

Evaluation of the apical extrusion of sodium hypochlorite gel in immature permanent teeth: An in vitro study

Dr. Anchal Sahu¹, Dr Asheesh Sawhny², Dr Richa Singh³, Dr. Mukta Bansal⁴, Dr. Saurav Paul⁵, Dr. Saurabh Sharma⁶.

Rama Dental College Hospital And Research Centre Kanpur, Mandhana.

¹Post Graduate Student, Department of Conservative Dentistry & Endodontics, Rama Dental College Hospital & Research Centre, Kanpur.

²Principal & HOD, Department of Conservative Dentistry & Endodontics, Rama Dental College Hospital & Research Centre, Kanpur.

³Reader, Department of Conservative Dentistry & Endodontics, Rama Dental College Hospital & Research Centre, Kanpur.

⁴Senior Lecturer, Department of Conservative Dentistry & Endodontics, Rama Dental College Hospital & Research Centre, Kanpur.

⁵Reader, Department of Conservative Dentistry & Endodontics, Rama Dental College Hospital & Research Centre, Kanpur.

⁶Reader, Department of Conservative Dentistry & Endodontics, Rama Dental College Hospital & Research Centre, Kanpur.

Abstract

Background.

Sodium hypochlorite (NaOCl) gel has been suggested as a safer substitute in open apices as compared to solution, with the same antimicrobial effect.

Objectives. This study aimed to compare the amount of the apical extrusion of NaOCl gel and solution in immature permanent teeth.

Material and methods:

An in vitro study was conducted at the Department of Conservative Dentistry And Endodontics, Rama Dental College Hospital And Research Centre, Mandhana, Kanpur. Thirty freshly extracted immature single-rooted human premolars were decoronated and the cavity was then accessed. The teeth were radiographed to determine the mesiodistal dimension of the apex. In addition, the surface area of the apical foramen was calculated to evaluate the amount of extrusion from the whole surface of the apex. The teeth were divided into 2 groups according to the size of the apex: ≤ 2.5 mm (group A) and > 2.5 mm (group B); each group was irrigated with 5 mL of NaOCl solution and 2 different commercial types of NaOCl gel for 60 s, and then the extruded irrigant was measured in a plastic vial.

Results:

The data was analyzed using the Kruskal–Wallis analysis. Based on the observed results, a statistically significant difference was noted ($p = 0$) between NaOCl solution and gel when the apical diameter was ≤ 2.5 mm, while there was no significant difference between the 2 types of NaOCl gel. No statistically significant difference was observed ($p = 0.2$) between NaOCl solution and gel when the apical diameter was > 2.5 mm. Conclusions. Sodium hypochlorite gel is safer than solution when irrigating immature teeth with the apical diameter ≤ 2.5 mm. Key words: sodium hypochlorite, apical extrusion, immature teeth

Introduction:

Sodium hypochlorite (NaOCl) is the most commonly used irrigant in endodontic treatment¹; it has been considered the main endodontic irrigant due to its antimicrobial effect and its ability to dissolve the soft tissue and pulpal residuals in the root canal.^{2,3} However, the cytotoxic activity of NaOCl may cause acute injuries to the periapical area when the compound is extruded beyond the apex, causing hemolysis, ulcerations and the destruction of endothelial and fibroblast cells, resulting in emphysema, trismus and sensory-motor defects.⁴ About 42% of endodontic practitioners described at least 1 occurrence of NaOCl extrusion beyond the apex during their career.⁵ The amount of the extruded irrigant might be related to applying high pressure on the syringes, wedging the needle and the large size of the apex, which is observed more frequently in immature teeth.⁶ Endodontic treatment of immature permanent teeth with necrotic pulp or apical pathosis has always been a challenge, since mechanical instrumentation might result in further weakening of the dentinal walls of the canal, making it more difficult to obtain an apical seal.⁷ Currently, there is a shift in treating these teeth toward revascularization, which would allow root development to continue, and according to many case reports, this procedure has proved its success.^{8,9} The success is dependent on 3 factors, which are stem cells, growth factors and scaffolds.¹⁰ Disinfecting the canal is considered an important factor in this type of treatment.¹¹ It has been found that the apical extrusion of NaOCl can harm the stem cells, affecting the success of this procedure.¹² Hence, the aim of this study was to compare the extrusion of NaOCl solution and gel. To the best of our knowledge, this is the first study to evaluate and compare the amount of extrusion between NaOCl solution and gel in immature permanent teeth.

