ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume – 9, Issue – 1, January – 2026, Page No. : 38 – 46

Effectiveness of Different Irrigation Systems and Irrigants on Smear Layer Removal Using SEM: An in Vitro Study

[1]Dr. Rakesh. G, MDS, Associate Professor, Department of Conservative Dentistry & Endodontics, CKS Theja Institute of Dental Sciences & Research, Tirupati, Andhra Pradesh, India

[2]Dr. P Karunakar, Professor, HOD, Department of Conservative Dentistry & Endodontics, Panineeya Dental College, Hyderabad, Telangana, India

[3]Dr. Raji Viola Solomon, Department of Conservative Dentistry & Endodontics, Panineeya Dental College, Hyderabad, Telangana, India

[4]Dr. Vamsee Krishna. N, MDS, Professor, Department of Conservative Dentistry & Endodontics, CKS Theja Institute of Dental Sciences & Research, Tirupati, Andhra Pradesh, India

[5]Dr. Bharathisuma, Associate Professor, Department of Conservative Dentistry & Endodontics, CKS Theja Institute of Dental Sciences & Research, Tirupati, Andhra Pradesh, India

Corresponding Author: Dr. Rakesh. G, MDS, Associate Professor, Department of Conservative Dentistry & Endodontics, CKS Theja Institute of Dental Sciences & Research, Tirupati, Andhra Pradesh, India

Citation of this Article: Dr. Rakesh. G, Dr. P Karunakar, Dr. Raji Viola Solomon, Dr. Vamsee Krishna. N, Dr. Bharathisuma, "Effectiveness of Different Irrigation Systems and Irrigants on Smear Layer Removal Using SEM: An in Vitro Study", IJDSIR- January – 2026, Volume – 9, Issue – 1, P. No. 38 – 46.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Objectives: The purpose of this study is to evaluate the effectiveness of the different irrigation systems and irrigants on the removal of the smear layer after instrumentation.

Methods: Ninety freshly extracted, single-rooted mandibular premolars prepared using NI-TI rotary files and subjected to different irrigation regimens Group 1: Endo Vac with NaOCl. Group 2: NaoCl/EDTA. Group 3: NaoCl/Citric acid Group. 4: Endo Activator with NaOCl Group 5: Endo Activator with NaOCl/EDTA Group 6: Endo Activator with NaOCl/Citric acid Group 7: 27 Gauge closed-end needle with NaOCl Group 8: 27 Gauge closed-end needle with NaOCl/EDTA Group 9: 27 Gauge closed-end needle with NaOCl/Citric acid. The roots were split longitudinally, and then SEM images were taken to evaluate the amount of residual SR.

Results: There is no statistically significant difference present between the cleaning efficiency of Endovac and Endoactivator in the coronal and middle location but statistically significant difference present in the apical region ($p<0.05$). There is a statistically significant

difference present in various irrigant solutions. ($p<0.05$) NaOCl+EDTA, and NaOCl+citric acid irrigation sequence groups showed better smear layer removal when compared to NaOCl alone.

Conclusion: None of the irrigation systems or solutions eradicate the smear layer. Endovac performed better in the apical third when compared to Endoactivator and needle irrigation regarding the smear layer removal. Among the irrigation solutions, NaOCl alone has the least smear layer removal efficacy when compared to and NaOCl+Citric acid, NaOCl+EDTA irrigation sequence groups.

Keywords: Conventional Needle Irrigation, Endovac, Endoactivator, Scanning Electron Microscopy, Smear Layer.

Introduction

An endodontic treatment aims to achieve complete disinfection of the root canal system and to prevent reinfection by proper instrumentation, irrigation, and three-dimensional obturation. Endodontic instrumentation techniques produce an amorphous layer known as the smear layer, on root canal walls.[1] It consists of organic and inorganic particles that range in size from 0.5 μm to 15 μm, which includes residues of dentine, pulp tissue, and odontoblastic processes and in infected teeth, Micro-organisms; and their by-products.[1] If the smear layer is present during biomechanical preparation, it may affect the success of the root canal treatment. Microorganisms remaining in the smear layer after the instrumentation of an infected root canal space can survive and reinfect the root canals.[2] The smear layer has also shown to hinder the penetration of intracanal disinfectants and sealers [3,4,5] into dentinal tubules. It has the potential of compromising the seal of the root filling.[6,7] An intact smear layer may prevent initial bacterial penetration of dentinal tubules. Degradation of the smear layer after treatment may contribute to leakage and reinfection of the root canal space.[8] Removal of the smear layer reduced the leakage of bacteria through the root canal system after a root filling.[9] Irrigation is an essential part of root canal debridement along with the instrumentation. It allows for cleaning beyond what might be achieved by root canal instrumentation alone. [10] it helps by killing microorganisms, flushing debris, lubricating the root canal system and, also by removing the smear layer from the root canal system.[11] Unfortunately, no irrigating solution is capable of removing the organic and inorganic elements of the smear layer. Sodium hypochlorite [11] is not able to completely dissolve the mineral components of dentin debris. The final irrigation sequence with [EDTA] and sodium hypochlorite [NaOCl] will remove the inorganic as well as organic ingredients of the smear layer.[12] Citric acid may also be used for smear layer removal as it is a chelating agent like EDTA. Concentrations ranging from 1% to 50% have been investigated.[12] Wayman et al. showed that the use of 10% citric acid and 2.5% NaOCl is a beneficial approach for smear layer removal.[13] Hulsmann et al. stated that smear layer removal is less predictable in the apical region as compared with the coronal and middle third of the root.[12] smaller apical canal dimensions hindering the penetration of irrigants and resulting in limited contact between the canal wall and the irrigants. A vapor lock that results in trapped air in the apical third of the root canals might hinder the exchange of irrigants and affect their debridement efficacy.[14] The ability of irrigants to reach the apical portion of the canal depends on the size of mechanical instrumentation, canal anatomy, and delivery system.[15] For optimal effectiveness, irrigants must have direct contact with the entire root canal wall.[16] Therefore, different manual and mechanical agitation techniques

