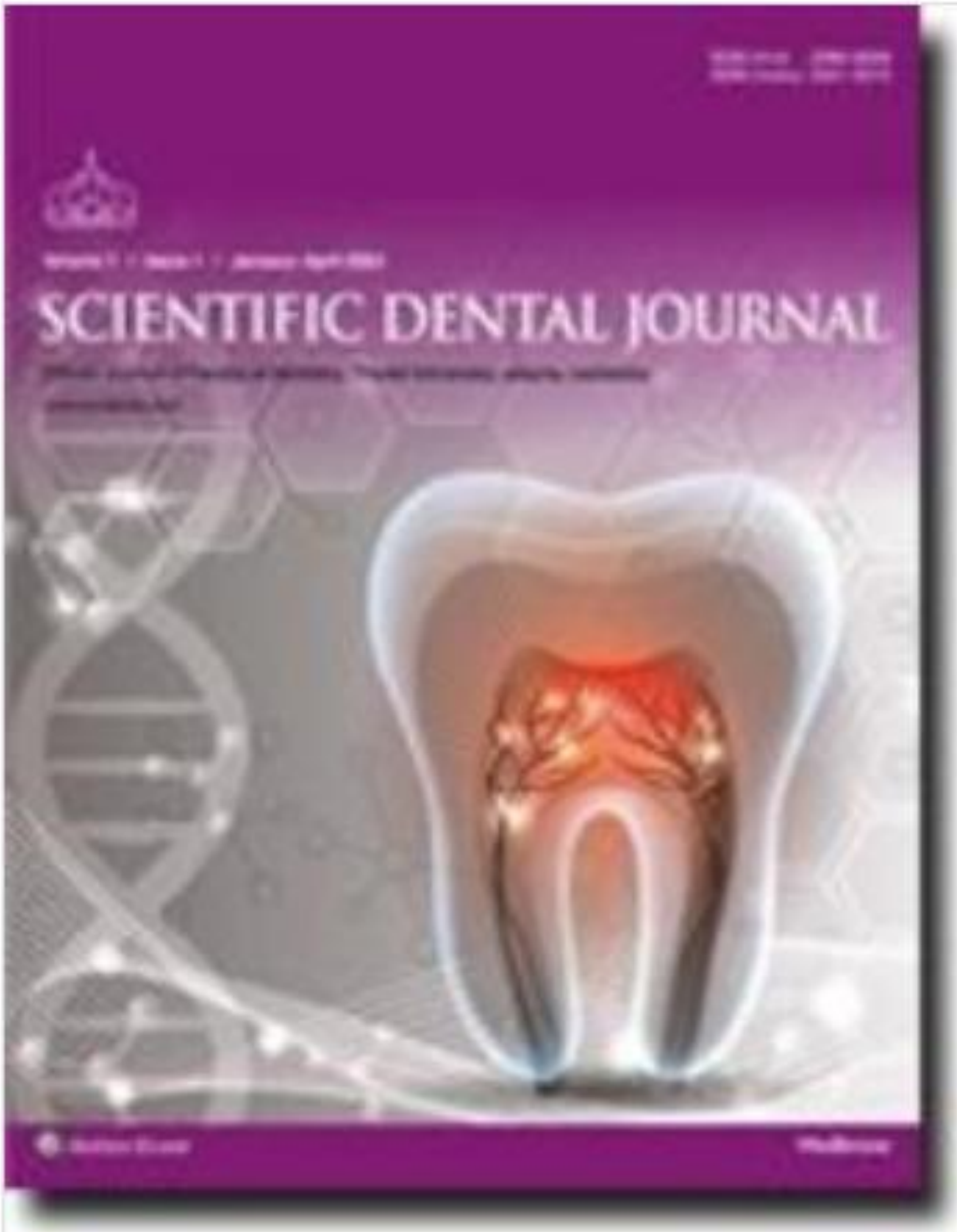

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Differences in Preparation Results of Two Reciprocal Ni-Ti Files with and Without Glide Path to the Changes on Root Canal Curvature

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Universitas Trisakti

Original Article

Differences in Preparation Results of Two Reciprocal Ni-Ti Files with and Without Glide Path to the Changes on Root Canal Curvature

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Abstract

Background: Maintaining the anatomy of the root canal is crucial in root canal treatment. The super-elastic property of the nickel-titanium (Ni-Ti) file system provides advantages in preparation of curved root canals, as it can reduce the force on the root canal wall, increase centering ability, and reduce iatrogenic errors. **Objective:** The aim of this article is to determine the differences in preparation results of two reciprocal Ni-Ti files with and without glide path to the changes of root canal curvature. **Materials and Methods:** Twenty pieces of endodontic blocks (ISO# 15, 16 mm, 2% tapered) were divided into four randomly assigned groups. Group 1 (without glide path) and Group 2 (with glide path) were prepared with Wave One Gold (WOG). Group 3 (without glide path) and Group 4 (with glide path) were prepared with Reciproc Blue (RB). Each subject was explored using K-file #10. Glide path was prepared with ProGlider (PG) #16. Digital images of before and after the root canal preparations were taken using a digital camera with the same angle and distance settings. The before and after photos were superimposed on each other, and the transportation at the inner and outer root canal walls in the coronal curvature, apical curvature, and apical end points was measured with software. **Results:** No significant difference was found between changes in the coronal curvature using WOG and RB, with and without glide path ($P > 0.05$). The same result was observed between WOG and RB groups with glide path at each measurement point. Significant differences were found between changes in apical curvature and apical point in the inner wall using WOG and RB without glide path ($P < 0.05$). **Conclusion:** There were differences in root canal curvature prepared using WOG and RB on the apical region when prepared without glide path, but no differences were found when prepared with glide path at each point measurement.

Keywords: *Canal transportation, Reciproc Blue, root canal treatment, Wave One Gold*

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Background

The purpose of root canal preparation is to clean the root canal and shape a conical canal to apical direction, with the largest diameter at the orifice of the root canal and the smallest diameter at the apical tip.[1] This ideal shape is very difficult to achieve in curved root canals or S-shaped root canals.[2] Maintaining root canal anatomy is an important thing, especially when treating curved root canals.[3] Aggressive instrumentation of the root canal walls will result in excessive dentin reduction, which may weaken the tooth

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structure. During root canal treatment, deviation from the initial root canal shape may occur and contribute a negative effect to the obturation quality and the success of endodontic treatment.[4] The efficiency of the preparation technique can be judged by the absence of root canal transportation and the short duration of root canal preparation. Root canal transportation is caused by the tendency of the file to return to its original form.[5]

