PENETRATION OF HEATED AND NON-HEATED SODIUM HYPOCHLORITE INTO LATERAL CANALS BY APICAL NEGATIVE PRESSURE IRRIGATION

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Abstract

The role of irrigation in root canal treatment is crucial; sodium hypochlorite is the most commonly used irrigant. Many methods were used to potentiate sodium hypochlorite, one of which is heating of the irrigant.

Negative pressure irrigation is a new method of irrigation that was introduced to deliver the solution through the whole root canal length. Sixty single rooted teeth were used in this study. A total of 360 simulated lateral canals were created, 6 in each tooth, with 2 lateral canals at 2, 4.5 and 6 mm of working length. To resemble the clinical situation, a closed system was created by coating each root with soft modeling wax. Roots were then randomly assigned to 3 experimental groups: group 1 (n = 20): apical negative pressure irrigation (ANP); group 2 (n = 20): apical negative pressure irrigation with heated irrigant (ANP + Heat); and control group 3 (n = 18): positive pressure irrigation. The samples were evaluated by direct observation of the images recorded by a photography machine. The results showed that ANP and ANP + Heat were more effective than needle irrigation at lateral canal penetration, but there was no significant difference between the groups 1 and 2.

Apical negative pressure irrigation is more effective than needle irrigation in penetrating into lateral canals. Heated irrigant did not penetrate better into these canals.

Keywords: lateral canal – irrigation – sodium hypochlorite – irrigant penetration.

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PÉNÉTRATION DE L'HYPOCHLORITE DE SODIUM CHAUFFÉ ET NON CHAUFFÉ DANS LES CANAUX LATÉRAUX PAR IRRIGATION APICALE NÉGATIVE

Résumé

Le rôle de l'irrigation dans le traitement du canal radiculaire est crucial; l'hypochlorite de sodium est la solution d'irrigation la plus utilisée. De nombreux procédés ont été utilisés pour potentialiser l'action de l'hypochlorite de sodium, dont l'échauffement de l'irrigant. L'irrigation négative sous pression est une nouvelle méthode d'irrigation qui a été introduite pour délivrer la solution sur toute la longueur du canal radiculaire. Soixante dents monoradiculées ont été utilisées dans cette étude. Un total de 360 canaux latéraux ont été créés, 6 dans chaque dent, avec 2 canaux latéraux à 2, 4,5 et 6 mm de longueur de travail. Pour simuler les mêmes conditions cliniques, un système fermé a été créé par le revêtement de chaque racine avec de la cire à modeler. Les racines ont ensuite été réparties au hasard à 3 groupes expérimentaux: groupe 1 (n = 20): irrigation apicale sous pression négative (ANP); groupe 2 (n = 20): irrigation apicale sous pression négative avec irrigant chauffé (ANP + chaleur); et le groupe témoin 3 (n = 18): irrigation sous pression positive. Les échantillons ont été évalués par observation directe des photos enregistrées par un appareil de photographie. Les résultats ont montré que l'ANP et l'ANP + chaleur étaient plus efficaces que l'aiguille d'irrigation à la pénétration du canal latéral, mais il n'y avait pas de différence significative entre les groupes 1 et 2.

L'irrigation apicale sous pression négative est plus efficace que l'irrigation sous pression positive. L'irrigant chauffé ne pénétrait pas mieux dans les canaux.

Mots-clés: canal latéral – irrigation – hypochlorite de sodium.

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Introduction

The aim of endodontic therapy is to eliminate most of the microorganisms in the root canal system, dissolve the vital and necrotic pulp debris, and fill the root canal system in a tridimensional manner in order to prevent any communication between the remaining bacteria and the periodontal ligament, and avoid any infection or re-infection of this ligament, and thus, guarantee the success of the treatment.

The root canal system has anatomical complexities that were shown by Hess since 1920. Nowadays, with the development of the micro-computed tomography, it became evident that in root canal treatment we are dealing with difficult anatomical complexities [1- 4] that cannot be totally instrumented [5].

