RESEARCH ARTICLE

Comparative evaluation of ethanol versus citric acid in removal of oil-based calcium hydroxide from the apical third of root canal system

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Abstract

Objective: To evaluate the effectiveness of ethanol compared to citric acid in the removal of oil-based calcium hydroxide from the apical third of the root canal system using passive ultrasonic irrigation.

Method: The in vitro study was conducted from September to October 2021 at the dental clinics of the Aga Khan University Hospital, Karachi, and comprised single-rooted teeth that were selected from institutional bank of extracted teeth. They were randomly divided into group A having 70% ethanol + passive ultrasonic irrigation, group B 10% citric acid + passive ultrasonic irrigation, group C positive controls and group D negative controls. The specimens were sectioned at 1mm and 3mm from the apex and examined under a dental operating microscope. A single examiner scored the specimens on two different occasions. Data was analysed using SPSS 25.

Results: Of the 90 teeth, there were 40(44.4%) in each of the 2 experimental groups and 5(5.5%) in each of the 2 control groups. At 3mm apical sections, ethanol was significantly more effective in the removal of oil-based calcium hydroxide (p=0.01). However, at 1mm from the apex, there was no significant difference between the experimental groups (p=0.064). Intragroup comparison showed that for groups A and B, residual medicament at 1mm sections was significantly greater than at 3mm sections (p<0.001, p=0.003).

Conclusion: Neither irrigant showed complete removal at 1mm and 3mm from the apex. However, at 3mm apical sections, 70% ethanol was significantly more effective compared to 10% citric acid.

Keywords: Calcium hydroxide, Root canal medicament, Endodontics, Citric acid, Ethanol. (JPMA 74: 464; 2024)

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Introduction

Root canal treatment is indicated when the dental pulp is irreversibly inflamed or necrotic.[1] In pulpal necrosis, the infection may progress from the coronal pulp to involve the apical third of the root canal system where 75% of the canal irregularities are present.[2] These ramifications are unlikely to be debrided using mechanical instrumentation alone, thus the use of an intracanal medicament is advocated.[2,3] For the purpose of disinfection, calcium hydroxide ($Ca[OH]_2$) is the medicament of choice owing to its superior antibacterial properties.[4]

$Ca(OH)_2$ is mixed with different vehicles and is available in many formulations. One of them is Metapex (Meta Biomed, Korea), which is an oil-based paste. It is thought to have an added antibacterial advantage, which could be due to two reasons: the incorporation of 38% iodoform in its composition or the presence of viscous oil as a vehicle, which may prolong the action of the medicament.[5] Conversely, the presence of oil is also a matter of concern because the oil-based dressing is very difficult to remove using conventional syringe irrigation.[6]

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Complete removal of the intracanal medicament is necessary because it interferes with the bonding and seal of endodontic materials.[7] Moreover, the solubility and dimensional instability of $Ca(OH)_2$ paste over time results in a compromised seal, thus jeopardising the endodontic treatment outcome.[8] The residual $Ca(OH)_2$ paste may also affect the physical properties of the sealers, their bond strength to dentin, dentinal tubular penetration, and the filling of the lateral canals.[7] This is particularly important in the apical third where a majority of canal irregularities are present, and the residual medicament might represent a path for bacterial infiltration.[8]

Mechanical instrumentation of the root canal system combined with copious irrigation with sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) is the most frequently used method for removing intracanal $Ca(OH)_2$.[9] Apart from these, a variety of chemicals such as maleic acid, citric acid, and phosphoric acid have also been tested in the past for the removal of oil-based $Ca(OH)_2$.[6] Of all these chemicals, citric acid has shown the most effective removal, but no attempt to date has been made to remove the oil-based dressing using ethanol as an irrigant.[6,10] Besides these chemicals, various mechanical methods, like manual or rotary instrumentation, and sonic or ultrasonic activation, have also been tested as an adjunct to remove oil-based $Ca(OH)_2$ dressing. Passive ultrasonic irrigation (PUI) has proven to be more effective than others because of its streaming pattern within the canals.[9]

Despite these advancements in irrigation techniques and using different types of irrigants, removing $Ca(OH)_2$ dressing from the apical third remains an endodontic challenge.[11] Moreover, literature has reported that no currently available strategy can completely or predictably aid in its removal.[12] Having said that, considering the importance of a tight apical seal, complete removal of medicament is indispensable. Therefore, the current study was planned to evaluate the effectiveness of ethanol compared to citric acid in the removal of oil-based $Ca(OH)_2$ from the apical third of canals using PUI. The null hypothesis tested was that there is no difference in the removal of oil-based Ca(OH)2 dressing using ethanol and citric acid.