The nickel-titanium (Ni-Ti) file system was introduced for endodontic treatment, which has better elasticity than stainless steel.[6] The super-elastic properties of Ni-Ti provide an advantage in the preparation of curved canals, as it reduces the force on the root canal walls, thus increasing the centering ability and reducing iatrogenic errors. Ni-Ti alloys may return to their original shape after tension or heat application due to the shape-memory effect.[7]

Ni-Ti has a high fracture incidence when used in narrow and curved root canals.[8] Continuous stress may weaken and fracture the instrument, which usually occurs at the maximum flexural point.[9] Developments in new technology to prevent the fracture of Ni-Ti instruments use a single-file reciprocation system.[10] This concept has various advantages over conventional rotary systems, e.g., better time efficiency because it only requires one file to prepare the root canal, ease of preparation, and safety in endodontic procedures due to the reduced incidence of instrument fracture and procedural errors.[11]

Reciprocating motion is a counterclockwise and clockwise movement intended to avoid taper locks and relieve the stress of the files.[10] Such movements prevent file fracture and increase resistance to cyclic fatigue and torsional fatigue.[8] It is known that there are several files with reciprocating motion. The most commonly used instruments are Reciproc® Blue (RB) (VDW, München, Germany) and Wave One Gold (WOG) (Dentsply Sirona, York, PA, USA).

Another important factor to avoid preparation errors is the glide path preparation. Preparing glide path is recommended, particularly in narrow or severe curved root canals. In contrast, reciprocal instruments may be used without glide path preparation. The study showed that glide path preparation is unnecessary in the majority of cases prepared using the reciprocal system.[12] Reciprocating instruments could go through the canal direction naturally to the tip of the root apex.[13]

Both manufacturers claimed that the heat treatment would increase the flexibility and fracture resistance of the instrument, but these two instruments have different cross-sectional shapes. This will affect the shape of the prepared root canal. This study aims to analyze the preparation results of two reciprocal Ni-Ti files with and without glide path preparation to the changes of root canal curvature.

Materials and Methods

This study was conducted for laboratory experimental research. This study used an endodontic block (ISO#15, 16 mm, 2% tapered, Endo Training Blocks S-Shape, Dentsply Sirona) made of transparent acrylic material that resembles the S-shaped root canal as the research sample.

A total of 50 endodontic blocks were prepared, and then 20 endodontic blocks were randomly selected and divided into four groups, with a total of five blocks for each test group. Groups 1 and 2 were explored with a K-file #010/2%, and root canal preparation was performed with WOG. Groups 3 and 4 were explored with a K-file #010/2%, and root canal preparation was performed with RB. Glide paths were prepared on Groups 2 and 4 with ProGlider (PG) (Dentsply Sirona) files before preparing the root canal with WOG (Dentsply Sirona)/RB (VDW). Each block was grouped and marked using a marker; then the preliminary photograph was taken at an angle of 90° with the same distance for each block.

Exploration with K-file #010/2% was performed with watch-winding (15–30°) and push/pull movement with light pressure until it reached the working length. Then the glide path was made and prepared according to the predetermined groups. Between file exchanges, the root canal was irrigated with 2 mL of distilled water, 2 mm apart from the apical foramen, using a 30 G side vent syringe. Then the root canals were dried using paper points.

The after-preparation photographs were taken using the same protocols as the preliminary photo. The brightness, contrast, and sharpness of the photos were adjusted using Adobe Photoshop CS6 (Adobe Inc., USA). The before and after preparation photos were combined and then superimposed. The measuring points were marked on the coronal curvature, the apical curvature, and the apical point [Figure 1]. The B line marked the coronal curvature, the C line marked the apical curvature, and the C line was at the apical point.

The transportation at the inner and outer root canal walls was measured using Adobe Photoshop CS6 software. Measurement of the transportation of the coronal curvature can be seen in Figure 2, the apical curvature in Figure 3, and apical point in Figure 4. One-way analysis of variance test was used to analyze the root canal transportation differences between WOG and RB, with and without glide path.

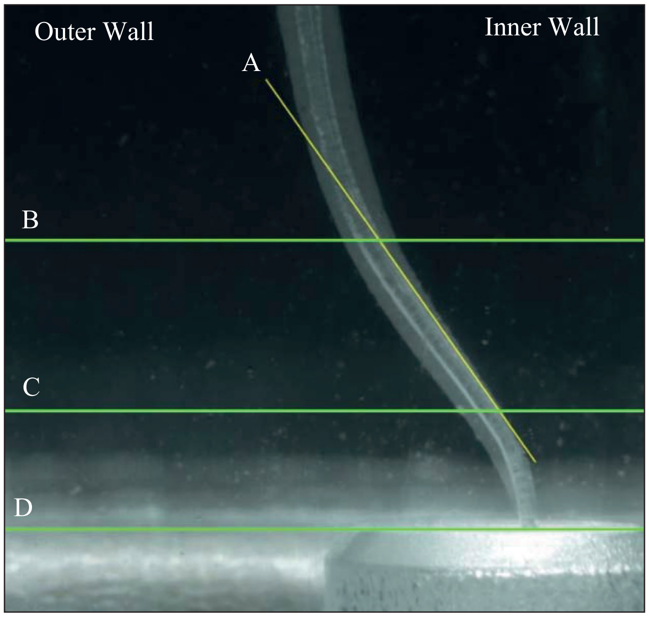

Figure 1: A digital photograph of an Endo Training Block which is S-shaped. The "A" line is an imaginary line drawn from the apically outmost point of the inner wall through the coronal direction according to the inclination of the curved canal. The "B" line is a horizontal line drawn where the imaginary line meets the outer point of the coronal curvature. The "C" line is a horizontal line drawn where the imaginary line meets the outer point of the apical curvature. The "D" line is a horizontal line drawn at the end of the apex of the endodontic block

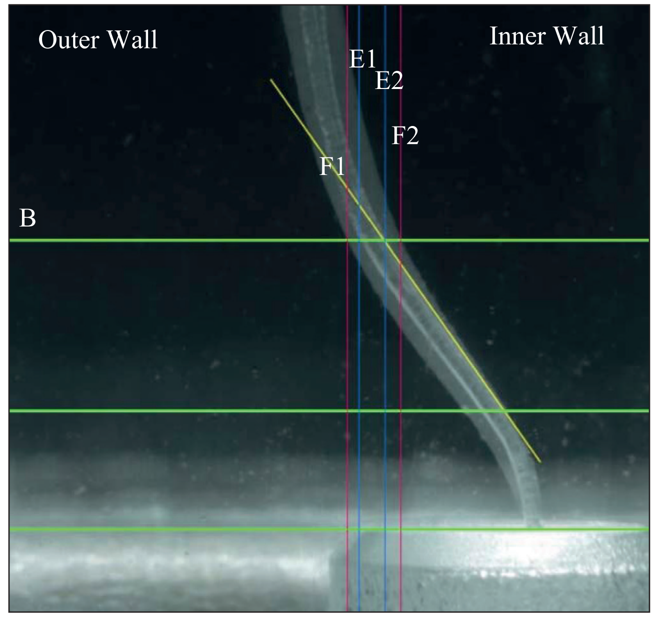

Figure 2: Measuring the transportation on the coronal curvature. The E1 and E2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to B line and marked as measuring point before preparation. The F1 and F2 lines are similar to the E lines and marked as measuring point after preparation. The transportations were measured by measuring the distance between E1 and F1, as well as E2 and F2