The desired action of the root canal irrigant is specified by as follows [6]:

- a broad antimicrobial spectrum and high efficacy against anaerobic and facultative microorganisms organized in biofilms;
- dissolves necrotic pulp tissue remnants;
- inactivates endotoxins;
- prevents the formation of a smear layer during instrumentation or dissolve the latter once it has been formed.

The role of irrigation is to produce clean canals that are ready to be filled. In order to act, sodium hypochlorite needs to be in contact with the targeted tissues; that's why many delivery and agitation methods were used to ameliorate the penetration of sodium hypochlorite into the root canal complexities.

These methods can be essentially divided into two main categories [7]; manual methods such as the conventional irrigation that uses a syringe and a side-vented needle and machine-assisted ones that may be sonics, ultrasonics, rotary brushes or apical negative pressure. Fukomoto et al. [8] described an intracanal aspiration technique that depends on apical negative pressure. It consists of placing a 0.55 mm stainless steel needle as intracanal aspirator in the apical part of the canal 2-3 mm from the apex and delivering the irrigant from a 0.41 mm needle placed 12 mm from the apex. They found that this technique was able to deliver the irrigant to the whole working length with minimal extrusion.

When the contact between sodium hypochlorite and the targeted tissues occurs, the following reactions take place: saponification, amino acid neutralization and chloramination. These reactions together are the mode of action of sodium hypochlorite [9]; they depend basically on the amount of available chlorine. In order to ameliorate the action of the irrigant, many techniques were suggested such as using higher concentrations of sodium hypochlorite [10, 11, 12], increasing the contact time [13], using more volume of irrigant [14, 15], altering the pH [16, 17], and using heated sodium hypochlorite [18, 19]. Heated sodium hypochlorite has more available chlorine than non-heated of the same concentration, and hence it has better tissue dissolving action and antimicrobial action. It also has lower viscosity and surface tension.

The aim of this study is to evaluate whether or not heated sodium hypochlorite can penetrate into artificial lateral canals better than non-heated irrigant using the intracanal aspiration technique of Fukomoto.

Materials and methods

60 extracted single-rooted teeth with straight to slightly curved canals were selected after taking two x-rays in two angulations to verify the presence of one canal. The included teeth were originally longer than 20 mm. They were first immersed in sodium hypochlorite 4.8% for two hours then scaled to remove any visible calculus. All the experimental procedures were done by the same operator. The roots were adjusted to 16 mm using a diamond separating disc on a low speed with copious water. A drop of Sure-Prep was put on the canal entrance, and patency was checked using #10 K-file (CC Cord UDM Germany). Then the roots were shaped using the Protaper system (Maillefer, Switzerland) driven by the endodontic motor Silver (VDW Germany) set on the settings of Protaper as recommended by the manufacturer. The working length was set at 15 mm. The sequence was done as recommended by the manufacturer, and each file was followed by 1.5 ml of sodium hypochlorite 4.8% as irrigation delivered using a syringe and Endo-Eze; an endodontic irrigation needle 27 G (Ultradent, USA) and at last, the canals received as a final irrigation 3 ml of NaOCl 4.8%, then aspiration, then 3 ml of EDTA, then aspiration, followed by another 3 ml of NaOCl 4.8% with a flow rate 3 ml/min. At the end each canal received 15 ml of NaOCl 4.8 % and 3 ml of EDTA 17%.

