EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 71, 3635:3641, OCTOBER, 2025
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
CONSERVATIVE DENTISTRY AND ENDODONTICS
Submit Date : 14-08-2025 • Accept Date : 27-08-2025 • Available online: 10-10-2025 • DOI : 10.21608/edj.2025.414183.3596

EFFECT OF THREE DIFFERENT FINAL IRRIGATION PROTOCOLS ON BOND STRENGTH OF EPOXY RESIN-BASED SEALER

Rahaf Ezzat Abou El Enen*,
Tarek Mohamed AbdelWahab** *and* Amro Abdul Razek***

ABSTRACT

Aim: This research focused on assessing impact of three distinct final irrigation protocols.; Sodium hypochlorite (NaOCl) only, NaOCl followed by Ethylenediaminetetraacetic acid (EDTA) and NaOCl followed by EDTA then NaOCl again on push-out bond strength (POBS) of AH-plus sealer to root dentine.

Methodology: Forty-five mandibular premolar teeth were decoronated and instrumented by ProTaper universal (Dentsply Maillefer, Ballaiques, Switzerland) rotary files up to F4. specimens were divided into three groups (n=15) according to final irrigation protocol (NaOCl, followed by EDTA and NaOCl followed by EDTA then NaOCl again). Lateral compaction technique was utilized to obturate all canals. POBS was assessed by universal testing machine.

Results: NaOCl followed by EDTA showed greatest value of POBS compared to NaOCl only. Where NaOCl followed by EDTA then NaOCl showed lowest value of POBS.

Conclusion: Final irrigation protocol NaOCl followed by EDTA then NaOCl again decreased AH plus POBS while NaOCl followed by EDTA enhanced its bonding strength.

KEYWORDS: AH plus, Irrigation, Bond strength, Sodium hypochlorite.

INTRODUCTION

Successful endodontic therapy depends on meticulous chemomechanical preparation followed by dense, homogeneous, gap-free, and impermeable obturation which minimizes bacterial contamination and microleakage while establishing strong apical barrier that prevents reinfection of the root canal.[1,2]

During mechanical preparation, 1 to 2 mm thick amorphous and porous layer known as "smear layer" is formed on dentinal surface, including

* Clinical Demonstrator of Endodontics, Department of Endodontics, Faculty of Oral and Dental Medicine, Delta University for Science and Technology, Gamasa, Dakahlia, Egypt
** Lecturer of Endodontics, Department of Endodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt
*** Professor of Endodontics, Department of Endodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

inorganic & organic contents, remnant of vital or necrotic pulp tissue, and bacterial microorganisms and their byproducts.[3] Its elimination is crucial to enhance penetration of irrigant into dentinal tubules and to ensure better adaptation of filling material.[4]

Several irrigants are used in order to achieve proper canal disinfection and to eliminate smear layer.[5] Sodium hypochlorite (NaOCl) is most frequently utilized irrigant because of its distinctive capacity to dissolve organic tissue through proteolytic action. So, it is can eliminate organic content of smear layer.[6] Chelating agents such as ethylenediaminetetraacetic acid (EDTA) are used alongside NaOCl in order to eliminate inorganic content of smear layer which cannot be removed by NaOCl.[5] Therefore, NaOCl followed by EDTA is most often utilized and recommended irrigation protocol.[7]

Christos Boutsioukis et al,[8] in a study investigating future direction of different final irrigation protocol, recommended reapplying NaOCl again after chelating agent. However, it may adversely affect the chemical and physical composition of dentine.[9]

Different irrigation protocols can change the microstructure of dentin, subsequently affect the adhesion .[10, 11] However, terminal irrigation protocol impact on POBS of endodontic sealers remains inconclusive.

SO, this study tests the null hypothesis that different final irrigation protocols have no effect on sealer POBS, our investigation concentrated on impact of three distinct final irrigation protocols: NaOCl only, NaOCl followed by EDTA, and NaOCl followed by EDTA then NaOCl again.

METHODOLOGY

The present study was approved by the Research Ethical Committee of faculty of Dentistry, Mansoura University (Under protocol ID: A01010023RC). The study was carried out in accordance with the ethical guidelines established by the Declaration of Helsinki.

Sample size calculation

A power analysis using G*Power 3.1, based on data from Donnermeyer D's 1984 study, determined 15 canals for each experimental group to ensure adequate statistical power.

Sample Selection

Forty-five extracted intact mandibular premolar human teeth removed due to periodontal problems were obtained from Oral and Maxillofacial department, Faculty of Dentistry, Mansoura university.