Result

The mean of root canal transportation (in mm) of each group can be seen in Table 1. The independent *t*-test was used to analyze the transportation of the outer and inner root canal walls at the coronal curvature, apical curvature, and apical points prepared using WOG and RB. The results showed that there was no significant difference on the inner or outer walls at the coronal curvature between the test groups prepared using WOG and RB, with and without glide path preparation ($P > 0.05$). Significant differences were found in the transportation of the apical curvature and the apical point at the inner wall between groups prepared using WOG and RB without glide path. Whereas in the preparation using both WOG and RB with glide path, there was no significant difference in root canal transportation at any measurement point on the inner wall or the outer wall at the coronal curvature, apical curvature, and apical point ($P > 0.05$). Root canal transportation on the outer wall tended to be greater in number on the RB group, with or without glide path preparation, whereas the group of WOG with or without glide path tended to have greater transportation on the inner walls. Complete results can be seen in Table 2.

Comparative analysis of root canal wall transportation was also performed within groups based on glide

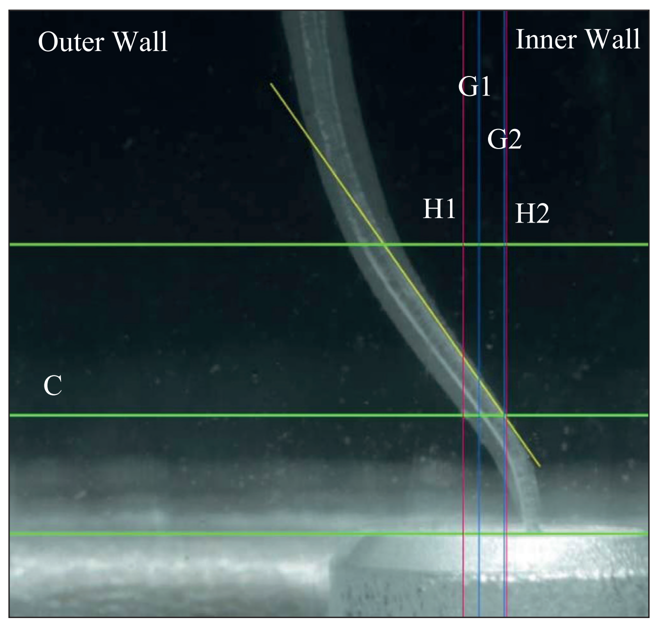

Figure 3: Measuring the transportation on the apical curvature. The G1 and G2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to C line and marked as measuring point before preparation. The H1 and H2 lines are similar to the G lines and marked as measuring point after preparation. The transportations were measured by measuring the distance between G1 and H1, as well as G2 and H2

path preparation [Table 3]. There was a statistically significant difference in the root canal transportation

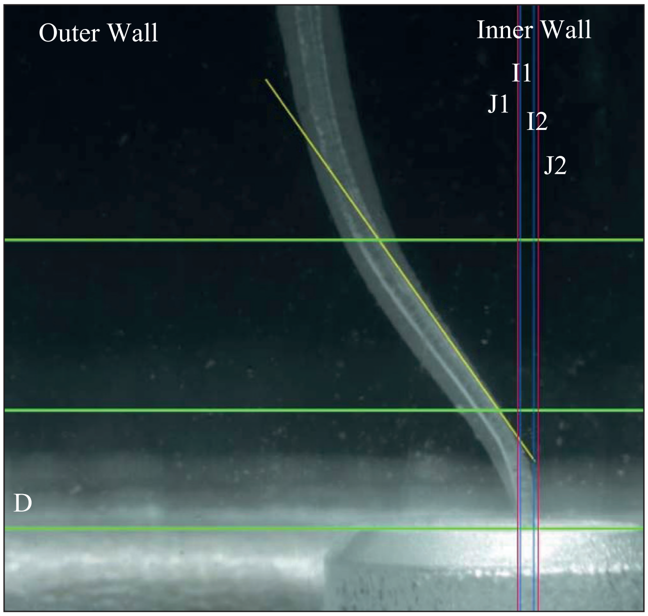

Figure 4: Measuring the transportation on the apical point. The I1 and I2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to D line and marked as measuring point before preparation. The J1 and J2 lines are similar to the I lines and marked as measuring point after preparation. The transportations were measured by measuring the distance between I1 and J1, as well as I2 and J2

Table 1: Transportation of root canals on outer and inner walls at coronal curvature, apical curvature, and apical point using WOG and RB

File instrument		*N*	Mean ± SD	
			Without glide path	With glide path
WOG	Coronal curvature	5		
	Outer wall		1.00 ± 0.81	1.51 ± 0.27
	Inner wall		2.44 ± 0.53	1.79 ± 0.28
	Apical curvature			
	Outer wall		1.35 ± 0.78	2.00 ± 0.33
	Inner wall		1.38 ± 0.45	0.33 ± 0.33
	Apical point			
	Outer wall		0.36 ± 0.42	0.62 ± 0.37
	Inner wall		1.78 ± 0.51	1.07 ± 0.74
RB	Coronal curvature	5		
	Outer wall		1.87 ± 0.35	1.85 ± 0.28
	Inner wall		1.87 ± 0.51	1.55 ± 0.35
	Apical curvature			
	Outer wall		1.91 ± 0.35	2.32 ± 0.40
	Inner wall		0.54 ± 0.46	0.36 ± 0.25
	Apical point			
	Outer wall		0.99 ± 0.58	0.32 ± 0.07
	Inner wall		0.67 ± 0.45	0.61 ± 0.24

on the inner walls at the coronal curvature ($P = 0.04$) and apical curvature ($P = 0.00$) within the WOG groups with and without glide path preparation. Root canal transportation on the outer wall tended to be greater in the WOG group with glide path, whereas greater transportation on the inner wall was found in the WOG group without glide path. The root canal transportation in the no glide path group was relatively greater than that of the glide path group at almost all measurement points except for the outer wall at the apical curvature.

The analysis in the group prepared with RB (Table 3) showed that there was no statistically significant difference in root canal transportation between the glide path and no glide path groups ($P > 0.05$). The root canal transportation in the no glide path group was relatively greater than that of the glide path group at almost all measurement points except for the outer wall at the apical curvature.

