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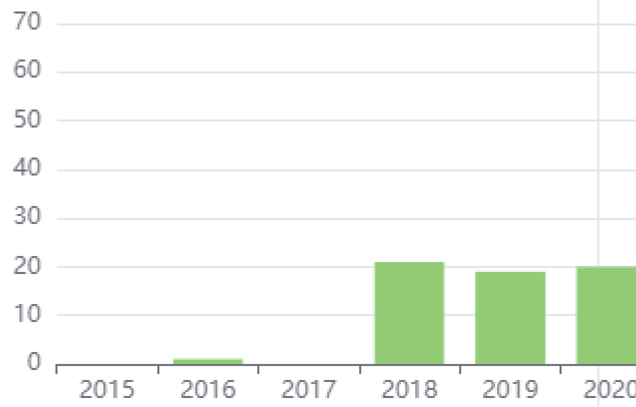

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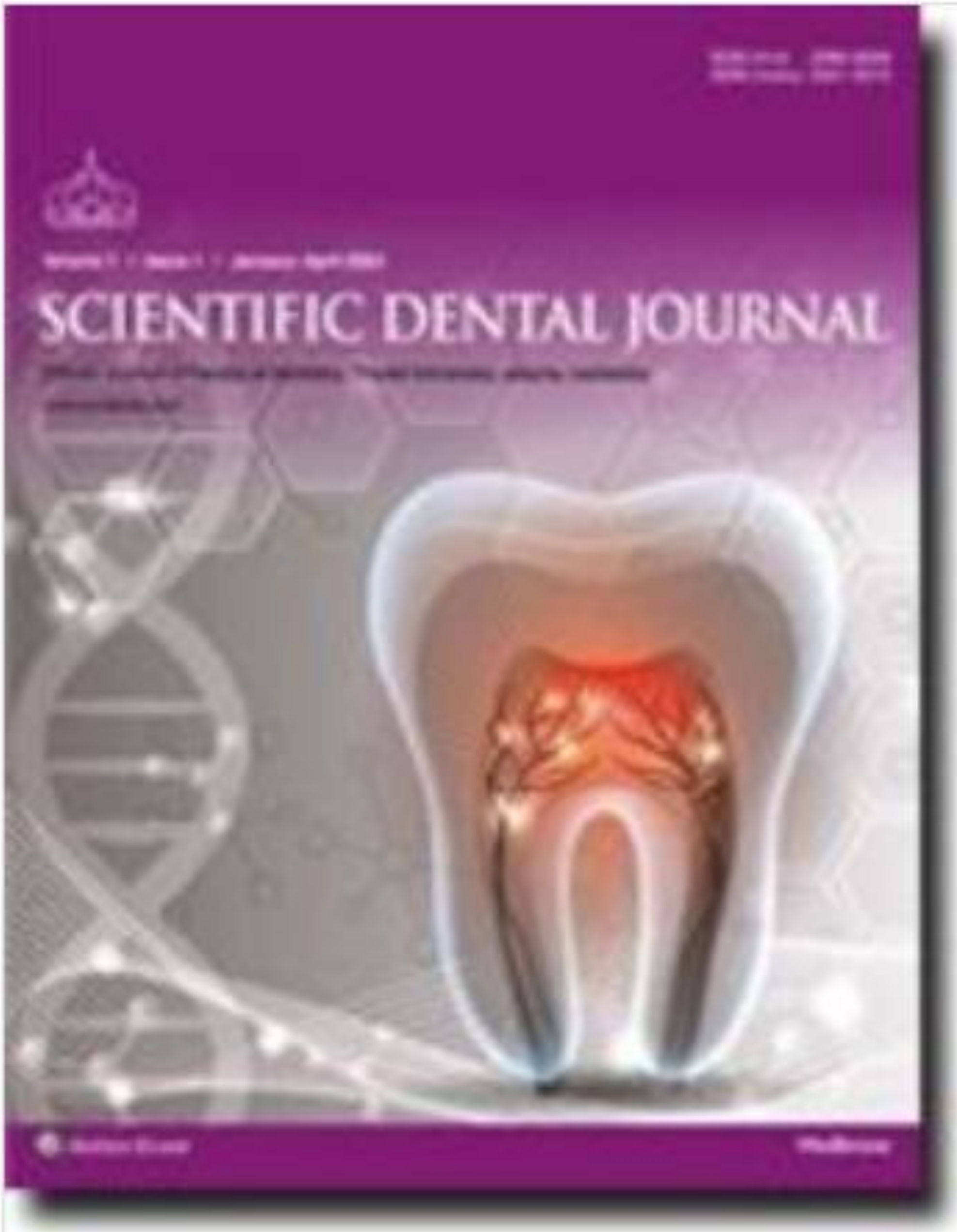