Materials and Methods

The in vitro study was conducted from September to October 2021 at the dental clinics of the Aga Khan University Hospital, Karachi, and comprised single-rooted teeth that were selected from the institutional bank of extracted teeth. After exemption was obtained from the institutional ethics review committee, the sample size was calculated using the World Health Organisation (WHO) calculator[13] while taking mean percentage of $Ca(OH)_2$ removal from the apical third as 97.07% and 83% for citric acid and ethanol respectively[10,13] and keeping the level of significance (α) 5% and power 80%.

The sample was raised using non-probability consecutive sampling technique. Single-rooted teeth with completed root formation and curvature <5 degrees, as determined by the schneider method, were included. Any samples with curved or multiple roots, previously filled teeth, and pre-existing cracks, caries, resorptions or calcifications were excluded.

All the teeth were cleaned to remove debris and soft tissue remnants. The teeth were disinfected with 5.25% NaOCl and stored in normal saline solution at room temperature. To standardise the length of specimens, the teeth were sectioned at 16mm from the apex. They were then mounted in wax blocks and a size 10K file was placed in the canal to check patency. The root canals were instrumented using Protaper Next rotary files (Dentsply, Sirona, United States) sequentially till X3 (30/07). Irrigation was performed with 3% NaOCL using a 3ml plastic syringe and a side-vented needle. Canals were dried with X3 paper points (Dentsply Maillefer, Sirona, United States).

The prepared specimens were filled with Metapex (Meta Biomed, South Korea) up to working length using lentulo spiral. Buccolingual and mesiodistal radiographs were taken to ensure the complete filling of canals. The root orifices were sealed with cotton and a temporary restorative material. The specimens were stored at 37°C and 100% humidity for 7 days (Figure 1).

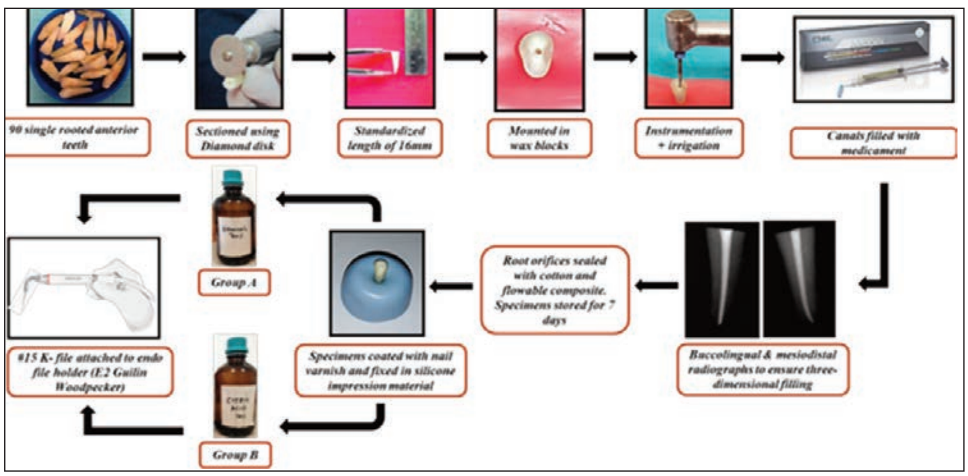

Figure-1: Specimen preparation and allocation into experimental groups on the basis of irrigation protocol.barotrauma, but due to worsening airspace disease (f), the patient eventually expired on the 19th day of admission.