Discussion

Cleaning and shaping of root canals are essential for proper irrigation, disinfection, and obturation. Maintaining the original anatomical shape, position, and size of the apical foramen of the root canal is also important.[14,15] The glide path can guide the direction of preparation for subsequent endodontic instruments. A smooth, central glide path may prevent iatrogenic errors and complications during chemical-mechanical preparation such as taper locks, ledge formation, transportation, and instrument fracture.[16] The study showed that creating a glide path can reduce the likelihood of debris being pushed apically.[17]

Several instruments and techniques have been developed for root canal preparation, including manual preparation with stainless steel K-files, a combination of reciprocating a handpiece with stainless steel K-files, and the use of Ni-Ti rotary instruments. The use of Ni-Ti rotary instruments has several advantages, such as shorter working time and glide path preparation, that maintain the anatomical shape of the root canals. However, the drawback of Ni-Ti instruments lies in the extent of resistance to cyclic fatigue. ProGlider (PG) is a rotary instrument for glide path preparation made of memory Ni-Ti wire (M-Wire), which has better resistance to cyclic fatigue compared with conventional Ni-Ti instruments.[16]

The effect of glide path creation was also analyzed in this study. The final file size that was used is #25, because the root canal transportation will be greater, along with a larger file size.[18] The endodontic blocks with a multi-curvature root canal (S-shaped) were used as samples to standardize experimental conditions and may describe the performance of each type of instrument used.[15] However, this endodontic block is unable to simulate how the instrument file works on natural tooth. Endodontic blocks have a higher surface hardness level than dentin, and there is a possibility that the surface of the endodontic block may soften during preparation. Assessment of the changes in the root canal shape after mechanical preparation is typically used to assess the mechanical properties of the file or the technique used that may affect the shaping ability of a file type.[19]

There are three microstructure phases of Ni-Ti, i.e., austenite, martensite, and R-phase. When Ni-Ti alloys are in the austenite phase, they have strong and hard properties, whereas in the martensite phase, they become flexible and elastic.[20] This study used WOG and RB rotary instruments. Both files are from the same generation and are based on the gold and blue heat-treated types. This material is martensitic with few austenite and R-phase properties, which give it a controlled memory effect, a pseudoplastic effect, a shape memory effect, superior flexibility, and good cyclic fatigue resistance.[21]

Based on this study, it is known that there is a difference in the root canal transportation on the inner wall at the

Table 2: Comparison of the root canal transportation between the group prepared using WOG ($x1$) and RB ($x2$) with or without glide path creation

		WOG (x_1)	RB (x_2)	($x_1 - x_2$)	*P*-value
Without glide path	Coronal curvature				
	Outer wall	1.00	1.87	−0.87	0.004*
	Inner wall	2.44	1.87	0.57	0.013*
	Apical curvature				
	Outer wall	1.35	1.91	−0.56	0.007*
	Inner wall	1.38	0.54	0.84	0.784
	Apical point				
	Outer wall	0.36	0.99	−0.63	0.011*
	Inner wall	1.78	0.67	1.11	0.000*
With glide path	Coronal curvature				
	Outer wall	1.51	1.85	−0.34	0.000*
	Inner wall	1.79	1.55	0.24	0.000*
	Apical curvature				
	Outer wall	2.00	2.32	−0.32	0.000*
	Inner wall	0.33	0.36	−0.03	0.000*
	Apical point				
	Outer wall	0.62	0.32	0.30	0.000*
	Inner wall	1.07	0.61	0.46	0.000*

*Significant ($P < 0.05$); n=5

Table 3: Effect of glide path preparation using PG on root canal transportation based on the type of rotary instrument

		Without glide path (x_1)	With glide path (x_2)	($x_1 - x_2$)	*P*-value
WOG	Coronal curvature				
	Outer wall	1.00	1.51	−0.51	0.000*
	Inner wall	2.44	1.79	0.65	0.000*
	Apical curvature	1.35	2.00	−0.65	
	Outer wall	1.38	0.33	1.05	0.000*
	Inner wall	0.36	0.62	−0.26	0.000*
	Apical point	1.78	1.07	0.71	
	Outer wall				0.025*
	Inner wall				0.000*
RB	Coronal curvature				
	Outer wall	1.87	1.85	0.02	0.855
	Inner wall	1.87	1.55	0.32	0.007*
	Apical curvature				
	Outer wall	1.91	2.32	−0.41	0.001*
	Inner wall	0.54	0.36	0.18	0.110
	Apical point				
	Outer wall	0.99	0.32	0.67	0.000*
	Inner wall	0.67	0.61	0.06	0.585

*Significant $P < 0.05$; n=5

apical curvature and apical point between the WOG group and the RB group without glide path preparation. Transportation in the WOG group (1.38 and 1.78 mm) was greater than that of the RB group (0.54 and 0.67 mm) at these two reference points. In the superimposition of before and after preparation photographs, there was no visible root canal shape changes in the preparation result of the two instruments. This indicates that the WOG instrument tends to straighten the curvature at the apical part of the S-shaped root canal. This is consistent with the previous study that preparation with the WOG instrument may straighten the curved root canal shape but still maintain the original curvature of the root canal.[22] A change in the curvature shape of the root canal can cause a reduction in working length of about 0.5 mm. Changes in the working length must be considered to avoid over-instrumentation. The study also showed that WOG can maintain the original shape of the root canal.[18]

Both of these instruments have super-elastic properties, but the thermo-mechanical treatment of the RB reduces the shape memory of this instrument, making it more flexible. This—combined with the cross-sectional shape of the RB, which does not have a cutting section at the tip of the file—makes RB better at maintaining the position of the apical foramen than WOG.[15] The previous study showed that the smallest transportation value in the apical region was obtained from the RB preparation results. The RB instrument showed a better ability at centralizing the preparation and maintaining the position of the apical foramen than WOG.[23] The presence of thermo-mechanical treatments on RB made significant differences in the inner root canal walls and transportation at the apical curvature and the apical point between the WOG and RB groups without glide path, but there was no difference in the outer or inner root canal walls at the coronal curvature or at the outer walls at the apical curvature or apical point. File #25 of the WOG and RB systems has almost the same taper degrees (0.08 for RB and 0.07 for WOG), so that the changes of the coronal curvature are not significantly different. This result is supported by research, which states that the increase in percentage of the apical area volume of the root canal instrumentation with file #25 of the RB system was 42.18%, compared with the WOG system of 91.16%. This shows that the WOG preparation may widen the apical area of the S-shaped canal.[24]