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Original Article

Differences in Apical Vapor Lock Formation after Sodium Hypochlorite Irrigation with and without Surfactant Using Two Needle Types

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ABSTRACT

Background: Endodontic irrigation with 5.25% sodium hypochlorite (NaOCl) solution using single side-vented and double side-vented needles is commonly used. Surfactant is added to reduce high surface tension of the NaOCl solution. Apical vapor lock, or air entrapment inside closed-end root canal system, lowers the efficacy of irrigants. Thus, the irrigants are hindered in penetrating the root canal system and can lead to risk of reinfection. **Objective:** The objective is to analyze the difference of 5.25% NaOCl solution with and without surfactant using two types of irrigation needle in the formation of apical vapor lock. **Methods:** Forty lower premolars were prepared and randomly divided into four groups (n = 10 per group) then irrigated with 5.25% NaOCl solution with and without surfactant using a single side-vented or double side-vented needle. Contrast medium was added so that the measurement of the apical vapor lock could be performed using a digital radiograph. Analysis was done with two-way analysis of variance and the Tukey method. **Results:** 5.25% NaOCl solution with a single side-vented needle showed a significant difference from 5.25% NaOCl solution with a double side-vented needle. 5.25% NaOCl solution with a surfactant using a single side-vented needle showed a significant difference from 5.25% NaOCl solution using a double side-vented needle, likewise NaOCl 5.25% using double side-vented needle group from NaOCl 5.25% with surfactant using single side-vented needle group. **Conclusion:** Minimal formation of an apical vapor lock resulted from the use of 5.25% NaOCl solution with a surfactant using a single side-vented needle.

Keywords: *Apical vapor lock, irrigation needle, sodium hypochlorite 5.25%, surface tension, surfactant*

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Background

The goal of root canal treatment is disinfection and filling of the root canal. Root canal disinfection is achieved by cleaning and shaping. Complex root canal systems make it difficult to achieve complete cleaning with mechanical preparation alone, so irrigation is necessary.[1]

Currently, there are various irrigation solutions that are widely used, such as sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), and chlorhexidine.[2] NaOCl, as one of the most widely used solutions, is an endodontic irrigation standard. NaOCl has antibacterial properties and the ability to dissolve necrotic tissue, vital pulp tissue, and organic components from dentin and bacterial biofilms. In root canal treatment, the NaOCl concentrations used are 2.5% NaOCl, 5.25% NaOCl without surfactants, and 5.25% NaOCl with surfactants. NaOCl in higher concentrations has a greater ability to dissolve tissue, so the same effectiveness can be achieved with less volume and frequency compared to NaOCl with lower concentration.[2]

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There are many types and sizes of irrigation needles on the market. Types of irrigation needles that are widely used either have a hole on one side (single side-vented) or have holes on both sides (double side-vented).[2] Single and double side-vented needles produce flow, but have less exchange of irrigation solutions compared to open-end needle. On the other hand, using these two types of needles, the irrigation solution moves more to the coronal end and only moves 1–1.5 mm to the apical end, so that the risk of extruding the irrigation solution is lower than with an open-end needle. Double side-vented needles give less pressure to the apical end compared to a single side-vented needle because the pressure of the irrigation solution is greater on the needle hole that is more coronal.[3] Single side-vented needles put the most pressure on the root canal wall on the side of the irrigation solution so that the lateral cleansing ability is better.[4]