Teeth included in this study were, single-rooted with single canal and completely formed root apex. Teeth with root caries, curved canals, cracks, open apex or external resorption were excluded.

Calculus and soft tissue were eliminated by ultrasonic scaler then all teeth were disinfected and preserved in chloramine-T solution until being used.

Sample Preparation

To set a standardized length at 15 mm, teeth were decoronated at (CEJ): cemetntoenameljunction level, using high speed carbide bure with water coolant.

Patency of root canal was confirmed using size 10 stainless steel k-file (Mani, INC, Japan). Working length was adjusted by advancing size 15 K-file until its tip was seen from apex then subtracting 1mm from that distance. To check the appropriate working length, radiograph was taken. All root apices were masked with baseplate wax to prevent the extrusion of irrigation. Preparation of root canals was done using ProTaper universal rotary files up to F4. Irrigation was carried out between each file with 3mm 2.5% NaOCl using a side-vented 27-gauge needle (Fanta, China).

Irrigation Protocol

Following instrumentation, samples were distributed randomly into three groups depending on final irrigation protocols (n = 15 per group):

- Group I (control group): 5 ml of (2.5% NaOCl) for 1 minute.
- Group II: (5 ml 2.5% NaOCl) for 1 minute then (5 ml 17% EDTA) for 1 minute.
- Group III: (5 ml 2.5% NaOCl) for 1minute, then (5ml 17% EDTA) for 1 minute then (5ml 2.5% NaOCl) for 1 minute. Saline was used between different irrigants.

Irrigation activation was done by passive ultrasonic activation using ED16 tip (Woodpecker, China) for 30 seconds.

Teeth Obturation

AH-plus sealer was used to obturate all canals with lateral compaction technique. Dryness of canals was done with size #40 paper points. Subsequently, a well-fitted master cone of size 40/0.04 gutta-percha (G.P.) was selected and its fit was confirmed radiographically. G.P cones were covered with the sealer and introduced into canal to full working length. #30 spreader was introduced 2 mm short of WL, and 25/0.02 accessory cones were added until canal was fully filled. All samples were sealed with Coltosol F (Coltene, Switzerland). Another post-obturation radiographs were taken to verify good obturation.

To guarantee full sealer setting. Incubator was used to keep all teeth for 7 days at 37°C and 100% humidity.

Push-out Assessment

Three sectioned slices of a filled root (typically 2mm thick) from coronal, middle and apical thirds of each root were cut using a water-cooled IsoMet4000 microsaw (Buehler, USA), equipped with a 0.6 mm thick diamond disc, measurement verification was done through a digital caliper, then slices placed on a supporting jig and compressive force is applied using universal testing machine, through metallic plunger or piston (Instron type 3345, England). Diameter of plunger tip was (1, 0.7,0.5) mm from coronal , middle and apical slices in same order from left to right.

Force is directed perpendicular and in an apico-coronal direction, pushing filling material out of canal space and maximum force at failure (in Newtons) was recorded using (Bluehill 3 software (version 3.3), Instron, US).

Push out bond strength (POBS) was obtained by dividing the highest recorded failure force (in Newtons) by the bonded surface area (in mm^2), and findings were expressed in terms of megapascals (MPa):

POBS=Maximum load (N) / area under load (mm2)

Statistical analysis

GraphPad Prism software (version 10.5; San Diego, CA, USA) performed the statistical analysis for this study. Shapiro–Wilk test was used to examine normality of data distribution. For datasets following a normal distribution, results were presented as mean ± standard deviation (SD).

Differences within and among groups were carried using one-way ANOVA, with Tukey's post hoc test applied for multiple comparisons. Significance was set at a p-value of ≤ 0.05.

RESULTS

Three distinct final irrigation methods varied significantly from one another overall.

NaOCl followed by EDTA then NaOCl again showed the lowest value of POBS when using it as a final irrigation protocol with mean value ranging from (2.197-2.459) MPa. Indicating that reusing NaOCl again after EDTA reduced bond strength.

NaOCl followed by EDTA gave highest value of POBS in compared with other groups through all root thirds, coronal with mean value of (7.893) MPa middle (7.852) MPa. and apical third with mean value of (5.699) MPa.

NaOCl as a single final irrigation protocol had moderate value of POBS with mean value ranging from (3.851-4.442) MPa. Table (1).