On completion of the shaping procedures, teeth were cleared using the modified technique first described by Robertson and Leeb and following the protocol described by de Gregorio et al. [20]. Briefly, the teeth were submerged in nitric acid 5% for 36 hours; the acid was renewed every 8 hours. Then they were cleared under tap water for 3 minutes. At this stage lateral canals were created in the decalcified teeth using # 6 K-files MMC 21 mm (Micro Mega France). The #6 k-files were cut to have an apical portion of 9 mm long, three cut #6 k-files were inserted attentively perpendicularly to the external buccal surface in a way that the file will enter the buccal wall, and then the palatal or lingual wall and perforate the lingual wall. 6 canals were created in each tooth and the sum was 360 canals. Then the teeth were dehydrated in ascending concentrations of ethanol as follows: 4 hours in 60% ethanol, then 4 hours in 80% ethanol, then 6 hours in 95% ethanol. The sum was 14 hours. After that, the teeth were sub-

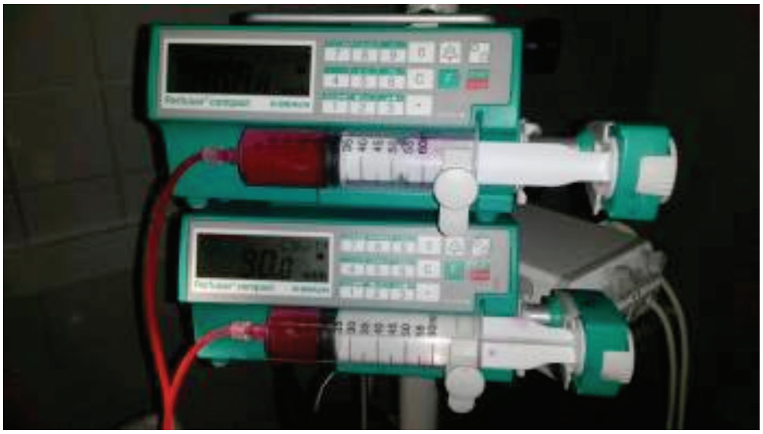

Fig.1: The two electric push-syringes with the contrast solution inside the 60 ml syringes.

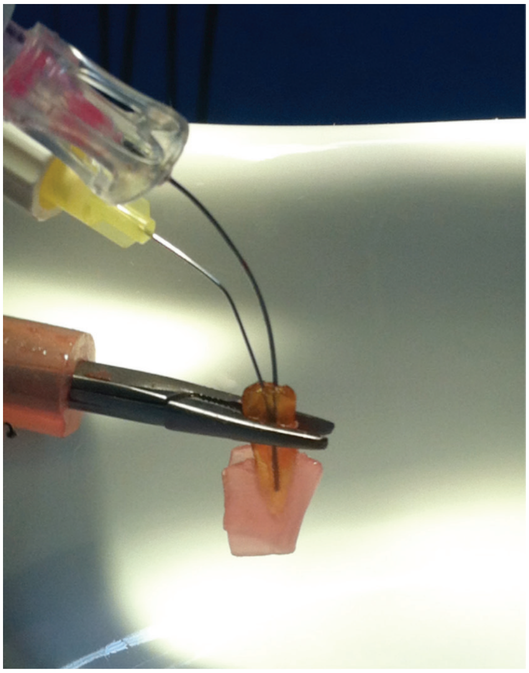

Fig. 2: The intracanal aspirator and the 27G delivering needle inside the canal.

Fig. 3: The T-connector that connects the two syringes to the 3m tube in order to heat the solution to 60 °C.

Fig. 4: The water heater with the 3 m tube inside it and the temperature of the water is 83 °C.

merged in methyl salicylate 99.9 % for 24 hours for clearing and re-hardening.

The contrast solution preparation

The contrast solution was prepared by mixing 50% sodium hypochlorite, 40% Omnipaque; an Iohexol intravascular contrast solution that contains 350mg I/ml (GE Healthcare Ireland) and 10% Red Detector; a caries indicator that contains Rhodamine B (Cerkamed, Poland) to obtain a stable red solution with viscosity similar to that of sodium hypochlorite, and density 1.08 g/ml which is close to that of sodium hypochlorite which is 1.11g/ml [20].