The irrigation needle must be able to reach the working length reduced by 1 mm in order to clean the entire root canal to the apical third because irrigant replacement was limited to 1–1.5 mm apical to the needle tip for all flow rates.[5] The most widely used irrigation needle sizes are 27G and 30G. The outer diameter of the 27G needle is 0.42 mm, while the outer diameter of the 30G needle is 0.32 mm, thus can advance deeper in root canal.[2]

Root canal preparation must be large enough in the apical segment to increase cleaning and disinfection and at the same time must be compatible with the root canal anatomy. This preparation is done to avoid accidents and risks for the tooth. Large volume of irrigant must be used when enlarging the canal. Larger preparations permit for a larger volume of irrigant in the canal, increasing the chances for improved chemical effects.[6]

One factor that determines the effectiveness of irrigation solutions is apical vapor lock. Apical vapor lock refers to air trapped within the root canal and often occurs in the apical third. The root is surrounded by bone, so the tip of the root canal forms a closed canal and air becomes trapped at the root during irrigation.[7,8]

Apical vapor lock hinders the ability of the irrigation solution to reach the entire root canal system, especially in the apical third, thereby reducing contact between the irrigation solution and the root canal wall. Thus, the cleaning effectiveness of the irrigation solution is reduced.[2,8]

Another factor that influences the effectiveness of irrigation solutions is surface tension. Surface tension is an intermolecular strength that has tendency to decrease area of solution contact and reduce capillarity; therefore, the effectiveness of the irrigation solution is reduced. The surface tension of the irrigation solution must be reduced which results in an increase of surface contact between the irrigation solution with dentin, thus it can penetrate the main and lateral ducts to reach areas that cannot be accessed by mechanical instrumentation.[9] Irrigation solution is given an additional surface modifier called surfactant (surface-active agents) to reduce surface tension.[10,11]

To date, there has been no research or literature reviews that discuss the difference in the effect of 5.25% NaOCl irrigation with and without surfactants using two types of irrigation needles in the formation of apical vapor lock. The purpose of this study is to determine what type of solution and type of irrigation needle can minimize the formation of apical vapor lock so that endodontic irrigation can be done effectively.

Materials and Methods

Case selection

This research is an experimental laboratory study *(in vitro)* with a posttreatment design. The study was conducted at Trisakti University, Jakarta, in September 2018.

Samples taken were of the lower premolar teeth with the criteria of a single, straight root canal, in which the apex of the tooth was closed, with no fractures or caries, and had never received endodontic treatment. To calculate the sample size, a preliminary study was conducted using seven samples for each treatment group. A minimum of four samples were obtained, and in this study, 10 samples were used per group.

Sample taking and treatment procedures

The premolar teeth were decoronated to a working length of 17 mm. Root canals were prepared to 30/0.07 size using 5 mL of 5.25% NaOCl irrigation solution with a 30G syringe and a single side-vented needle at every change in file. The needle was inserted according to the working length minus 1 mm. The sample was rinsed with 5 mL of 17% EDTA solution for 1 min, then rinsed again with 10 mL of distilled water and dried with paper points. The coronal end and apex were coated with nail polish. All samples were converted to closed systems by covering the apical foramen with inlay wax.[12-14]

Samples of 40 premolar teeth that had been mounted in the application container were divided by random allocation into one control group (Group I) and three treatment groups (Groups II, III, and IV), each consisting of 10 samples: Group I: single side-vented needle with 5.25% NaOCl solution without surfactant; Group II: double side-vented needle with 5.25% NaOCl solution without surfactant; Group III: single side-vented needle with 5.25% NaOCl solution with surfactant; Group IV:

double side-vented needle with 5.25% NaOCl solution with surfactant.