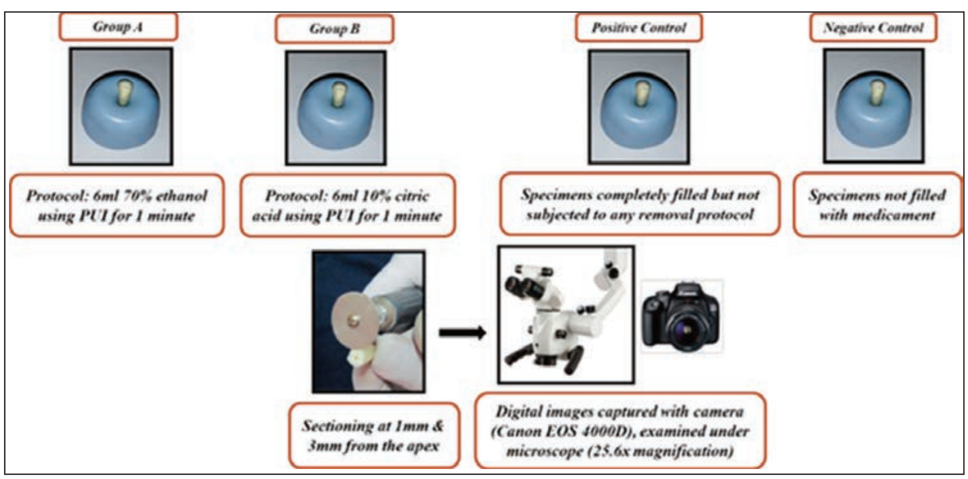

Figure-2: Experimental groups A and B, positive control group C and negative control group D. The specimens after sectioning were evaluated under dental operating microscope (25.6x magnification).

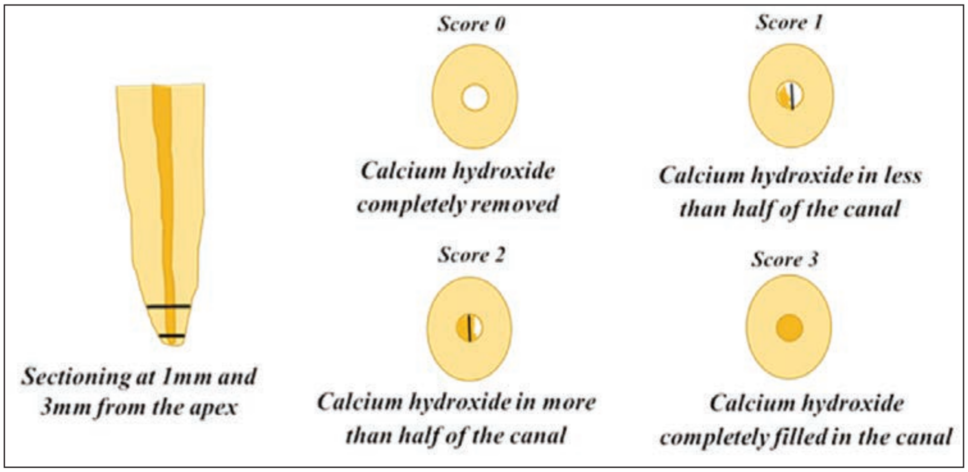

Figure-3: Residual medicament scoring criterion.

After 7 days, the samples were coated with two coats of varnish, including the apical foramen, and were then fixed in silicone impression material (Aquasil, Dentsply, Sirona, United States) to create a closed system. After access was reopened, the specimens were randomly divided using a computer-generated randomisation sequence (RANDOM.ORG)[14] on the basis of removal methods into experimental group A having 70% ethanol+PUI, experimental group B having 10% citric acid+PUI, group C positive controls and group D negative controls (Figure 2).

In group A, removal of $Ca(OH)_2$ paste was done with 6ml 70% ethanol divided into 3 applications of 2ml with each application ultrasonically activated for 1 minute. The activation was carried out using a size 15K file attached to a stainless steel endo file holder (E2, Guilin Woodpecker EMS, United Kingdom) with an ultrasonic unit (EMS Piezon Master 200, China) at a power setting of 10%. The file was activated inside the canal 2mm short of the working length, and was moved passively in an up-and-down manner to ensure that it does not bind with the canal walls. The excess chemical was removed with paper points after irrigation.

In group B, the same protocol as for group A was followed for $Ca(OH)_2$ removal with 10% citric acid.

In group C, the specimens were filled with $Ca(OH)_2$, but were not subjected to any removal protocol.

In group D, the specimens were instrumented but were not filled with $Ca(OH)_2$.