Based on the glide path preparation using PG, there was no significant difference in the WOG group when compared with the RB group. This showed that the Ni-Ti PG instrument can maintain the curvature of the root canal and has a centering capability. The study showed that 33% of the glide path preparation results using the PG instrument showed no transportation at the 2 mm point from the apex.[25] The study showed that there were no significant differences in root canal transportation in the preparation result using WOG and RB with glide path preparation using Flexofile #15.[23] The study showed that root canal preparation using WOG and RB instruments maintained the original shape of the root canal curvature and was safe to use. The difference in alloy base material (gold and blue wire heat-treated) did not affect the shaping ability of these two types of instruments.[26]

The analysis of the RB group showed no significant difference in root canal transportation between the non-glide path group and the glide path group at any measurement points. This suggests that the RB instrument can maintain the curvature shape of the root canal and prevent apical transportation, and that is not affected by the glide path prior to preparation. The study showed that there was a difference in apical transportation of root canals prepared using RB with glide path preparation using PG compared with no glide path. The difference in transportation obtained was 0.13 mm.[27] The study showed that apical transportation of more than 0.3 mm negatively affects the sealing ability of the root canal filling material.[28]

The study showed that developments in technology may produce instruments fabricated from gold wire such as the Wave One Gold Glider (WOGG) and reciprocating instruments such as the R-Pilot, which have much better cyclic fatigue resistance compared with PG. This may be due to the better thermo-mechanical properties of gold wire compared with M-wire and the reciprocation motion, which is more resistant to cyclic fatigue than rotary motion.[16] The previous study also reported that creating a glide path using WOGG takes less time when compared with a K-file.[14]

Glide path preparation is essential for both rotary and reciprocating Ni-Ti instruments to work properly.[18] The study showed that glide path preparation may significantly reduce working time.[29] For safer, more efficient, and predictable results, creating glide path is still recommended prior to root canal preparation.[14]

There was a limitation of this study, thus it is necessary to conduct further research to evaluate the interaction between these instruments and natural tooth. Measurements in this study were carried out in a two-dimensional image, so it is advisable to carry out further research with three-dimensional image assessments to provide more accurate results.

Conclusion

Based on the results of this study, it can be concluded that there are significant differences in the curvature of the root canal prepared using WOG and RB on the inner walls at the apical curvature and apical point without glide path preparation. Root canal preparation without glide path can lead to greater canal transportation when compared with the results of preparations using Ni-Ti-based instruments such as PG for glide path preparation. The PG instrument used for glide path preparation preserves the original shape of the root canal curvature and prevents apical transportation. The use of endodontic blocks in this study does not fully reflect the interaction between rotary instruments and natural tooth.

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Nil.

Conflicts of interest

The authors declare no conflict of interest.

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Differences in Preparation Results of Two Reciprocal Ni-Ti Files with and Without Glide Path to the Changes on Root Canal Curvature

by Wiena Widyastuti FKG

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Original Article

Differences in Preparation Results of Two Reciprocal Ni-Ti Files with and Without Glide Path to the Changes on Root Canal Curvature

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Abstract

Background: Maintaining the anatomy of the root canal is crucial in root canal treatment. The super-elastic property of the nickel-titanium (Ni-Ti) file system provides advantages in preparation of curved root canals, as it can reduce the force on the root canal wall, increase centering ability, and reduce iatrogenic errors. **Objective:** The aim of this article is to determine the differences in preparation results of two reciprocal Ni-Ti files with and without glide path to the changes of root canal curvature. **Materials and Methods:** Twenty pieces of endodontic blocks (ISO# 15, 16 mm, 2% tapered) were divided into four randomly assigned groups. Group 1 (without glide path) and Group 2 (with glide path) were prepared with Wave One Gold (WOG). Group 3 (without glide path) and Group 4 (with glide path) were prepared with Reciproc Blue (RB). Each subject was explored using K-file #10. Glide path was prepared with ProGlider (PG) #16. Digital images of before and after the root canal preparations were taken using a digital camera with the same angle and distance settings. The before and after photos were superimposed on each other, and the transportation at the inner and outer root canal walls in the coronal curvature, apical curvature, and apical end points was measured with software. **Results:** No significant difference was found between changes in the coronal curvature using WOG and RB, with and without glide path ($P > 0.05$). The same result was observed between WOG and RB groups with glide path at each measurement point. Significant differences were found between changes in apical curvature and apical point in the inner wall using WOG and RB without glide path ($P < 0.05$). **Conclusion:** There were differences in root canal curvature prepared using WOG and RB on the apical region when prepared without glide path, but no differences were found when prepared with glide path at each point measurement.

Keywords: *Canal transportation, Reciproc Blue, root canal treatment, Wave One Gold*

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Background

The purpose of root canal preparation is to clean the root canal and shape a conical canal to apical direction, with the largest diameter at the orifice of the root canal and the smallest diameter at the apical tip.[1] This ideal shape is very difficult to achieve in curved root canals or S-shaped root canals.[2] Maintaining root canal anatomy is an important thing, especially when treating curved root canals.[3] Aggressive instrumentation of the root canal walls will result in excessive dentin reduction, which may weaken the tooth

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structure. During root canal treatment, deviation from the initial root canal shape may occur and contribute a negative effect to the obturation quality and the success of endodontic treatment.[4] The efficiency of the preparation technique can be judged by the absence of root canal transportation and the short duration of root canal preparation. Root canal transportation is caused by the tendency of the file to return to its original form.[5]

The nickel-titanium (Ni-Ti) file system was introduced for endodontic treatment, which has better elasticity than stainless steel.[6] The super-elastic properties of Ni-Ti provide an advantage in the preparation of curved canals, as it reduces the force on the root canal walls, thus increasing the centering ability and reducing iatrogenic errors. Ni-Ti alloys may return to their original shape after tension or heat application due to the shape-memory effect.[7]

Ni-Ti has a high fracture incidence when used in narrow and curved root canals.[8] Continuous stress may weaken and fracture the instrument, which usually occurs at the maximum flexural point.[9] Developments in new technology to prevent the fracture of Ni-Ti instruments use a single-file reciprocation system.[10] This concept has various advantages over conventional rotary systems, e.g., better time efficiency because it only requires one file to prepare the root canal, ease of preparation, and safety in endodontic procedures due to the reduced incidence of instrument fracture and procedural errors.[11]

Reciprocating motion is a counterclockwise and clockwise movement intended to avoid taper locks and relieve the stress of the files.[10] Such movements prevent file fracture and increase resistance to cyclic fatigue and torsional fatigue.[8] It is known that there are several files with reciprocating motion. The most commonly used instruments are Reciproc® Blue (RB) (VDW, München, Germany) and Wave One Gold (WOG) (Dentsply Sirona, York, PA, USA).