The irrigation solution is a 5.25% NaOCl solution without a surfactant or 5.25% NaOCl solution with a surfactant and an iomeprol contrast agent (0.81 g/mL) at a ratio of 55:45.[13,15] This irrigation solution mixture provides radiopacity on the part of the root canal that is exposed to the irrigation solution so that the water column or air space will appear radiolucent. Samples in the 5.25% NaOCl solution without surfactants group and the 5.25% NaOCl solution with surfactants group were irrigated as much as 1 mL with a single side-vented needle and a double side-vented needle, respectively. Irrigation is carried out with the aid of a peristaltic irrigation pump (Vatea, ReDent Nova, Israel) at flow rate 5 mL/min [Figure 1].

Measurement

Radiographs were taken of all samples after the irrigation process was carried out to analyze the empty space that had not been exposed to the contrast agent. The direction of the X-ray was perpendicular to the long axis of the tooth. Radiography was done digitally from the buccal lingual direction and then analyzed with EZ Dent-i software. The measurement was taken once [Figure 2].

Statistical analysis

Shapiro–Wilk normality test was used to determine the distribution of the data collected. Homogeneity test is needed to show that the data are homogeneous. After the data are proved to be normally distributed and homogeneous, two-way analysis of variance (ANOVA) was done to determine the differences between the four research groups. Finding significant differences in the two-way ANOVA test due to treatment ($P < 0.05$), a multiple-*post hoc* test using the Tukey method was needed

Results

Result showed that there were significant differences between each group in this study. The homogeneity test shows that the data are homogeneous. Next, two-way ANOVA shows significant differences [Figure 3].

- Group I – NaOCl + 1 side: 5.25% NaOCl solution using single side vent needle
- Group II – NaOCl + 2 side: 5.25% NaOCl solution using double side vent needle
- Group III – NaOCl Surfactant + 1 side: 5.25% NaOCl solution with surfactant using single side vent needle
- Group IV – NaOCl Surfactant + 2 side: 5.25% NaOCl solution with surfactant using double side vent needle.

Significant differences occurred in the Tukey test of the 5.25% NaOCl solution group using a single side-vented

Figure 1: (a) Vatea irrigation pump (b) Radiographic examination to find out the number and shape of root canals (c) Iomeprol 400

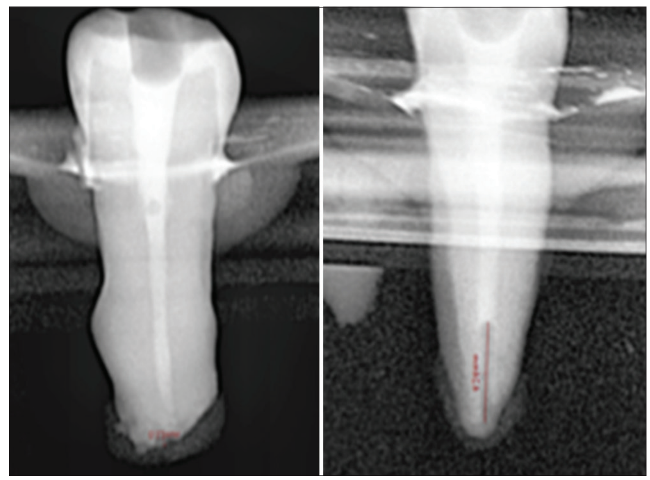

Figure 2: Apical vapor lock measurement on samples

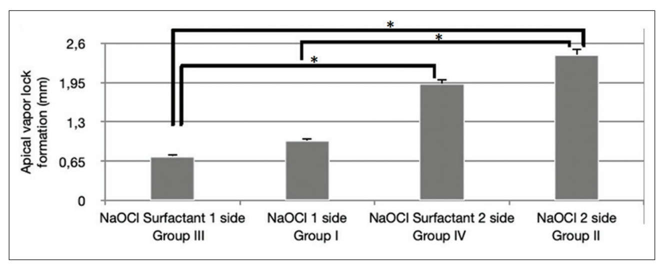

Figure 3: The average value ($\bar{x}$) and standard deviation for the formation of apical vapor lock based on the type of irrigation solution and the type of irrigation needle. *P<0,05

needle compared with the 5.25% NaOCl solution group using a double side-vented needle ($P < 0.05$). The Tukey test between the 5.25% NaOCl solution group and the surfactant using a single side-needle with the 5.25% NaOCl group and the surfactant using a double side-needle also showed significant differences ($P < 0.05$). In addition, the Tukey test between the 5.25% NaOCl solution group using a double side-needle with the 5.25% NaOCl solution group with the surfactant using a single side-needle also showed significant differences ($P < 0.05$).