The specimens were sectioned with a diamond disk (Microdont, Brazil) at 1mm and 3mm from the apex. The sectioned samples were then examined under a dental operating microscope with 25.6x magnification (AM-4000, ALLTION, Guangxi, China), and the digital images were captured with a camera (Canon EOS 4000D). All clinical procedures were performed by the primary investigator, whereas the specimens were analysed by a co-investigator on two different occasions to ensure reliability. The investigator who scored the specimens was blinded to the study groups to eliminate bias.

The criterion defined in literature was used to score the specimens for residual medicament in the apical sections[15] as: $Ca(OH)_2$ completely removed=0, $Ca(OH)_2$ in <50% of the canal=1. $Ca(OH)_2$ in >50% of the canal=2, and $Ca(OH)_2$ completely filled in the canal=3 (Figure 3).

The scores for the specimens at 1mm and 3mm from the apex were recorded in a customised proforma.

Data was analysed using SPSS 25. The intra-examiner reliability was determined using the intraclass correlation coefficient (ICC). Shapiro-Wilk test was used to assess normality of data distribution. Mann-Whitney U test was applied to compare the effectiveness of medicament removal between the experimental groups at 3mm and 1mm sections. For intragroup comparison, Wilcoxon sign rank test was used. $P<0.05$ was considered significant.

Results

ICC for intra-examiner reliability was 0.89 (95% confidence interval: 0.85-0.92) showing 'good' to 'excellent' reliability ($p<0.001$).

Of the 90 teeth, there were 40(44.4%) in each of the 2 experimental groups and 5(5.5%) in each of the 2 control groups. At 3mm apical sections, ethanol was significantly more effective in the removal of oil-based calcium hydroxide ($p=0.01$). However, at 1mm from the apex, there was no significant difference between the experimental groups ($p=0.064$) (Table 1).

Intragroup comparison showed that for groups A and B, residual medicament at 1mm sections was significantly greater than at 3mm sections ($p<0.001$, $p=0.003$) (Table 2).

Table-1: Comparison of medicament removal between the two study protocols.

Apical cross-section	Median (IQR)		*p*-value
	70% ethanol	10% citric acid	
3mm from apex (n=40)	1 (0-2)	2 (1-3)	0.010*
1mm from apex (n=40)	3 (1-3)	3 (2-3)	0.064

IQR: Interquartile range; *Mann-Whitney U test; *p-value <0.05

Table-2: Intragroup comparison for medicament removal.

Materials	Median (IQR)		*p*-value
	3mm from apex (n=40)	1mm from apex (n=40)	
70% ethanol	1 (0-2)	3 (1-3)	<0.001*
10% citric acid	2 (1-3)	3 (2-3)	0.003*

IQR: Interquartile range. *Wilcoxon sign rank test; **p*-value <0.05

Discussion

The apical third of the root canal system has the most complex anatomy owing to the presence of irregularities in the form of apical deltas, ramifications and lateral canals.[2] The presence of $Ca(OH)_2$ remnants in these complexities compromises the fluid-tight seal necessary for successful endodontic treatment.[8] Therefore, the current study focussed on the apical third of the root canal system.

The current findings were in line with Dias et al. who used ethanol to remove water-based $Ca(OH)_2$ dressing.[10] However, the current study, to the best of our knowledge, is the first to use ethanol as an irrigant to remove oil-based $Ca(OH)_2$ dressing. Since there was no head-to-head comparison for ethanol and citric acid, therefore the present study aimed at assessing the effectiveness of ethanol compared to citric acid, using PUI in the removal of oil-based $Ca(OH)_2$ from the apical third of canals.

The results revealed that neither ethanol nor citric acid was able to completely remove the oil-based $Ca(OH)_2$ from the apical third of the root canal system. Nevertheless, ethanol was significantly more effective in the removal at 3mm compared to citric acid. Hence, it could be speculated that ethanol may have penetrated silicone oil better, but because of the complex apical anatomy, complete removal was not possible even with the use of ultrasonics.[14]

In the current study, the specimens were evaluated under a dental operating microscope with 25.6x magnification, and a subjective scoring criterion[15] was used. To mitigate the chances of bias between the examiners when using subjective parameters, a single investigator blinded to the study groups scored the samples on two occasions with an almost perfect agreement. One may argue that the residual medicament might have been evaluated using quantitative assessment, but since the focus of the study was on complete removal of medicament, this did not affect the results of the current study. Moreover, quantitative assessment is beneficial when intratubular analysis is intended.[10,16,17]