Material and methods

The sample size was calculated according to a prior pilot study using the G*Power software (v. 3.1) and 30 single-rooted immature human premolars, freshly extracted due to orthodontic treatment, were used as the total specimen. The criteria for tooth selection were as follows: lack of internal or external resorption as well as of visible caries, fractures or cracks under a stereoscopic microscope (Meiji Techno Co., Ltd., Saitama, Japan) at $\times 2$ magnification.

The teeth were cleaned with the CK-6 hand scaler instrument (Zeffiro–Lascod, Florence, Italy) to remove the soft tissue residual and were stored in plastic containers with 0.5% chloramine T for 1 week, and then moved to other containers filled with 0.9% saline and stored in a refrigerator at the temperature of 4°C until used.

Preparation of specimens

Conventional access cavity preparation was done using a 2-millimeter round bur and the roof of the pulp was removed with the Endo-Z® bur (Dentsply, Ballaigues, Switzerland). Then, the pulp was removed using barbed broaches (VDW GmbH, Munich, Germany). The teeth were decoronated to standardize the tooth length to 15 mm and the measurements were done using a digital caliper. The teeth were covered with 2 layers of nail polish to seal the roots.

Determining the dimensions of the apical foramen

The surface area of the apices was measured by capturing the apex with a digital camera (Samsung NX500; Samsung, San Jose, USA) under a stereomicroscope (Meiji Techno Co.,

Ltd.) at $\times 2$ magnification. An endodontic ruler was set beside the foramen to calibrate the pixels by measuring the logical length of each 1 mm in pixels. The borders of the apical foramen were selected with a pen tool and the surface area in mm² was calculated from the measurement log after setting the measurement scale of the length in pixels according to the logical length of 1 mm. The teeth were inserted in a putty condensation silicone (ZetaPlus®; Zhermack GmbH, Marl, Germany) and radiographed in mesiodistal and buccolingual directions (imaging systems by Vatech Co., Ltd., Hwaseon to ensure that the canals are straight ($<5^\circ$) according to Schneider¹³ and to determine the mesiodistal dimension of the apices in order to make clinical simulation.

Study groups and irrigation protocol

The teeth were then divided into 2 groups:

– group A: teeth with radiographically confirmed apical diameter ≤ 2.5 mm (surface area ≤ 6.9 mm²); – group B: teeth with radiographically confirmed apical diameter > 2.5 mm (surface area > 6.9 mm²). The teeth in each group were irrigated with 5 mL of 3 different irrigants:

- NaOCl solution 5.25%
- NaOCl gel 2.25%
- NaOCl gel 2.25%

After each irrigation, the teeth were washed with 5 mL of saline and dried using paper points. The irrigation was done with a 27-gauge side vent needle (Endo-Top; CERKAMED, Stalowa Wola, Poland), placed at 3 mm of the working length by adding a rubber stopper to the needle. The irrigation protocol was employed according to the Institutional Review Board of the Oregon Health & Science University (Portland, USA) as the final irrigation; the flow rate was 5 mL/60 s with 30 s of irrigation and 60 s of waiting,¹⁴ a vertical movement with the needle was done 1–2 mm away from the apex every 6 s.

Collecting the extruded irrigants

The Myers and Montgomery model was used in this study.¹⁵ A hole was made in the center of a plastic lid, and the teeth were inserted up to the level of the cemento-enamel junction and fixed to the vial with a composite (Tetric N-Ceram®; Ivoclar Vivadent, Zurich, Switzerland). A 22-gauge needle was bent and inserted into the lid to equalize the air pressure inside and outside the plastic vial. An empty plastic container was weighed using a 0.01-gram balance weight. Then, 5 mL of each irrigant was placed in the weighed container and the weight of the irrigant was calculated by subtracting the weight of the empty plastic container. The irrigant extruded after the irrigation was measured in the same way as previously described. The container was replaced with a new one after each irrigation.

The weights [g] of the extruded irrigants were transformed to volumes [mL] using the following equation:

$$\text{volume of extruded irrigant} = \frac{\text{weight of extruded irrigant} \times 5}{\text{weight of 5 mL of irrigant}}$$

Test of viscosity

Kinematic viscosity was measured by determining the time it took each irrigant to flow in a glass capillary U-tube inserted into a room temperature viscometer bath (JP SELECTA, Abrera, Barcelona, Spain), and multiplying this time by the calibration constant of the specific tube.