- Intragroup analysis revealed no statistically differences in POBS among coronal, middle, and apical thirds within Group I ($p = 0.309$) and Group III ($p = 0.796$). However, Group II exhibited a significant variation across root levels ($p < 0.001$), with bond strength progressively decreased apically.
- Inter group comparison: in all third, differences among groups were statistically significant as coronal (p=0.001*), middle and apical value were the same (p=<.001)

So, the results indicating that using NaOCl followed by EDTA enhances the POBS in all root thirds especially coronal and middle thirds while using NaOCl followed by EDTA then NaOCl decreases the POBS.

Failure mode

Analysis of failure modes revealed that NaOCl + EDTA final irrigation irrigation protocol showed greatest proportion of the two failure modes which are mixed and cohesive, Conversely, the NaOCl + EDTA + final NaOCl rinse group exhibited the highest number of adhesive failures. Figure (2).

TABLE (1) POBS in megapascals (MPa) expressed as Mean ± Standard between thirds at different irrigants for AH plus sealer.

Region	NaOCl	NaOCl +EDTA	NaOCl+EDTA+NaOCl	P-value
Coronal Third	4.442^{Aa}±.644	7.893^{Ab}±1.657	2.363^{Ac}±.654	0.001*
Middle Third	4.252^{Aa}±.610	7.852^{Ab}±1.040	2.197^{Ac}±.630	<.001*
Apical Third	3.851^{Aa}±.691	5.699^{Bb}±1.045	2.459^{Ac}±.523	<.001*
Anova (p value)	0.309	<.001*	0.796	

In columns, different superscript uppercase letters signify significant differences among thirds (Bonferroni, $p < 0.05$); within rows, distinct lowercase letters represent significant differences ($p < 0.05$)

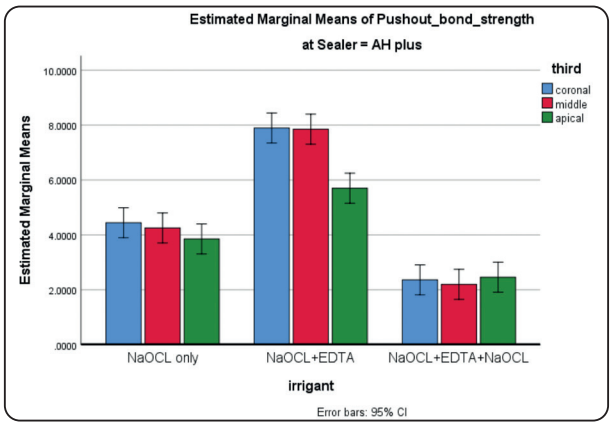

Fig. (1) POBS among root canal thirds using distinct irrigants with AH Plus sealer

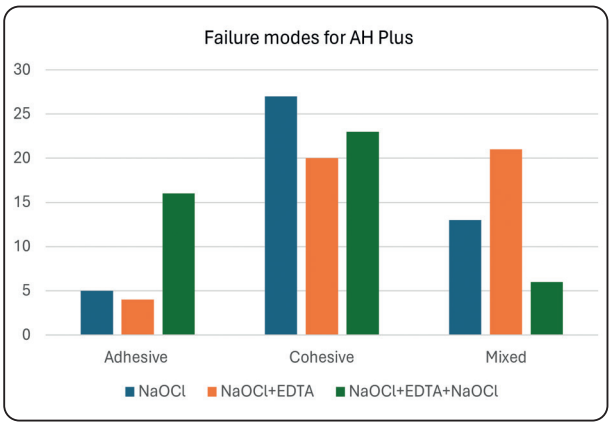

Fig. (2) Bar chart showing the failure mode; illustrating distribution of failure modes among specimens with cohesive failure being the most prevalent type

DISCUSSION

Effective Adhesion is mandatory for long-term endodontic treatment success and for reducing microleakage.[12] Among various factors influencing this adhesion, final irrigation protocol has a significant role in modifying the dentinal surface and influencing the interaction between sealer and dentine,[11] hence, we evaluate how three distinct final irrigation protocols; NaOCl only, NaOCl followed by EDTA and NaOCl followed by EDTA then NaOCl again affect the bonding performance of AH-plus.

Bond strength between filling materials and dentine had been assessed in current study through Push out test.[13]

Our findings rejected the null hypothesis, which held that bond strength is unaffected by application of various endodontic irrigation protocol. Based on our result, NaOCl followed by EDTA then NaOCl again showed lowest value while NaOCl followed by EDTA showed highest value of POBS when compared to other groups.