Discussion

This study revealed that there were significant differences of apical vapor lock formation using different irrigation solution. The result of apical vapor lock formation was the least in group NaOCl with surfactant using single side needle (0.735 ± 0.529), followed by group NaOCl without surfactant using single side needle (0.995 ± 0.592). Group NaOCl with surfactant with double side needle (1.934 ± 0.758) and group NaOCl without surfactant with double side needle (2.414 ± 1.194) showed more apical vapor lock formation.

The results of this study prove that the type of needle used for root canal irrigation affects the formation of apical vapor lock. Needles with single side vent cause fewer apical vapor lock formations than double side-vented needles. The results of this study are in accordance with the research of Boutsioukis *et al*.[3] and Vinothkumar *et al*.,[16] in which needles with a single side vent were more effective to reduce vapor lock formation than needles with double side vents.

Based on the means and standard deviations, the smallest value of apical vapor lock was obtained in the use of a 5.25% NaOCl solution with a surfactant and a single side-vented needle. This is consistent with research from Giardino *et al*.,[17] which shows that the addition of surfactants to NaOCl will reduce the surface tension of NaOCl, thereby increasing the ability to wet the dentin with the irrigant.

NaOCl concentrations for irrigation solutions vary between 0.5% and 6%. In root canal treatment, NaOCl 2.5% and 5.25% were used with and without surfactant. This study uses 5.25% NaOCl because NaOCl in high concentrations has a greater ability to dissolve tissue, despite having higher toxicity and viscosity. This increases the effectiveness and efficiency of NaOCl as an irrigation solution compared to a lower solution.[2]

NaOCl is mixed with a contrast agent iomeprol 400 (810 mg/mL) to provide radiopaque images needed to make observations. Iomeprol solution is soluble in water and has been widely used in the health sector to improve detection ability.[11] Research by Fenchel *et al*.[15] shows that the difference in viscosity between iomeprol 300 and iomeprol 400 does not differ significantly. The comparison of the mixture of irrigation solution and contrast agent is 55:45 so that the viscosity and viscosity are the same as the 5.25% pure NaOCl solution.[13]

In this study, the apex of the tooth was coated with inlay wax. When the teeth are dripped with inlay wax, the Protaper Next X3 file that corresponds to the size of the last preparation is inserted into the root canal to prevent the wax inlay from entering. The purpose of the coating is to make the root canal become a closed system where the apical vapor lock can form.[12-14]

Apical vapor lock formation is measured using a digital radiograph in the buccal lingual direction, then measured quantitatively by measuring the length of the bubbles formed in millimeters. Thus, the apical vapor lock variable is a dependent variable with quantitative scale data (ratio). On the other hand, the independent variable is the type of needle, namely a single side-vented or double side-vented needle, and the type of solutions, namely 5.25% NaOCl with or without surfactants, which are nonmetric data (categorical data).

The first limitation of this study is that apical patency was not achieved. Apical vapor lock is caused by a closed system root canal, so one effective way to reduce the formation of apical vapor lock is apical patency, which ensures that the root canal is free of debris. This is achieved using a small file size of 10, which is inserted into the root canal with a working length plus 0.5–1 mm. By doing this, the root canal becomes an open system.[12-14] However, this study was carried out in a condition where the root canal was closed with inlay wax to determine apical vapor lock formation, so it did not reflect the actual conditions *in vivo*.

