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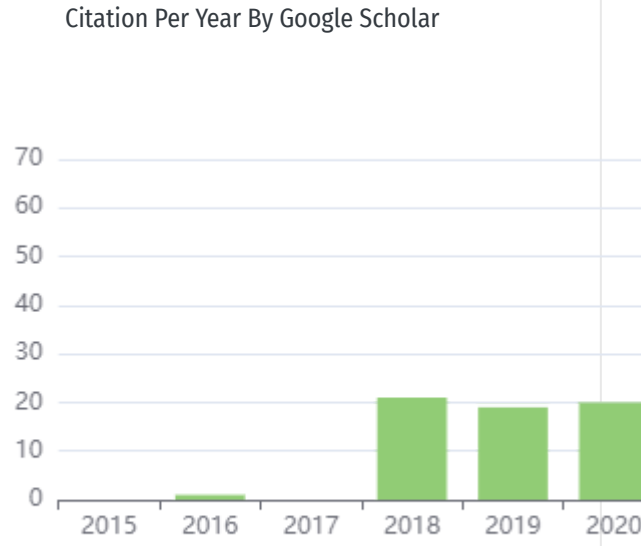

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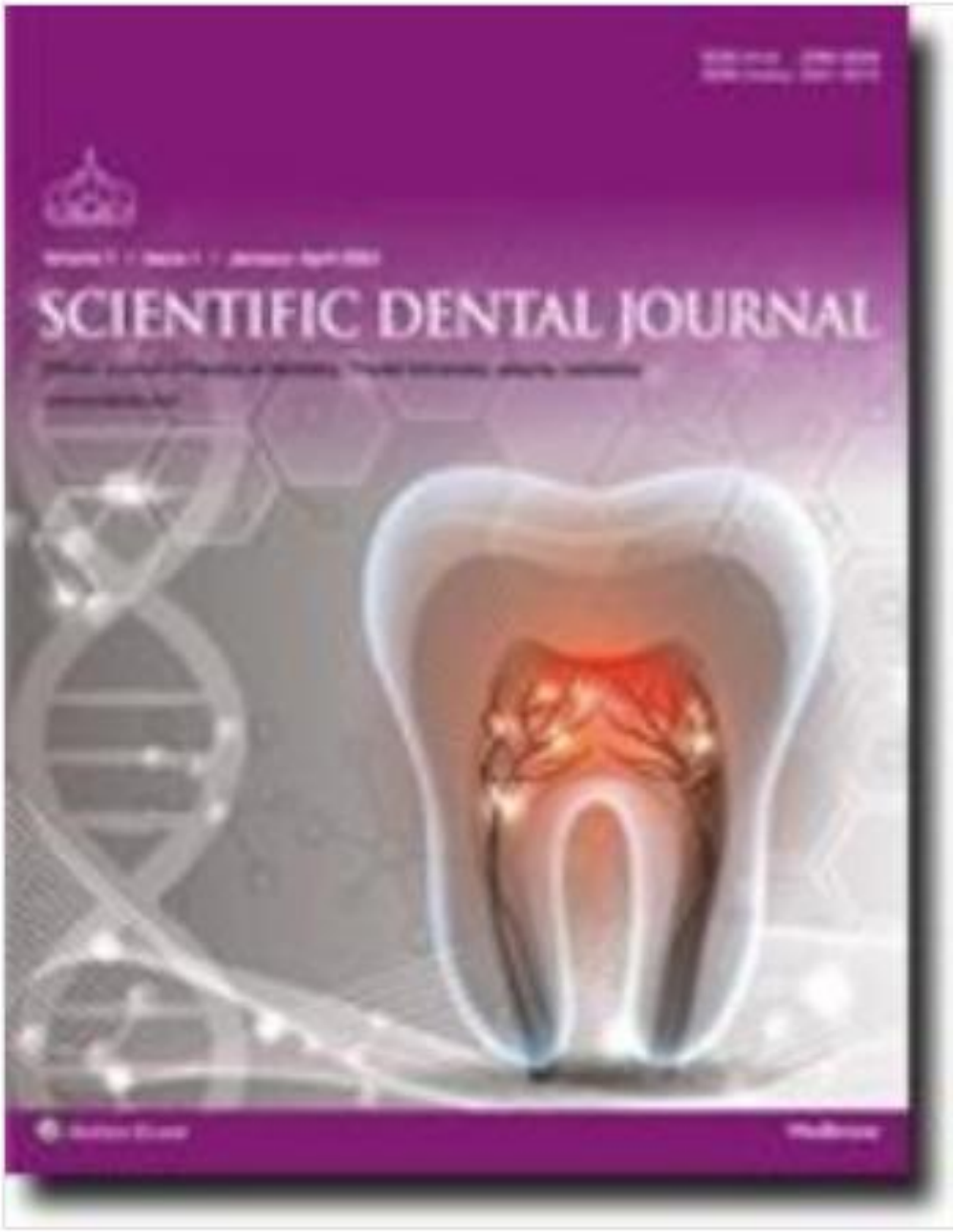