Applying NaOCl then EDTA then NaOCl again showed the lowest value of bond strength with AH plus as excceive or recurrent exposure to NaOCl following EDTA may jeopardize the peritubular and intertubular dentine's structural integrity due to over decalcification or collagen degradation causing dentin erosion, which would impair sealer bonding.[14]

NaOCl followed by EDTA as final irrigation protocol had a positive effect on POBS of AH-plus sealer to root dentine when compared with groups that were irrigated with other protocols.

Our study aligns with results of **David Donnermeyer** *et al*. 2019 [15] who examined how final irrigation solutions affect POBS of different types of sealers. AH Plus showed higher bond strength with smear layer removal, improved by EDTA after NaOCl.

However, **Farag** et al.[16]study disproved the relation between NaOCl and using chelator on the POBS. Indicated that neither EDTA nor citric acid following NaOCl significantly enhanced POBS of epoxy resin sealer compared to NaOCl alone.

AH Plus sealer demonstrated higher POBS when NaOCl followed by EDTA irrigation protocol was used, because final irrigation with EDTA significantly reduces dentin wetness, creating a substrate that better supports the hydrophobic nature of AH Plus, [17] as irrigation with EDTA, demineralizes dentin, opens dentinal tubules, and increases dentine roughness.[18] [19]

The increased POBS of AH Plus sealer in samples which were irrigated with NaOCl followed by EDTA attributed to improvement in surface wetting when both EDTA and NaOCl irrigation solutions are used compared to NaOCl alone. This is likely because effective smear layer removal allows closer contact between dentin surface and sealer, improving sealer penetration.[20] .

AH-plus bond strength is favorable as covalent link can be seen in between epoxide rings in AH-plus and amino groups in dentine collagen. The application of (NaOCl) and (EDTA) facilitates increased exposure of collagen fibrils, thereby improving the infiltration of resin sealer tags into the dentinal substrate.[21]

POBS of AH plus lowered when using NaOCl alone, this decrease in bond strength can be attributed to absence of EDTA's demineralizing effect, which is essential for exposing dentinal collagen matrix. while NaOCl is effective in dissolving organic tissue and disinfecting root canal, it does not demineralize dentin. As a result, collagen network remains partially obscured by mineralized debris, limiting availability of amino groups for covalent bonding with the epoxide rings in AH Plus . [22]

Based on the analysis of failure patterns, mostly cohesive pattern was found. This came in agreement with **Germain Sfeir** et al.[23] This confirms the better adhesive performance of this sealer because of its bond between amino group in dentine and epoxy resin, resulting in strong sealer-dentin adhesion,

while the bond between sealer and gutta-percha is weaker as gutta percha is chemically inactive and doesn't form covalent or ionic bonds with most sealers,[24] and it has a low surface energy, meaning it doesn't allow sealers to wet or spread well on its surface,[25] poor wetting leads to weak adhesion reducing the true meaning of the adhesion.[26]

This study is limited as push-out test was conducted in vitro, which does not accurately replicate real clinical conditions.

CONCLUSION

Reapplying NaOCl again after NaOCl and EDTA negatively affects the AH-plus POBS, while using NaOCl followed by EDTA only as a final protocol enhances the sealer POBS.

Finally, more researches are needed to determine whether using a chelating agent is essential or not.