Experimental groups

After the clearing procedure, two teeth were lost. The remaining teeth were coated apically with modeling wax to create a closed system and simulate the clinical situation. During the placement of the wax, a 40/ 0.06 gutta-percha cone was inserted in the canal to prevent the wax from entering the canal, and the wax covered all the lateral foramens. The teeth were randomly assigned to 2 experimental groups and a control group. The contrast solution was delivered using two 60-ml syringes that were pushed using two electric push-syringes adjusted to deliver 90 ml/hour or 1.5 ml/minute (Fig. 1). The two syringes were connected using a T-connector so that together they delivered 3 ml/min. In all the experimental groups, the irrigant's flow rate was 3 ml/min. All the teeth were irrigated for 30 seconds.

Apical negative pressure

20 teeth received the contrast solution using the negative pressure method of irrigation described by Fukumoto [8]. An injection needle 25G was used as intracanal aspirator (external diameter 0.50 mm, internal diameter 0.35 mm). Its end was flattened and it was placed 3mm from the working length. The contrast solution was delivered using a 27G Endo-Eze irrigation tip (external diameter 0.40 mm, internal diameter 0.20 mm) placed 12mm from the working length with a flow rate 3 ml/min (Fig. 2).

Apical negative pressure with contrast solution heated to 60°C

20 teeth received the contrast medium using the same technique described above, but the contrast medium was heated to reach the canal having a temperature of 60 degrees.

After the T-connector (Fig. 3), the irrigant passed in a 3m long tube whose internal diameter is 2.5 mm and outer diameter is 4 mm, immersed in a hot water bath of 80±3 degrees, so that after 15 cm when it goes out of the bath, the temperature of the irrigant would be 60°C for a flow rate of 3 ml/min (Fig. 4). As a result, about 14.7 ml were inside the tube.

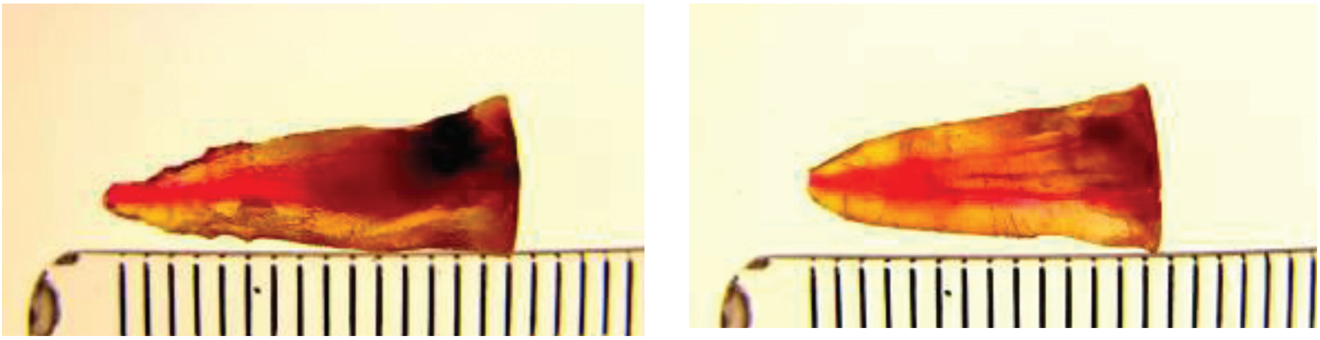

Fig. 5: Specimens irrigated by apical negative pressure.