Furthermore, advanced assessment tools, such as an electron microscope or confocal laser scan microscope, could have been used as opposed to a dental operating microscope. However, analysis using a laser microscope requires the use of a fluorescent dye and there are chances of possible interaction between dye material and the tested chemicals.[10] The possibility of such interaction was discarded as no dye was used in the current study. Likewise, the use of an electron microscope should be reserved where the depth of cleanliness or tubular penetration of the sealers needs to be evaluated.[17]

A standardised methodology was followed in the current study. All the clinical procedures were performed by a single investigator, and a constant volume as well as time of irrigation was ensured for both the experimental groups. Although, there is strong evidence in favour of the use of ultrasonics, Zorzin et al. demonstrated that a high volume of irrigation resulted in better removal of the intracanal medicament regardless of the solution activation.[18] Therefore, a combination of both a high volume of irrigant and PUI was used in the current study.

Ethanol has been used in previous studies as a final rinse to improve the wettability of root canal dentin, resulting in enhanced sealer penetration.[19,20] However, this was the first attempt to remove oil-based $Ca(OH)_2$ using ethanol without the use of rotary instrumentation which is thought to weaken the root canal dentin. One may have concerns regarding the cytotoxic effects of ethanol, which is commonly used as a fixative agent, but this was not a problem in the current case as the samples were exposed to irrigant for a short time period.[21]

The current study has limitations as it lacked a group with standard NaOCl and EDTA irrigation protocol, as utilised in previous studies.[14,22] Moreover, curved and multi-rooted teeth were not taken into consideration where removal of intracanal medicament might present a great challenge due to anatomical constraints.

On the basis of current findings, the oil-based $Ca(OH)_2$ dressing should be used with caution as it is difficult to remove, and the residual medicament might result in a compromised endodontic outcome. Likewise, more dynamic methods of irrigation should be tested in conjunction with ethanol for the complete removal of oil-based $Ca(OH)_2$ paste.

Conclusion

Neither ethanol nor citric acid completely removed oil-based $Ca(OH)_2$ from the apical third of the root canal system. However, 70% ethanol was significantly more effective in the removal of medicament at 3mm apical sections compared to 10% citric acid.

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Conflicts of Interest: None.