Another important factor to avoid preparation errors is the glide path preparation. Preparing glide path is recommended, particularly in narrow or severe curved root canals. In contrast, reciprocal instruments may be used without glide path preparation. The study showed that glide path preparation is unnecessary in the majority of cases prepared using the reciprocal system.[12] Reciprocating instruments could go through the canal direction naturally to the tip of the root apex.[13]

Both manufacturers claimed that the heat treatment would increase the flexibility and fracture resistance of the instrument, but these two instruments have different cross-sectional shapes. This will affect the shape of the prepared root canal. This study aims to analyze the preparation results of two reciprocal Ni-Ti files with and without glide path preparation to the changes of root canal curvature.

Materials and Methods

This study was conducted for laboratory experimental research. This study used an endodontic block (ISO#15, 16 mm, 2% tapered, Endo Training Blocks S-Shape, Dentsply Sirona) made of transparent acrylic material that resembles the S-shaped root canal as the research sample.

A total of 50 endodontic blocks were prepared, and then 20 endodontic blocks were randomly selected and divided into four groups, with a total of five blocks for each test group. Groups 1 and 2 were explored with a K-file #010/2%, and root canal preparation was performed with WOG. Groups 3 and 4 were explored with a K-file #010/2%, and root canal preparation was performed with RB. Glide paths were prepared on Groups 2 and 4 with ProGlider (PG) (Dentsply Sirona) files before preparing the root canal with WOG (Dentsply Sirona)/RB (VDW). Each block was grouped and marked using a marker; then the preliminary photograph was taken at an angle of 90° with the same distance for each block.

Exploration with K-file #010/2% was performed with watch-winding (15–30°) and push/pull movement with light pressure until it reached the working length. Then the glide path was made and prepared according to the predetermined groups. Between file exchanges, the root canal was irrigated with 2 mL of distilled water, 2 mm apart from the apical foramen, using a 30 G side vent syringe. Then the root canals were dried using paper points.

The after-preparation photographs were taken using the same protocols as the preliminary photo. The brightness, contrast, and sharpness of the photos were adjusted using Adobe Photoshop CS6 (Adobe Inc., USA). The before and after preparation photos were combined and then superimposed. The measuring points were marked on the coronal curvature, the apical curvature, and the apical point [Figure 1]. The B line marked the coronal curvature, the C line marked the apical curvature, and the C line was at the apical point.

The transportation at the inner and outer root canal walls was measured using Adobe Photoshop CS6 software. Measurement of the transportation of the coronal curvature can be seen in Figure 2, the apical curvature in Figure 3, and apical point in Figure 4. One-way analysis of variance test was used to analyze the root canal transportation differences between WOG and RB, with and without glide path.

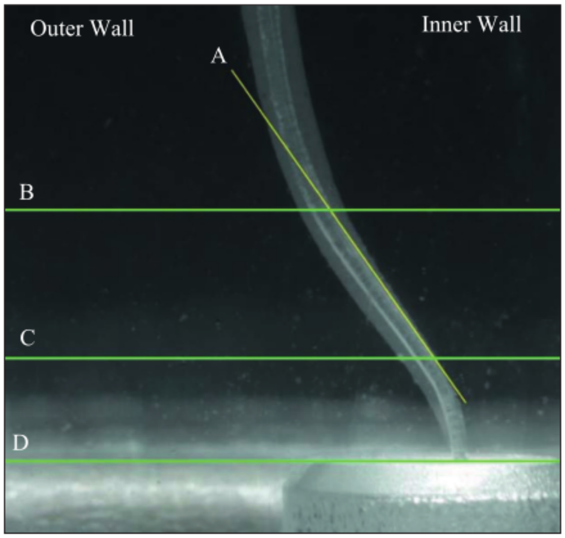

Figure 1: A digital photograph of an Endo Training Block which is S-shaped. The "A" line is an imaginary line drawn from the apically outmost point of the inner wall through the coronal direction according to the inclination of the curved canal. The "B" line is a horizontal line drawn where the imaginary line meets the outer point of the coronal curvature. The "C" line is a horizontal line drawn where the imaginary line meets the outer point of the apical curvature. The "D" line is a horizontal line drawn at the end of the apex of the endodontic block

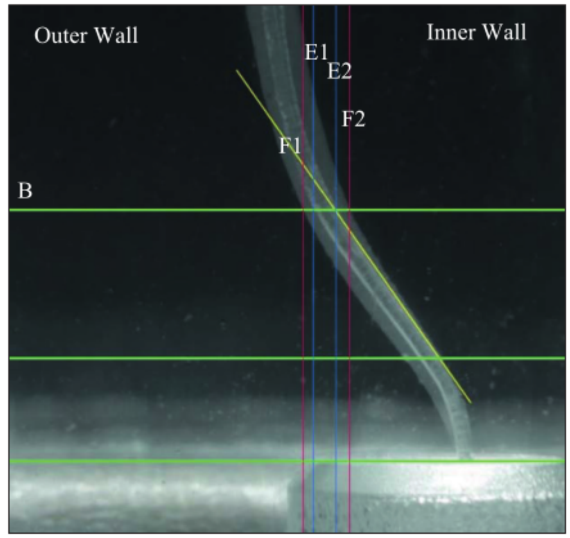

Figure 2: Measuring the transportation on the coronal curvature. The E1 and E2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to B line and marked as measuring point before preparation. The F1 and F2 lines are similar to the E lines and marked as measuring point after preparation. The transportations were measured by measuring the distance between E1 and F1, as well as E2 and F2

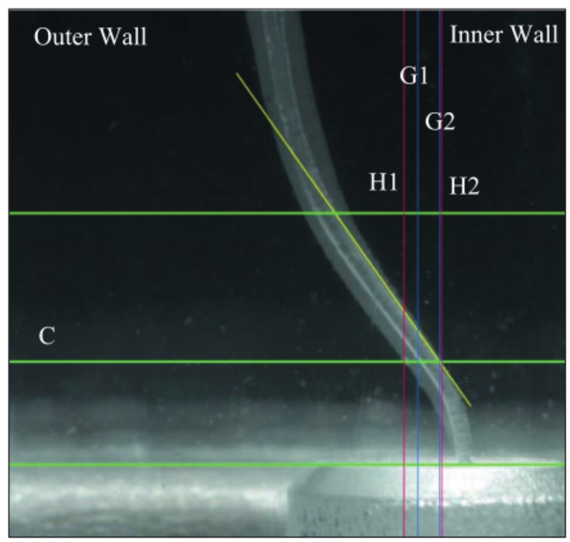

Figure 3: Measuring the transportation on the apical curvature. The G1 and G2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to C line and marked as measuring point before preparation. The H1 and H2 lines are similar to the G lines and marked as measuring point after preparation. The transportations were measured by measuring the distance between G1 and H1, as well as G2 and H2

Result

The mean of root canal transportation (in mm) of each group can be seen in Table 1. The independent *t*-test was used to analyze the transportation of the outer and inner root canal walls at the coronal curvature, apical curvature, and apical points prepared using WOG and RB. The results showed that there was no significant difference on the inner or outer walls at the coronal curvature between the test groups prepared using WOG and RB, with and without glide path preparation ($P > 0.05$). Significant differences were found in the transportation of the apical curvature and the apical point at the inner wall between groups prepared using WOG and RB without glide path. Whereas in the preparation using both WOG and RB with glide path, there was no significant difference in root canal transportation at any measurement point on the inner wall or the outer wall at the coronal curvature, apical curvature, and apical point ($P > 0.05$). Root canal transportation on the outer wall tended to be greater in number on the RB group, with or without glide path preparation, whereas the group of WOG with or without glide path tended to have greater transportation on the inner walls. Complete results can be seen in Table 2.