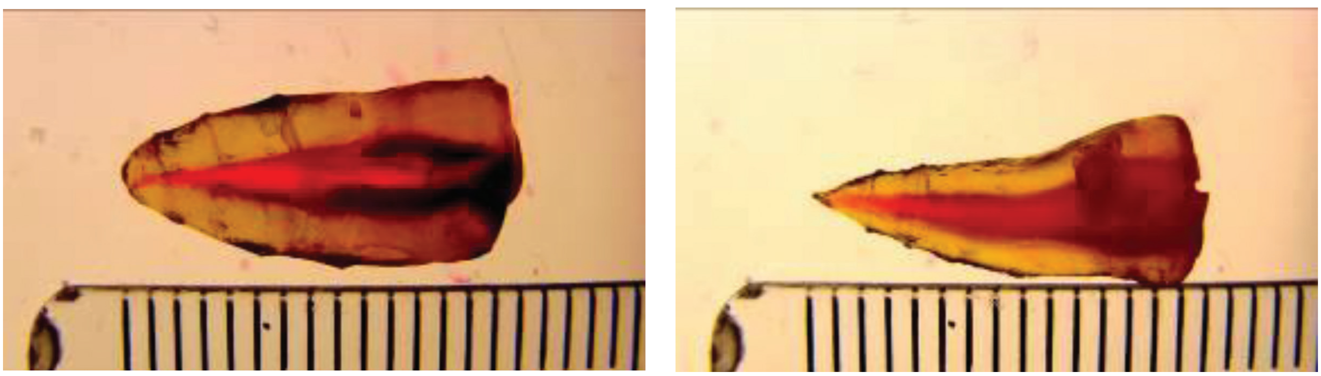

Fig. 6: Specimens irrigated by apical negative pressure with the contrast solution heated to 60 degrees.

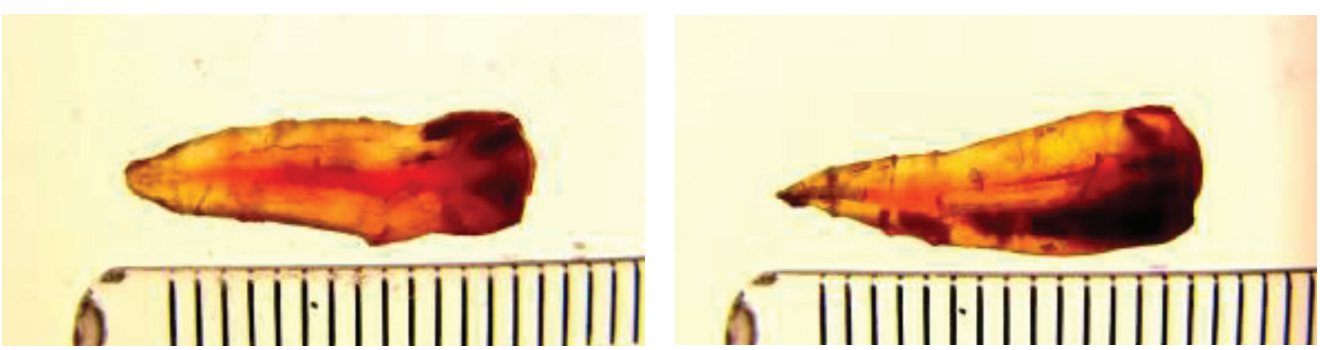

Fig. 7: Specimens irrigated by needle irrigation.