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Original Article

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 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 ($P < 0.05$).

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

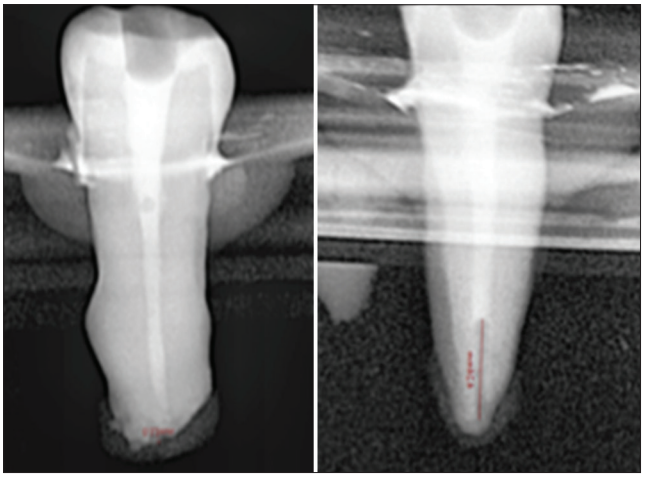

Figure 2: Apical vapor lock measurement on samples

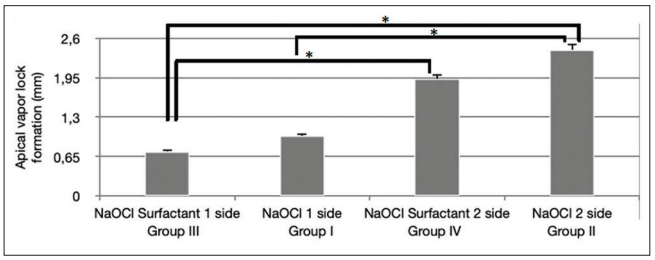

Figure 3: The average value ($\bar{x}$) and standard deviation for the formation of apical vapor lock based on the type of irrigation solution and the type of irrigation needle. *P<0,05

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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Nil.

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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Original Article

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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.[2,4]

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 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 ($P < 0.05$).

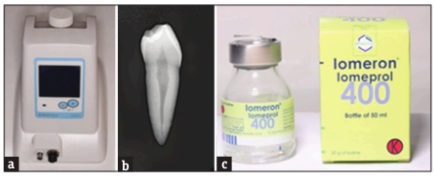

Figure 1: (a) Vatea irrigation pump (b) Radiographic examination to find out the number and shape of root canals (c) Iomeprol 400

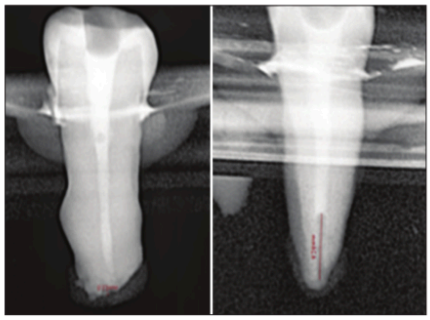

Figure 2: Apical vapor lock measurement on samples

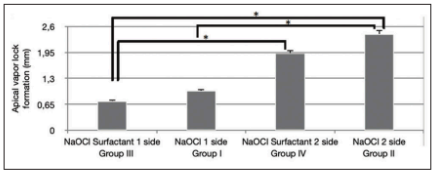

Figure 3: The average value ($\bar{x}$) and standard deviation for the formation of apical vapor lock based on the type of irrigation solution and the type of irrigation needle. *P<0,05

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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Nil.

Conflicts of interest

There are no conflicts of interest.

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