REFERENCES

1. Vemuri S, Rachamadugu ES, Naveena T, Garlapati R, Bolla N, Basam RCJJoCD, Endodontics. Comparative evaluation of the effect of three different obturation techniques on push-out bond strength of AH Plus Bioceramic and EndoCeramic sealers: An in vitro study. 2024;27(10):1026-31.
2. Razmi H, Bolhari B, Dashti NK, Fazlyab M. The effect of canal dryness on bond strength of bioceramic and epoxy-resin sealers after irrigation with sodium hypochlorite or chlorhexidine. Iranian endodontic journal. 2016;11(2):129.
3. Topçuoğlu HS, Tuncay Ö, Demirbuga S, Dinçer AN, Arslan HJJoe. The effect of different final irrigant activation techniques on the bond strength of an epoxy resin–based endodontic sealer: a preliminary study. 2014;40(6):862-6.
4. Violich D, Chandler N. The smear layer in endodontics–a review. International endodontic journal. 2010;43(1):2-15.
5. Zehnder M. Root canal irrigants. Journal of endodontics. 2006;32(5):389-98.
6. Beltz RE, Torabinejad M, Pouresmail M. Quantitative analysis of the solubilizing action of MTAD, sodium hypochlorite, and EDTA on bovine pulp and dentin. Journal of endodontics. 2003;29(5):334-7.
7. Saunders W, Saunders E. The effect of smear layer upon the coronal leakage of gutta-percha root fillings and a glass ionomer sealer. International Endodontic Journal. 1992;25(5):245-9.
8. Boutsioukis C, Arias-Moliz MT. Present status and future directions–irrigants and irrigation methods. International Endodontic Journal. 2022;55:588-612.
9. Haapasalo M, Qian W, Shen Y. Irrigation: beyond the smear layer. Endodontic Topics. 2012;27(1):35-53.
10. de Assis DF, do Prado M, Simão RA. Evaluation of the interaction between endodontic sealers and dentin treated with different irrigant solutions. Journal of endodontics. 2011;37(11):1550-2.
11. Tartari T, Wichnieski C, Silva RM, Letra A, Duarte MAH, Bramante CM. Final irrigation protocols can be used to promote stable long-term bond strength of AH Plus to dentin. Journal of Applied Oral Science. 2023;31:e20230005.
12. Kikly A, Jaâfoura S, Kammoun D, Sahtout S. Sealing ability of endodontic cements: An in vitro study. International Journal of Dentistry. 2020;2020(1):5862598.
13. Pasdar N, Seraj B, Fatemi M, Taravati S. Push-out bond strength of different intracanal posts in the anterior primary teeth according to root canal filling materials. Dental research journal. 2017;14(5):336.
14. Ramírez-Bommer C, Gulabivala K, Ng YL, Young A. Estimated depth of apatite and collagen degradation in human dentine by sequential exposure to sodium hypochlorite and EDTA: a quantitative FTIR study. International Endodontic Journal. 2018;51(4):469-78.
15. Donnermeyer D, Vahdat-Pajouh N, Schäfer E, Dammaschke TJO. Influence of the final irrigation solution on the push-out bond strength of calcium silicate-based, epoxy resin-based and silicone-based endodontic sealers. 2019;107:231-6.
16. Farag H, Etman W, Alhadainy H, Darrag A. Effect of different irrigating protocols on push out bond strength of Resilon/Epiphany obturation system. Tanta Dental Journal. 2015;12(4):241-8.
17. Ravikumar J, Bhavana V, Thatimatla C, Gajjarapu S, Reddy SGK, Reddy BR. The effect of four different irrigating solutions on the shear bond strength of endodontic sealer to dentin–An In-vitro study. Journal of international oral health: JIOH. 2014;6(1):85.

18. Alkhudhairy FI, Yaman P, Dennison J, McDonald N, Herrero A, Bin-Shuwaish MS. The effects of different irrigation solutions on the bond strength of cemented fiber posts. Clinical, cosmetic and investigational dentistry. 2018:221-30.

19. Mohan RP, Pai ARV. The comparison between two irrigation regimens on the dentine wettability for an epoxy resin based sealer by measuring its contact angle formed to the irrigated dentine. Journal of Conservative Dentistry and Endodontics. 2015;18(4):275-8.

20. Tummala M, Chandrasekhar V, Rashmi AS, Kundabala M, Ballal V. Assessment of the wetting behavior of three different root canal sealers on root canal dentin. Journal of conservative dentistry: JCD. 2012;15(2):109.

21. Carvalho N, Prado M, Senna P, Neves A, Souza E, Fidel S, et al. Do smear-layer removal agents affect the push-out bond strength of calcium silicate-based endodontic sealers? International endodontic journal. 2017;50(6):612-9.

22. Vilanova W, Carvalho-Junior J, Alfredo E, Sousa-Neto MDd, Silva-Sousa YTC. Effect of intracanal irrigants on the bond strength of epoxy resin-based and methacrylate resin-based sealers to root canal walls. International endodontic journal. 2012;45(1):42-8.

23. Sfeir G, Bukiet F, Hage W, El Hachem R, Zogheib C. Impact of final irrigation protocol on the push-out bond strength of two types of endodontic sealers. Materials. 2023;16(5):1761.

24. Khanvilkar U, Dundappa J, Chaubey N, Jha A, Paliwal A, Kumar R. Comparison of Apical Sealing Capacity of ActiV GP/Glass Ionomer Sealer Versus Resilon/RealSeal and Gutta Percha/AH plus Sealers. Cureus. 2023;15(12).

25. Nikhil V, Jaiswal S, Bajpai G. In vitro evaluation of the contact angle formed between AH Plus, Hybrid Root Seal and mineral trioxide aggregate Plus sealer with dentin and gutta-percha. Journal of Conservative Dentistry and Endodontics. 2018;21(2):180-3.

26. Tay FR, Pashley DH. Monoblocks in root canals: a hypothetical or a tangible goal. Journal of endodontics. 2007;33(4):391-8.