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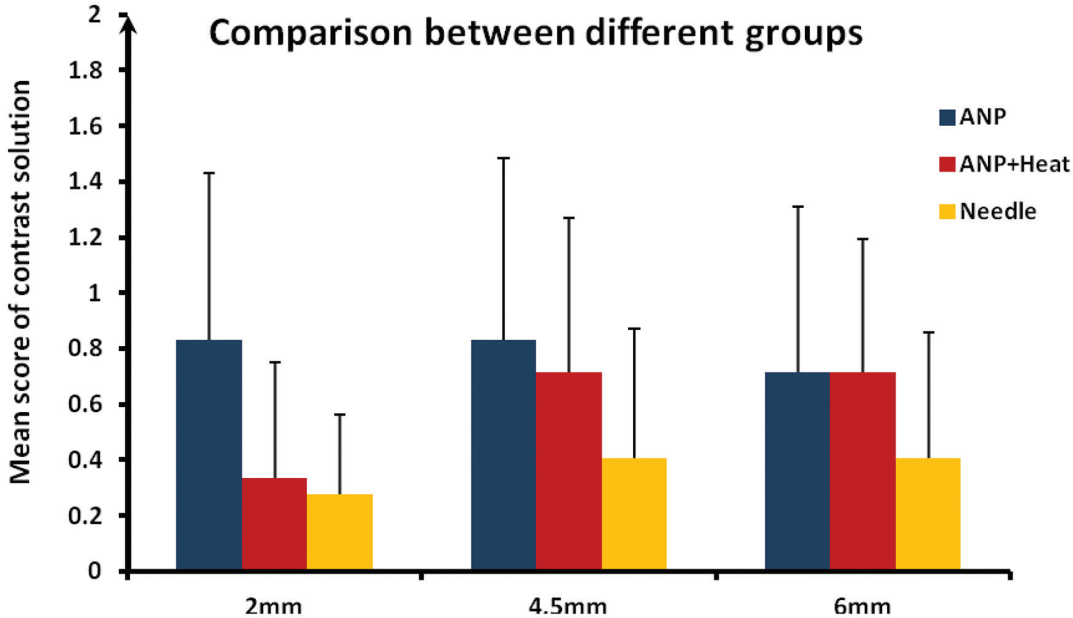

Table 1: The One-Sample Test showing the mean score of contrast solution that was significantly different from 0 in all groups for different levels.

The output of the tube was connected to a 27G irrigation tip and the experiment was done as above.

Needle irrigation (control)

18 teeth received the contrast solution using a syringe and the Endo-Eze irrigation tip which was inserted 3mm from the working length.

Imaging and evaluation of the penetration of the contrast solution into the lateral canals

After finishing the experiment, the irrigated cleared teeth -having the contrast solution inside- were placed on a light source and photographed using Canon LEGRIA HF M406 which was set on macro settings. The images taken were scored by the operator and two independent calibrated observers in a way that "0" stands for the absence of contrast solution in both canals at the same level, "1" for the presence of contrast solution in one canal at the same level, and "2" for the presence of contrast solution in both canals at the same level. The images to be evaluated were given numbers that corresponded to the images in a random way. The three evaluators scored the images without any idea about the group they belong to. Figures 5, 6 and 7 represent the specimens after imaging.

Statistical Analysis

Statistical analyses were performed using a software program (SPSS for Windows, Version 16.0, Chicago, IL). The level of significance was set at $\alpha = 0.05$. The primary outcome variable of the study was the score of the penetration of contrast solution in the canals at the same level. This is an ordinal variable with 3 categories.

It was measured by three evaluators. The reproducibility between measurements was evaluated using the intraclass correlation coefficient (ICC). The average of the three measurements was then obtained for the statistical analyses.

Repeated measure analyses of variance was conducted with one within subjects factor (levels: 2mm; 4.5mm; 6mm) and one between subjects factor (irrigation groups: needle; ANP; ANP + Heat). They were followed by univariate analyses and multiple comparisons tests.

One Sample t tests were conducted to explore significant difference between the mean score penetration and the 0 value which mean the absence of contrast solution in canals.

Results

Reproducibility between evaluators

The ICC was calculated to assess the reproducibility between measurements among evaluators for each group at each canal's level.

At the level 2mm, the reproducibility was important for the group ANP (ICC=0.902; p <0.001), the group ANP + Heat (ICC = 0.865; p <0.001) and moderate with the needle group (ICC= 0.530; p <0.001).

At the level 4.5mm, the reproducibility was important for the group ANP (ICC=0.918; p <0.001), the group ANP + Heat (ICC = 0.782; p <0.001) and the needle group (ICC= 0.601; p =0.010).

At the level 6mm, the reproducibility was important for the group ANP (ICC=0.857; p <0.001), the group ANP + Heat (ICC = 0.654; p <0.001) and the needle group (ICC= 0.670; p =0.003).

Finally, the average measure of the three evaluators was obtained and used for the statistical analyses.