Statistical analysis

The normality of the data was checked using the Kolmogorov–Smirnov test, and the Kruskal–Wallis test was used to determine if there was a statistically significant difference in the volume of the apically extruded irrigants between group A and group B. In this study, the level of significance (p-value) was set at 0.05 and the statistical analysis was performed using the IBM SPSS software v. 23 (IBM Corp., Armonk, USA). Descriptive statistics, including minimum and maximum, means, and standard deviations (SD) were also calculated.

Results

The minimum and maximum, mean, and SD results of NaOCl viscosity are shown in Sodium hypochlorite gel Harpic has shown the highest viscosity, followed by NaOCl gel WC Net Bleach and NaOCl solution (Carmel). The extrusion volumes were statistically significantly different between the 3 types of irrigants in group A (apex ≤ 2.5 mm) ($p = 0.000$). Sodium hypochlorite solution (Carmel) had the highest amount of extrusion, followed by NaOCl gel WC Net Bleach, and the least amount was noted for NaOCl gel Harpic.

The pairwise comparison test showed that NaOCl solution (Carmel) had a significantly higher amount of extrusion than NaOCl gel WC Net Bleach ($p = 0.000$) and Harpic ($p = 0.000$), and it also revealed that there was no statistically significant difference between NaOCl gel WC Net Bleach and Harpic ($p = 0.813$) (Table 3). The extrusion volumes were not statistically significantly different between the 3 types of irrigants in group B (apex > 2.5 mm) ($p = 0.214$).

Discussion

The purpose of this study was to compare the amount of the extrusion of NaOCl solution and gel. Many studies have compared the amount of the extrusion of NaOCl solution with different irrigating systems. However, the studies have been limited to mature permanent teeth and few studies have modified mature teeth to resemble immature teeth.^{16,17} In this study, real freshly extracted immature premolars with different apical diameters were used to simulate the actual clinical situation. Sodium hypochlorite gel was chosen, because no studies have evaluated the amount of its extrusion beyond the apex. Also, research showed its effectiveness as an intracanal irrigant; Al-Sudani and Al Omar proved its efficacy in removing the smear layer at 2.5% concentration compared to NaOCl solution at the same concentration.¹⁸ This result was consistent with the study done by Zand et al., who observed no significant difference between 2.5% NaOCl gel and solution in smear layer removal.¹⁹ Furthermore, Nejad Shamsi et al. reported the same effect of NaOCl gel on the growth of *E. faecalis* as in the case of NaOCl solution at the same concentration, thus considering it safe as an intracanal irrigant.²⁰

In this study, 2 different types of commercial NaOCl gel were selected, as the manufacturers always keep the additional materials added secret. Nail varnish was used to seal the root and

prevent the leakage from the lateral root canals. Arora and Tewari found that the apical foramen would have an oval, triangular, kidney, or irregular forms.²¹ For this reason, the surface area was calculated using Adobe Photoshop to evaluate the amount of apical extrusion from the whole surface of the apical foramen, regardless of its pattern and shape, and then the mesiodistal diameter was measured radiographically to obtain the results similar to the clinical situation. A side vent needle was chosen, as it can move the irrigant sideways and reduce the extrusion.²² Despite the difference in viscosity between NaOCl gel and solution, the pressure applied on the plunger of the syringe would also be different; therefore, the flow rate was standardized to be 5 mL/60 s in all the specimens. Up-and-down movements were done every 6 s to evoke agitation.²² This study showed significantly less extrusion of NaOCl gel compared to solution in group A, where the apical diameter was less than 2.5 mm; this reduction took place despite the higher pressure applied on the plunger of the syringe when irrigating with the gel form as compared to solution at the same flow rate. Although the results of this study showed that the mean value of apical extrusion of NaOCl gel in group A was high (4 mL), and this could be referred to the extremely immature teeth used in this study, it is thought that NaOCl gel could dissolve soft tissues to a lesser extent than solution. The results also showed no statistically significant difference between the 2 types of NaOCl gel. These results were consistent with the results of the viscosity test, as the viscosity of NaOCl gel was 226.666 cSt for Harpic and 190 cSt for WC Net Bleach, while the least viscosity was observed in the case of NaOCl solution (0.563 cSt). Moreover, group B showed no statistically significant difference between NaOCl gel and solution, which indicates that all the irrigants would extrude apically when the dimensions are large enough.

Conclusions:

Sodium hypochlorite solution cannot be used as an intracanal irrigant in immature teeth because of the high risk of apical extrusion.