Comparative analysis of root canal wall transportation was also performed within groups based on glide path preparation [Table 3]. There was a statistically significant difference in the root canal transportation

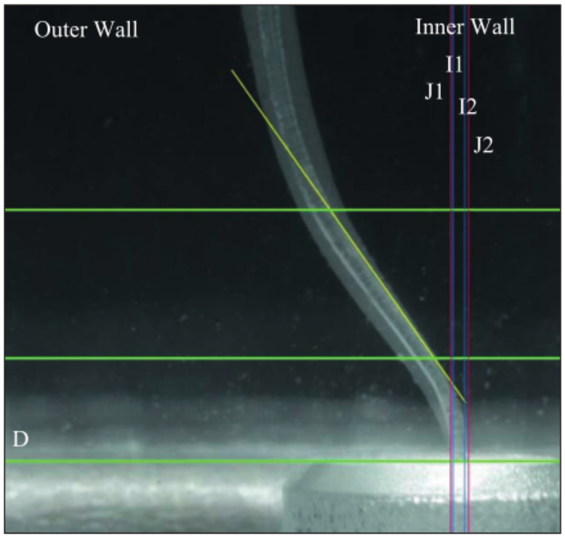

Figure 4: Measuring the transportation on the apical point. The I1 and I2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to D line and marked as measuring point before preparation. The J1 and J2 lines are similar to the I lines and marked as measuring point after preparation. The transportations were measured by measuring the distance between I1 and J1, as well as I2 and J2

Table 1: Transportation of root canals on outer and inner walls at coronal curvature, apical curvature, and apical point using WOG and RB

File instrument		*N*	Mean ± SD	
			Without glide path	With glide path
WOG	Coronal curvature	5		
	Outer wall		1.00 ± 0.81	1.51 ± 0.27
	Inner wall		2.44 ± 0.53	1.79 ± 0.28
	Apical curvature			
	Outer wall		1.35 ± 0.78	2.00 ± 0.33
	Inner wall		1.38 ± 0.45	0.33 ± 0.33
	Apical point			
	Outer wall		0.36 ± 0.42	0.62 ± 0.37
	Inner wall		1.78 ± 0.51	1.07 ± 0.74
RB	Coronal curvature	5		
	Outer wall		1.87 ± 0.35	1.85 ± 0.28
	Inner wall		1.87 ± 0.51	1.55 ± 0.35
	Apical curvature			
	Outer wall		1.91 ± 0.35	2.32 ± 0.40
	Inner wall		0.54 ± 0.46	0.36 ± 0.25
	Apical point			
	Outer wall		0.99 ± 0.58	0.32 ± 0.07
	Inner wall		0.67 ± 0.45	0.61 ± 0.24

on the inner walls at the coronal curvature ($P = 0.04$) and apical curvature ($P = 0.00$) within the WOG groups with and without glide path preparation. Root canal transportation on the outer wall tended to be greater in the WOG group with glide path, whereas greater transportation on the inner wall was found in the WOG group without glide path. The root canal transportation in the no glide path group was relatively greater than that of the glide path group at almost all measurement points except for the outer wall at the apical curvature.

The analysis in the group prepared with RB (Table 3) showed that there was no statistically significant difference in root canal transportation between the glide path and no glide path groups ($P > 0.05$). The root canal transportation in the no glide path group was relatively greater than that of the glide path group at almost all measurement points except for the outer wall at the apical curvature.

Discussion

Cleaning and shaping of root canals are essential for proper irrigation, disinfection, and obturation. Maintaining the original anatomical shape, position, and size of the apical foramen of the root canal is also important.[14,15] The glide path can guide the direction of preparation for subsequent endodontic instruments. A smooth, central glide path may prevent iatrogenic errors and complications during chemical-mechanical preparation such as taper locks, ledge formation, transportation, and instrument fracture.[16] The study showed that creating a glide path can reduce the likelihood of debris being pushed apically.[17]

Several instruments and techniques have been developed for root canal preparation, including manual preparation with stainless steel K-files, a combination of reciprocating a handpiece with stainless steel K-files, and the use of Ni-Ti rotary instruments. The use of Ni-Ti rotary instruments has several advantages, such as shorter working time and glide path preparation, that maintain the anatomical shape of the root canals. However, the drawback of Ni-Ti instruments lies in the extent of resistance to cyclic fatigue. ProGlider (PG) is a rotary instrument for glide path preparation made of memory Ni-Ti wire (M-Wire), which has better resistance to cyclic fatigue compared with conventional Ni-Ti instruments.[16]

The effect of glide path creation was also analyzed in this study. The final file size that was used is #25, because the root canal transportation will be greater, along with a larger file size.[18] The endodontic blocks with a multi-curvature root canal (S-shaped) were used as samples to standardize experimental conditions and may describe the performance of each type of instrument used.[15] However, this endodontic block is unable to simulate how the instrument file works on natural tooth. Endodontic blocks have a higher surface hardness level than dentin, and there is a possibility that the surface of the endodontic block may soften during preparation. Assessment of the changes in the root canal shape after mechanical preparation is typically used to assess the mechanical properties of the file or the technique used that may affect the shaping ability of a file type.[19]

There are three microstructure phases of Ni-Ti, i.e., austenite, martensite, and R-phase. When Ni-Ti alloys are in the austenite phase, they have strong and hard properties, whereas in the martensite phase, they become flexible and elastic.[20] This study used WOG and RB rotary instruments. Both files are from the same generation and are based on the gold and blue heat-treated types. This material is martensitic with few austenite and R-phase properties, which give it a controlled memory effect, a pseudoplastic effect, a shape memory effect, superior flexibility, and good cyclic fatigue resistance.[21]

Based on this study, it is known that there is a difference in the root canal transportation on the inner wall at the

Table 2: Comparison of the root canal transportation between the group prepared using WOG ($x1$) and RB ($x2$) with or without glide path creation