Comparison between different groups

At the level 2mm, the mean score of contrast solution penetration was significantly different between groups (p = 0.001). It was significantly higher with the ANP group and lower with the ANP + Heat and needle group (p = 1.000).

At the level 4.5mm, the mean score of contrast solution penetration was significantly different between groups (p <0.05). It was significantly lower with the needle group and better with the ANP and ANP + Heat groups (p = 0.792).

At the level 6mm, the mean score of contrast solution penetration was significantly different between groups (p <0.05). It was significantly lower with the needle group and better with the ANP and ANP + Heat groups (p = 1.000).

Comparison between different levels

When the apical negative pressure method was used at room temperature, the mean score of contrast solution was not significantly different between canals' levels (p = 0.621).

When the apical negative pressure method was used with contrast solution heated to 60°C, the mean score of contrast solution penetration was significantly different between groups (p = 0.002). It was significantly lower at 2mm level and higher at 4.5mm and 6 mm level (p = 1.000).

When the needle method was used, the mean score of contrast solution penetration was not significantly different between groups (p = 0.505).

The One Sample t test showed that the mean score of contrast solution was significantly different from 0 in all groups for different levels (p <0.05) (Table 1).

Discussion

Complex anatomy of the root canal system was shown by Hess since 1920. With the development of the micro computed tomography, it became evident that in root canal treatment we deal with root canal system that is rich in complexities. To simulate the complexities, lateral canals were created in this model.

The clearing technique that was used in this experiment is the modified technique that was first described by Robertson and Leeb in 1982 and following the protocol described by de Gregorio et al. [20]. The main principle of clearing techniques is decalcifying the teeth, and then storing them in an oil of high refractive index. Another technique that was described by Venturi et al. suggested using other decalcifying agents of lower concentration with a buffering agent, clarification that needs more time to complete the decalcification. The authors state that this technique gives better clearing results with less damage on the organic matrix of the dentin [21].

In order to reduce the bias, all the teeth were prepared, shaped, cleared, and irrigated by the same operator. The flow rate of the irrigant in all the experimental groups was standardized at 3ml/min and the time of final rinse was 30 seconds for all groups. Also, the imaging was done in a reproducible way, and the presence or absence of the contrast solution was scored, in addition to the operator, by two blinded independent and calibrated evaluators.

In the current study, the model that was used is human extracted teeth that were cleared. After clearing, the teeth become more hydrophobic because the methyl salicylate is oil. But, as long as this was the case in all the teeth, the results were compared regardless of this point. The situation may be different in vivo, where the teeth are humid and the lateral canals are filled with pulp remnants and tissues.

The contrast medium used in this study was the same as described by de Gregorio et al. [20]. Another contrast solution described by Castelo-Baz et al. [22] was 80% NaOCl and 20% china ink; this solution may have produced better contrast in the canals.

The efficacy of Endovac microcannula was studied and was shown to deliver the irrigant to all the working length, but it has weak effect on delivering the irrigant into lateral canals [23]. The intracanal aspirator used in this study differs from Endovac microcannula and resembles more the Endovac macrocannula.

Many studies were done to evaluate the benefits of heating sodium hypochlorite and the effect on its antimicrobial [24] and tissue dissolving actions [25] as well as on its penetration into dentin [26]. However, in our knowledge, no studies were done until now to evaluate whether or not heating sodium hypochlorite ameliorates its penetration into simulated lateral canals.