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References

1. Carrotte PV. An introduction to endodontics. BDJ Team 2021;8:31–4. doi: 10.1038/s41407-021-0582-3.
2. Ricucci D, Pascon EA, Siqueira JF Jr. The Complexity of the Apical Anatomy. In: Versiani MA, Basrani B, Sousa-Neto MD, eds. The Root Canal Anatomy in Permanent Dentition. Cham, Switzerland: Springer International Publishing AG, 2019; pp 241-54. Doi: 10.1007/978-3-319-73444-6_8
3. Siddique R, Nivedhitha MS. Effectiveness of rotary and reciprocating systems on microbial reduction: A systematic review. J Conserv Dent 2019;22:114-22. doi: 10.4103/JCD.JCD_523_18.
4. Reddy S, Prakash V, Subbiya A, Mitthra S. 100 years of Calcium Hydroxide in Dentistry: A review of literature. Indian J Forensic Med. Toxicol 2020;14:1203-19.
5. Cwikla SJ, Bélanger M, Giguère S, Progulske-Fox A, Vertucci FJ. Dentinal tubule disinfection using three calcium hydroxide formulations. J Endod 2005;31:50-2. doi: 10.1097/01.don. 0000134291.03828.d1.
6. Ballal NV, Kumar SR, Laxmikanth HK, Saraswathi MV. Comparative evaluation of different chelators in removal of calcium hydroxide preparations from root canals. Aust Dent J 2012;57:344-8. doi: 10.1111/j.1834-7819.2012.01710.x.
7. Uzunoglu-Özyürek E, Erdoğan Ö, Aktemur Türker S. Effect of Calcium Hydroxide Dressing on the Dentinal Tubule Penetration of 2 Different Root Canal Sealers: A Confocal Laser Scanning Microscopic Study. J Endod 2018;44:1018-23. doi: 10.1016/j.joen.2018.02.016.
8. Ahmed H, Balani P. Influence of Calcium Hydroxide as an Intracanal Medicament on Apical Seal. J Adv Med Med Res 2022;34:97-106. DOI: 10.9734/JAMMR/2022/v34i231265.
9. Alturaiki S, Lamphon H, Edrees H, Ahlquist M. Efficacy of 3 different irrigation systems on removal of calcium hydroxide from the root canal: a scanning electron microscopic study. J Endod 2015;41:97-101. doi: 10.1016/j.joen.2014.07.033.
10. Dias-Junior LCL, Castro RF, Fernandes AD, Guerreiro MYR, Silva EJNL, Brandão JMDS. Final Endodontic Irrigation with 70% Ethanol Enhanced Calcium Hydroxide Removal from the Apical Third. J Endod 2021;47:105-11. doi: 10.1016/j.joen.2020.09.017.
11. Donnermeyer D, Wyrsch H, Bürklein S, Schäfer E. Removal of Calcium Hydroxide from Artificial Grooves in Straight Root Canals: Sonic Activation Using EDDY Versus Passive Ultrasonic Irrigation and XPendo Finisher. J Endod 2019;45:322-6. doi: 10.1016/j.joen. 2018.11.001.
12. Marques-da-Silva B, Alberton CS, Tomazinho FSF, Gabardo MCL, Duarte MAH, Vivan RR, et al. Effectiveness of five instruments when removing calcium hydroxide paste from simulated internal root resorption cavities in extracted maxillary central incisors. Int Endod J 2020;53:366-75. doi: 10.1111/iej.13223.
13. Lwanga SK, Lemeshow S. Sample size determination in health studies: a practical manual. Geneva, Switzerland: World Health Organization; 1991. [Online] 1991 [Cited 2023 November 04]. Available from URL: https://apps.who.int/iris/handle/10665/40062
14. Haahr M. Random.org: True Random Number Service. [Online] 1998-2024 [Cited 2023 November 04]. Available from URL: https://www.random.org/
15. Wang Y, Guo LY, Fang HZ, Zou WL, Yang YM, Gao Y, et al. An in vitro study on the efficacy of removing calcium hydroxide from curved root canal systems in root canal therapy. Int J Oral Sci 2017;9:110-16. doi: 10.1038/ijos.2017.14.
16. Topçuoğlu HS, Düzgün S, Ceyhanlı KT, Aktı A, Pala K, Kesim B. Efficacy of different irrigation techniques in the removal of calcium hydroxide from a simulated internal root resorption cavity. Int Endod J 2015;48:309-16. doi: 10.1111/iej.12316.
17. Moon YM, Shon WJ, Baek SH, Bae KS, Kum KY, Lee W. Effect of final irrigation regimen on sealer penetration in curved root canals. J Endod 2010;36:732-6. doi: 10.1016/j.joen.2009.12.006.
18. McMichael GE, Primus CM, Opperman LA. Dentinal Tubule Penetration of Tricalcium Silicate Sealers. J Endod 2016;42:632-6. doi: 10.1016/j.joen.2015.12.012.
19. Chen H, Zhao X, Qiu Y, Xu D, Cui L, Wu B. The Tubular Penetration Depth and Adaption of Four Sealers: A Scanning Electron Microscopic Study. Biomed Res Int 2017;2017:2946524. doi: 10.1155/2017/2946524.
20. Zorzin J, Wießner J, Wießner T, Lohbauer U, Petschelt A, Ebert J. Removal of Radioactively Marked Calcium Hydroxide from the Root Canal: Influence of Volume of Irrigation and Activation. J Endod 2016;42:637-40. doi: 10.1016/j.joen.2016.01.005.
21. Stevens RW, Strother JM, McClanahan SB. Leakage and sealer penetration in smear-free dentin after a final rinse with 95% ethanol. J Endod 2006;32:785-8. doi: 10.1016/j.joen.2006.02.027.
22. Pantoja CAMS, Silva DHD, Soares AJ, Ferraz CCR, Gomes BPFA, Zaia AA, et al. Influence of ethanol on dentin roughness, surface free energy, and interaction between AH Plus and root dentin. Braz Oral Res 2018;32:e33. doi: 10.1590/1807-3107bor-2018.vol32.0033.

Author Contribution:

NN and FU: Study conception and design; data analysis and interpretation, final approval.
NN: Data acquisition and drafting
FU: Critical revision
Both the authors agree to be accountable for all aspects of the work.