The second limitation of this study is that irrigation was carried out using the positive pressure irrigation method in which the pressure of the solution is given from the coronal to the apical direction. Research by Pasricha *et al*.[7] shows that apical negative pressure, for example, with Endovac, is more effective and produces less apical vapor lock compared to positive pressure irrigation. The third limitation of this study is that irrigation is done passively without agitation. Pasricha *et al*.[7] also showed that agitation, both manually and with the help of machines, is important to reduce apical vapor lock. Agitation can be done manually, sonically, ultrasonically, or with laser.

The key point of this research is that, until now, there has been no research or literature reviews that discuss the difference in the effect of 5.25% NaOCl irrigation with and without surfactants using different types of irrigation needles on the formation of apical vapor lock. The authors wished to examine this topic to determine the combination of solution mixture and irrigation needle type that can minimize the formation of apical vapor lock, so that endodontic irrigation can be done effectively.

The second key point of this study is teeth that are used as samples are natural teeth that had not gone through the tooth clearing process. The reason is because teeth that have undergone the clearing process exhibit changes in the surface of the dentin due to decalcification caused by the strong acids, drying, and replacement of inorganic components with organic oils that are hydrophobic (e.g., methyl salicylate). These results in the reduction of hydrophilic nature of dentin, thus the contact angle of the irrigation solution is greater and the possibility of apical vapor lock formation is greater. The reason why resin blocks were not used is similar, because the surface properties of the resin blocks are more hydrophilic than dentin, so they do not reflect the actual conditions *in vivo*.[8]

Computational fluid dynamics software can provide more accurate results compared to natural teeth and resin blocks because the contact angle between the root canal wall and the irrigation solution is made according to the actual conditions. Nevertheless, this method was not used in this study because there is a limitation of this method, where the ideal condition in software does not always applicable in most cases. The authors chose to use natural teeth to better reflect *in vivo* conditions.[8]

The clinical implication of this study is that the principle of positive pressure irrigation can result in minimal apical vapor lock formation using single side-vented needle. 5.25% NaOCl concentration can be used as final irrigation with or without surfactant with the same results.

Conclusion

The principle of positive pressure irrigation can result in minimal apical vapor lock formation using single side-vented needle. The addition of a surfactant to 5.25% NaOCl solution had an effect on the formation of apical vapor lock. Irrigation is an important factor in the success of root canal treatment because it dissolves organic and inorganic tissue. Further research needs to be done regarding the formation of apical vapor lock with the principle of positive pressure irrigation with 5.25% NaOCl solution in teeth with double root canals and teeth with bent root canals.

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Conflicts of interest

There are no conflicts of interest.

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Differences in Apical Vapor Lock Formation after Sodium Hypochlorite Irrigation with and without Surfactant Using Two Needle Types

by Wiena Widyastuti FKG

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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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Rahmi Amtha
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.

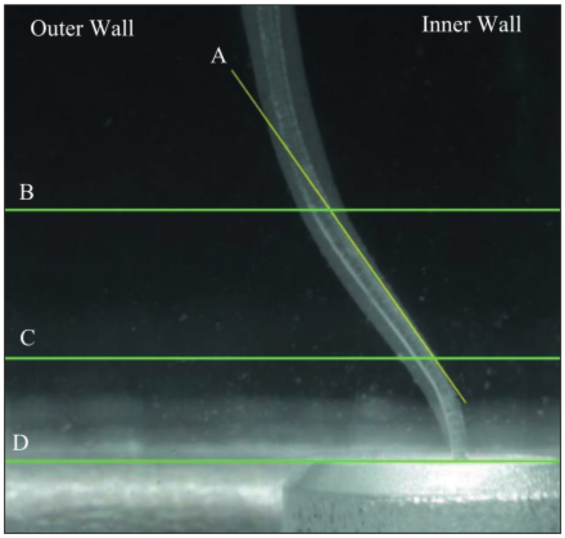

Figure 1: A digital photograph of an Endo Training Block which is S-shaped. The "A" line is an imaginary line drawn from the apically outmost point of the inner wall through the coronal direction according to the inclination of the curved canal. The "B" line is a horizontal line drawn where the imaginary 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