Several studies showed that heating sodium hypochlorite to 60°C can potentiate its actions, specifically its antimicrobial and tissue dissolving actions [27, 19]. In the same time, this heating does not affect the short-term stability of sodium hypochlorite; preheated sodium hypochlorite can keep 100% of its available chlorine at 60°C till 60 minutes [19]. As for the effect on the periodontal ligament, a study found that activating sodium hypochlorite ultrasonically will raise the temperature of the irrigant to 53.5 ± 2.7 °C. In order to deliver irrigant from a syringe with the same temperature into the canal, the syringe irrigant should have a temperature of 68-69°C [28]. A study using thermal couples compared the temperature rise on the root surfaces using three different thermoplasticized methods of obturation. The authors found that when the temperature rises in the internal surface of the root by 26.63 °C it raises the temperature of the outer surface by 6.23°C [29]. This means that an interradicular temperature rise to 63.63°C will raise the outer temperature of the root to 43.23°C. This raise will not cause any damage for the periodontal ligament, as the critical temperature rise that may cause damage to the periodontal ligament is 10°C. Heating the irrigant to 60°C will not harm the periodontal ligament; however, we will get better antibacterial effect and better tissue dissolving effect. This may be justified by the thermal properties of dentin which has a low thermal conductivity [30].

In this study, the teeth were covered by modeling wax to create a closed system that simulates the clinical situation, whereas, a study mentioned that the periapical region exerts certain pressure [31]. But as long as all the samples were prepared under the same conditions, the results of this study are comparable to each other.

The final apical file used was F4 from Protaper which has an apical size and taper 40/.06. This apical size and taper were shown to enhance the debridement directly by their mechanical effect [32] and indirectly by enhancing better irrigant flow in the canal using needle irrigation [33]. Also, the aspiration of the irrigant in negative pressure techniques would be closer to the ideal [34, 35].

Several studies showed that apical negative pressure devices (Endovac and Fukumoto's method of irrigation) were superior to other methods of irrigation and activation in delivering the irrigant to the working length [8, 23, 36]. Also, studies showed that the apical negative pressure methods of irrigation were safer than other techniques of irrigation because less extrusion of the irrigant happened [37]. In addition, the resulting apical pressure when using these methods of irrigation was less than the central venous pressure which is 5.88 mm Hg [31]. That is why those criteria were not evaluated in the present study. Other studies have reported a weak penetration of the irrigant into lateral canals when using the Endovac. In the current study, Fukumoto's method of intracanal aspiration was used and not Endovac. This method's efficacy in delivering the irrigant into lateral canals was not evaluated before.

The aim of this study was to evaluate whether or not heating sodium hypochlorite ameliorates its penetration into artificial lateral canals using the intracanal aspiration method described by Fukumoto. The needle irrigation group was used as control group. The results showed that the penetration of the irrigant into lateral canals in the ANP group was better than that in the needle irrigation group at the three levels. The ANP +Heat group showed significantly better results than the needle group at the levels 4.5mm and 6mm but not at the level 2mm. There were no significant differences between ANP and ANP + Heat at the 4.5 mm and the 6 mm levels, but there was a significant difference between the two groups at the level 2 mm.

The difference between the groups ANP and ANP + Heat at the level 2 mm may be justified by the altered flow pattern of the irrigant beyond the aspirator's tip in the group ANP + Heat. Heating the irrigant decreases its viscosity and consequently increases the Reynolds number of the irrigant. The Reynolds number is determined by the equation $Re = \rho UL/\mu$ where ρ is the density of a fluid, μ its viscosity, U its velocity and L is a characteristic length scale. When the viscosity decreases, the Re increases. Fluids with high Re flow in turbulent pattern, whereas, when Re is low the flow pattern is laminar [38]. The fluid flow around the aspirating needle is laminar in both cases because it is driven by the intracanal aspirator from the coronal part of the canal towards the aspirator's tip. But beyond the aspirator's tip, which means in the apical 3 mm of the canal, the irrigant's flow may be influenced by the Re which will lead to a turbulent flow pattern unlike the laminar pattern which may create, depending on the velocity of the irrigant inside the canal, an important shear stress. This may be a justification, but further studies should be conducted in order to verify this point.

Conclusion

Within the limitations of this study, the intracanal aspiration technique described by Fukumoto was significantly better than the conventional needle irrigation technique in leading the irrigant into apical lateral canals. Heated sodium hypochlorite did not penetrate into more lateral canals than non-heated irrigant. More studies should be done considering this parameter.

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