have been proposed to deliver the irrigants into the apical area of the root canal. The traditional needle irrigation technique delivers solutions no more than 0.1 to 1mm beyond the needle tip.[17] Needle irrigation is insufficient for complete cleaning of the complex anatomy of the root canal system, which consists of lateral canals, isthmuses, fins, and accessory canals. The Endoactivator (Dentsply Tulsa Dental, Tulsa, OK, USA) is a sonically driven irrigant activation system designed to produce vigorous intra-canal fluid agitation, that increase the efficacy of irrigation better than a traditional needle.[19] Endovac (Discus Dental, Culver City, CA), a negative pressure irrigation system, is safe and effective, especially within the apical zone of the root canal. The purpose of this study is to evaluate the effectiveness of the EndoVac, Endoactivator, and conventional needle irrigation by using NaOCl, Citric acid, and EDTA on smear layer removal.

Materials and Methods

Ninety extracted single-rooted mandibular premolars, without internal or external resorption, caries, and cracks, are selected for this study. External surfaces of the teeth were debrided with a hand scaler. All teeth were stored in physiological saline at room temperature until use. All the selected teeth were decoronated at cement- enamel junction and sectioned to 13mm in length. The working length was determined by deducting 1 mm from the length recorded when a10 K file (Mani, Tochigi, Japan) placed through the apical foramen. All the canals were instrumented with rotary nickel-titanium pro-taper files (Dentsply Maillerfer, Switzerland) S_x to F_3 using a crown down technique and irrigated. Irrigation with 2 mL of 5% NaOCl between every file change, using a plastic syringe with a 27 gauge closed-end needle (Kerrhawe, Bioggio, Switzerland). The samples were randomly divided into nine groups based on different irrigation systems and irrigants used for smear layer removal (n=10) Group 1: The canals were irrigated by using the EndoVac system (Discus Dental, Culver City, CA) in which micro-cycles were used. The micro-cannula was placed at the WL and was repositioned regularly 2 mm up and down in the canal. This constant active irrigation was used during the first cycle, with 4 mL of 5% NaOCl. The active irrigation was followed by a second passive cycle, with 4 mL of 5% NaOCl. Group 2: The same protocol for irrigation was followed as for group 1, but this group underwent a further active cycle micro-irrigation with EDTA. The first cycle used 4 mL of 5% NaOCl, the second cycle 4 mL of 17% EDTA, and the third cycle 4 mL of 5% NaOCl. Group 3: The same protocol for irrigation was followed as for Group 1, but this group underwent a further active cycle micro-irrigation with citric acid. The first cycle used 4 mL of 5% NaOCl, the second cycle 4 mL of 10% citric acid, and the third cycle 4 mL of 5% NaOCl. Group 4: 4 mL of 5% NaOCl solution was infused into the canal by using a closed-end needle, and then the solution sonically activated by using the appropriate bits (30.04) of the EndoActivator system(Dentsply Tulsa Dental, Tulsa, OK, USA) The tip was left free. It could reach up to 2 mm from working length. The EndoActivator device was used with "up and down" short vertical movements with an oscillation of 2-3 mm for 30 seconds. Finally, a rinse of 4 mL of 5% NaOCl was applied with a closed-end needle. Group 5: 4 mL of 5% NaOCl and then 4 mL of 15% EDTA were each activated for by using the polymer tip (30.04) of the EndoActivator system. The tip was left free and could reach up to 2 mm from working length. The EndoActivator device was used with ‘‘up and down’’ short vertical movements with an oscillation of 2-3 mm for 30 seconds. Finally, a rinse of 4 mL of 5% NaOCl was applied with a closed-end needle. Group 6: 4 mL of