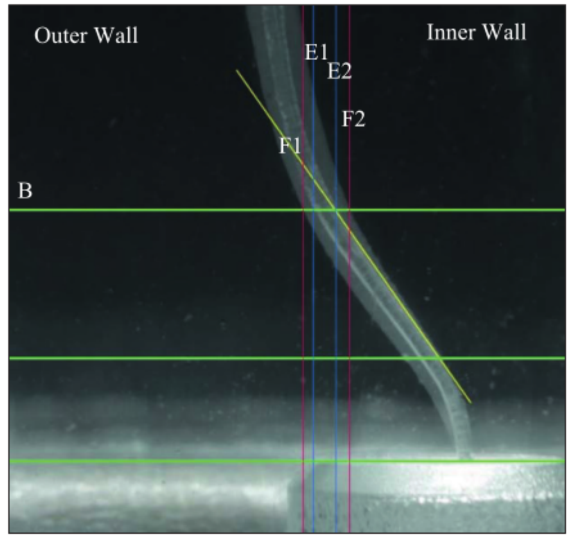

Figure 2: Measuring the transportation on the coronal curvature. The E1 and E2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to B line and marked as measuring point before preparation. The F1 and F2 lines are similar to the E lines and marked as measuring point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

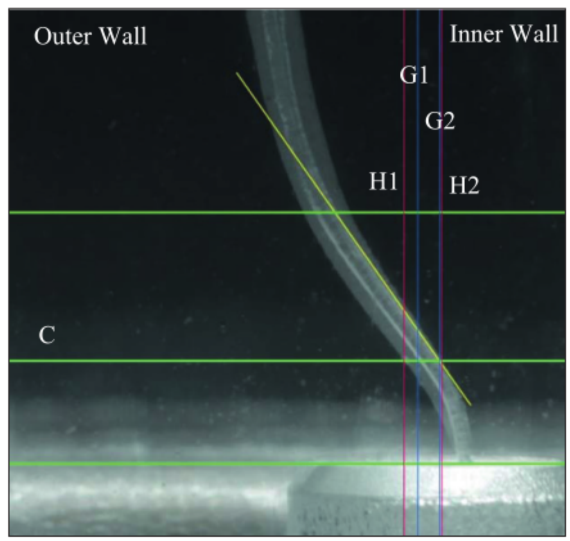

Figure 3: Measuring the transportation on the apical curvature. The G1 and G2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to C line and marked as measuring point before preparation. The H1 and H2 lines are similar to the G lines and marked as measuring point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

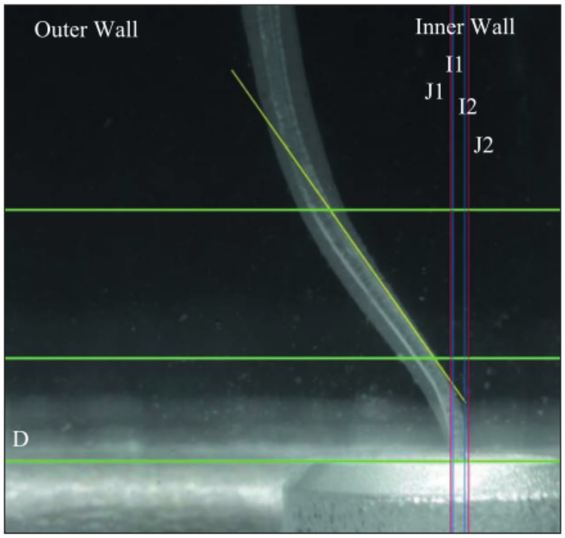

Figure 4: Measuring the transportation on the apical point. The I1 and I2 lines are vertical lines drawn from the outer and inner walls of the canal perpendicular to D line and marked as measuring point before preparation. The J1 and J2 lines are similar to the I lines and marked as measuring point after 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 Apical Vapor Lock Formation after Sodium Hypochlorite Irrigation with and without Surfactant Using Two Needle Types

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