References

1. Wright PP, Walsh LJ. Optimizing antimicrobial agents in endodontics. In: Kumavath RN, ed. Antimicrobial Agents. Croatia: InTech; 2017:87–107.
2. Rahimi S, Janani M, Lotfi M, et al. A review of antibacterial agents in endodontic treatment. Iran Endod J. 2014;9(3):161–168.
3. Mohammadi Z. Sodium hypochlorite in endodontics: An update review. Int Dent J. 2008;58(6):329–341.
4. Guivarc'h M, Ordioni U, Ahmed HM, Cohen S, Catherine JH, Bukiet F. Sodium hypochlorite accident: A systematic review. J Endod. 2017;43(1):16–24.
5. Kleier DJ, Averbach RE, Mehdi pour O. The sodium hypochlorite accident: Experience of diplomates of the American Board of Endodontics. J Endod. 2008;34(11):1346–1350.
6. Mathew ST. Risks and management of sodium hypochlorite in endodontics. J Oral Hyg Heal. 2015;3(3):3–7.
7. Wigler R, Kaufman AY, Lin S, Steinbock N, Hazan-Molina H, Torneck CD. Revascularization: A treatment for permanent teeth with necrotic pulp and incomplete root development. J Endod. 2013;39(3):319–326.
8. da Silva Limoeiro AG, dos Santos AHB, Kato AS, Freire LG, da Silveira Bueno CE. Pulp revascularization: A case report [in Portuguese]. Dent Press Endod. 2015;5(2):74–77.

9. Saeki K, Fujita Y, Shiono Y, Morimoto Y, Maki K. Pulp revascularization in immature permanent tooth with apical periodontitis using mineral trioxide aggregate. *Case Rep Med.* 2014;2014:564908.
10. Namour M, Theys S. Pulp revascularization of immature permanent teeth: A review of the literature and a proposal of a new clinical protocol. *ScientificWorldJournal.* 2014;2014:737503.
11. He L, Zhong J, Gong Q, et al. Treatment of necrotic teeth by apical revascularization: Meta-analysis. *Sci Rep.* 2017;7(1):13941.
12. Martin DE, de Almeida JF, Henry MA, et al. Concentration-dependent effect of sodium hypochlorite on stem cells of apical papilla survival and differentiation. *J Endod.* 2014;40(1):51–55.
13. Balani P, Niazi F, Rashid H. A brief review of the methods used to determine the curvature of root canals. *J Res Dent.* 2015;3:57–63.
14. Nielsen BA, Craig Baumgartner J. Comparison of the EndoVac System to needle irrigation of root canals. *J Endod.* 2007;33(5):611–615.
15. Myers GL, Montgomery S. A comparison of weights of debris extruded apically by conventional filing and canal master techniques. *J Endod.* 1991;17(6):275–279.
16. Aksel H, Askerbeyli S, Cigdem C, Serper A. Effect of needle insertion depth and apical diameter on irrigant extrusion in simulated immature permanent teeth. *Braz Oral Res.* 2014;28(1):1–6.
17. Velmurugan N, Sooriaprakas C, Jain P. Apical extrusion of irrigants in immature permanent teeth by using EndoVac and needle irrigation: An in vitro study. *J Dent (Tehran).* 2014;11(4):433–439.
18. Al-Sudani DA, Al Omar HA. Evaluation of sodium hypochlorite (NaOCl) gel as an endodontic irrigant. *J Biomater Tissue Eng.* 2011;1(2):215–218.
19. Zand V, Lotfi M, Soroush MH, Abdollahi AA, Sadeghi M, Mojadadi A. Antibacterial efficacy of different concentrations of sodium hypochlorite gel and solution on *Enterococcus faecalis* biofilm. *Iran Endod J.* 2016;11(4):315–319.
20. Nejad Shamsi P, Atash Biz Yeganeh L, Vadiati Saberi B, Forghan Parast K, Taghavi Kashan A. Antibacterial effect of sodium hypochlorite gel and solution on *Enterococcus faecalis*. *3DJ.* 2017;6(1):27–30.
21. Arora S, Tewari S. The morphology of the apical foramen in posterior teeth in a North Indian population. *Int Endod J.* 2009;42(10):930–939.
22. Jena A, Sahoo SK, Govind S. Root canal irrigants: A review of their interactions, benefits, and limitations. *Compend Contin Educ Dent.* 2015;36(4):256–261