		WOG (x_1)	RB (x_2)	(x_1-x_2)	*P*-value
Without glide path	Coronal curvature				
	Outer wall	1.00	1.87	−0.87	0.004*
	Inner wall	2.44	1.87	0.57	0.013*
	Apical curvature				
	Outer wall	1.35	1.91	−0.56	0.007*
	Inner wall	1.38	0.54	0.84	0.784
	Apical point				
	Outer wall	0.36	0.99	−0.63	0.011*
	Inner wall	1.78	0.67	1.11	0.000*
With glide path	Coronal curvature				
	Outer wall	1.51	1.85	−0.34	0.000*
	Inner wall	1.79	1.55	0.24	0.000*
	Apical curvature				
	Outer wall	2.00	2.32	−0.32	0.000*
	Inner wall	0.33	0.36	−0.03	0.000*
	Apical point				
	Outer wall	0.62	0.32	0.30	0.000*
	Inner wall	1.07	0.61	0.46	0.000*

*Significant ($P < 0.05$); n=5

Table 3: Effect of glide path preparation using PG on root canal transportation based on the type of rotary instrument

		Without glide path (x_1)	With glide path (x_2)	($x_1 - x_2$)	*P*-value
WOG	Coronal curvature				
	Outer wall	1.00	1.51	−0.51	0.000*
	Inner wall	2.44	1.79	0.65	0.000*
	Apical curvature	1.35	2.00	−0.65	
	Outer wall	1.38	0.33	1.05	0.000*
	Inner wall	0.36	0.62	−0.26	0.000*
	Apical point	1.78	1.07	0.71	
	Outer wall				0.025*
	Inner wall				0.000*
RB	Coronal curvature				
	Outer wall	1.87	1.85	0.02	0.855
	Inner wall	1.87	1.55	0.32	0.007*
	Apical curvature				
	Outer wall	1.91	2.32	−0.41	0.001*
	Inner wall	0.54	0.36	0.18	0.110
	Apical point				
	Outer wall	0.99	0.32	0.67	0.000*
	Inner wall	0.67	0.61	0.06	0.585

*Significant $P < 0.05$; n=5

apical curvature and apical point between the WOG group and the RB group without glide path preparation. Transportation in the WOG group (1.38 and 1.78 mm) was greater than that of the RB group (0.54 and 0.67 mm) at these two reference points. In the superimposition of before and after preparation photographs, there was no visible root canal shape changes in the preparation result of the two instruments. This indicates that the WOG instrument tends to straighten the curvature at the apical part of the S-shaped root canal. This is consistent with the previous study that preparation with the WOG instrument may straighten the curved root canal shape but still maintain the original curvature of the root canal.[22] A change in the curvature shape of the root canal can cause a reduction in working length of about 0.5 mm. Changes in the working length must be considered to avoid over-instrumentation. The study also showed that WOG can maintain the original shape of the root canal.[18]

Both of these instruments have super-elastic properties, but the thermo-mechanical treatment of the RB reduces the shape memory of this instrument, making it more flexible. This—combined with the cross-sectional shape of the RB, which does not have a cutting section at the tip of the file—makes RB better at maintaining the position of the apical foramen than WOG.[15] The previous study showed that the smallest transportation value in the apical region was obtained from the RB preparation results. The RB instrument showed a better ability at centralizing the preparation and maintaining the position of the apical foramen than WOG.[23] The presence of thermo-mechanical treatments on RB made significant differences in the inner root canal walls and transportation at the apical curvature and the apical point between the WOG and RB groups without glide path, but there was no difference in the outer or inner root canal walls at the coronal curvature or at the outer walls at the apical curvature or apical point. File #25 of the WOG and RB systems has almost the same taper degrees (0.08 for RB and 0.07 for WOG), so that the changes of the coronal curvature are not significantly different. This result is supported by research, which states that the increase in percentage of the apical area volume of the root canal instrumentation with file #25 of the RB system was 42.18%, compared with the WOG system of 91.16%. This shows that the WOG preparation may widen the apical area of the S-shaped canal.[24]

Based on the glide path preparation using PG, there was no significant difference in the WOG group when compared with the RB group. This showed that the Ni-Ti PG instrument can maintain the curvature of the root canal and has a centering capability. The study showed that 33% of the glide path preparation results using the PG instrument showed no transportation at the 2 mm point from the apex.[25] The study showed that there were no significant differences in root canal transportation in the preparation result using WOG and RB with glide path preparation using Flexofile #15.[23] The study showed that root canal preparation using WOG and RB instruments maintained the original shape of the root canal curvature and was safe to use. The difference in alloy base material (gold and blue wire heat-treated) did not affect the shaping ability of these two types of instruments.[26]

The analysis of the RB group showed no significant difference in root canal transportation between the non-glide path group and the glide path group at any measurement points. This suggests that the RB instrument can maintain the curvature shape of the root canal and prevent apical transportation, and that is not affected by the glide path prior to preparation. The study showed that there was a difference in apical transportation of root canals prepared using RB with glide path preparation using PG compared with no glide path. The difference in transportation obtained was 0.13 mm.[27] The study showed that apical transportation of more than 0.3 mm negatively affects the sealing ability of the root canal filling material.[28]

The study showed that developments in technology may produce instruments fabricated from gold wire such as the Wave One Gold Glider (WOGG) and reciprocating instruments such as the R-Pilot, which have much better cyclic fatigue resistance compared with PG. This may be due to the better thermo-mechanical properties of gold wire compared with M-wire and the reciprocation motion, which is more resistant to cyclic fatigue than rotary motion.[16] The previous study also reported that creating a glide path using WOGG takes less time when compared with a K-file.[14]

Glide path preparation is essential for both rotary and reciprocating Ni-Ti instruments to work properly.[18] The study showed that glide path preparation may significantly reduce working time.[29] For safer, more efficient, and predictable results, creating glide path is still recommended prior to root canal preparation.[14]

There was a limitation of this study, thus it is necessary to conduct further research to evaluate the interaction between these instruments and natural tooth. Measurements in this study were carried out in a two-dimensional image, so it is advisable to carry out further research with three-dimensional image assessments to provide more accurate results.

Conclusion

Based on the results of this study, it can be concluded that there are significant differences in the curvature of the root canal prepared using WOG and RB on the inner walls at the apical curvature and apical point without glide path preparation. Root canal preparation without glide path can lead to greater canal transportation when compared with the results of preparations using Ni-Ti-based instruments such as PG for glide path preparation. The PG instrument used for glide path preparation preserves the original shape of the root canal curvature and prevents apical transportation. The use of endodontic blocks in this study does not fully reflect the interaction between rotary instruments and natural tooth.

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Conflicts of interest

The authors declare no conflict of interest.

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