5% NaOCl and then 4 mL 10% citric acid were each activated by using polymer tip (30.04) of the EndoActivator system. The tip was left free and could reach up to 2 mm from working length. The EndoActivator device was used with ‘‘up and down’’ short vertical movements with an oscillation of 2-3 mm for 30 seconds. Finally, a rinse of 4 mL of 5% NaOCl was applied with a closed-end needle. Group 7: Each canal was irrigated with 4 mL of 5% NaOCl by using a closed-end needle that was inserted to the deepest apical point possible without binding, and then this procedure was repeated. Group 8: The final irrigation sequence was 4 mL of 5% NaOCl, 4 mL of 17% EDTA, and 4 mL of 5% NaOCl, which were applied using a closed-end needle that was inserted to the deepest apical point possible without binding. Group 9: The final irrigation sequence was 4 mL of 5% NaOCl, 4 mL of 10% citric acid, and 4 mL of 5% NaOCl, which were applied using a closed-end needle that was inserted to the deepest apical point possible without binding.

Specimen Preparation for Scanning Electron Microscope Imaging

All the teeth were grooved vertically on the buccal and lingual surface of the root, using a water-cooled diamond bur. The roots were then split with a surgical chisel, which resulted in a mesial and distal half for each canal. The canal halves were sputter-coated and viewed with an SEM.(LEO Evo 40X VP; Carl Zeiss AG, Oberkochen, Germany) Digital images at ×2000 were taken at the center of coronal, middle, and apical thirds of each root canal for evaluation of the smear layer removal. The SEM images were scored by using the criteria reported by Torabinejad *et al.* 1. No smear layer: absence of any smear layer on the root surface, with open and clean dentinal tubules. 2. Moderate smear layer: absence of the smear layer on the surface, with dentinal tubules laden with the smear layer. 3. A large amount of the smear layer: complete coverage of the root canal walls with the smear layer, with the dentinal tubules laden with debris. Data were analyzed using SPSS version 23

Results

Normality distribution testing by Shapiro-Wilk test the test of normality distribution showed non-normal distribution so, non-parametric tests like Kruskal Wallis and Mann Whitney U test were done. The level of statistical significance was set to $p < 0.05$. There were statistically significant differences ($P < 0.05$) in the results for removal of the Smear Layer(SR) among the irrigant activation devices (table 2). Endovac has superior cleaning efficacy at the apical third when compared to Endoactivator and needle irrigation. There were statistically significant differences ($P < 0.05$) in the results for removal of the SR among the irrigants (table 3), EDTA + Sodium hypochlorite irrigation sequence has the best cleaning efficacy at apical, middle third of root canal followed by Sodium hypochlorite + Citric acid irrigation. Sodium hypochlorite alone has the least cleaning efficacy at all levels of the root canal. . The results for each of the groups in the study are shown in table 3 in the form of the percentage distribution of the SR. None of the irrigation system or solution eliminates smear layer.

Table 1: Frequency distribution according to Scores in various groups

Group	Location	1.0		2.0		3.0	
		N	%	N	%	N	%
1.0	Coronal	0	0.0	5	50.0	5	50.0
	Middle	0.0	0.0	3	30.0	7	70.0

	Apical	0	0.0	0	0	10	100.0
2.0	Coronal	8	80.0	2	20.0	0	0
	Middle	0	0	8	80.0	2	20.0
	Apical	0	0.0	4	40.0	6	60.0
3.0	Coronal	8	80.0	2	20.0	0	0.0
	Middle	0	0.0	8	80.0	2	20.0
	Apical	0	0.0	1	10.0	9	90.0
4.0	Coronal	0	0.0	5	50.0	5	50.0
	Middle	0	0.0	3	30.0	7	70.0
	Apical	0	0.0	0	0.0	10	100.0
5.0	Coronal	9	90.0	1	10.0	0	0.0
	Middle	0	0.0	9	90.0	1	10.0
	Apical	0	0.0	0	0.0	10	100.0
6.0	Coronal	8	80.0	2	20.0	0	0.0
	Middle	0	0.0	8	80.0	2	20.0
	Apical	6	60.0	0	0.0	10	100.0
7.0	Coronal	1	10.0	3	30.0	6	60.0
	Middle	0	0.0	3	30.0	7	70.0
	Apical	0	0.0	0	0.0	10	100.0
8.0	Coronal	2	20.0	8	80.0	0	0.0
	Middle	0	0.0	4	40.0	6	60.0
	Apical	0	0.0	0	0.0	10	100.0
9.0	Coronal	2	20.0	7	70.0	1	10.0
	Middle	0	0.0	3	30.0	7	70.0
	Apical	0	0.0	0	0.0	10	100.0

Table 2: Inter equipment comparison of the efficacy

Group	Mean Rank	Mean Rank	Mean Rank
Endovac	38.50	41.50	38.45
Endoactivator	49.00	44.50	46.07
Side vented needle	49.00	50.50	51.98
H value	15.012	8.063	8.471
p-value	0.001*	0.018*	0.014*

**-Statistically highly significant (p<0.001)

Table 3: Inter irrigation solution comparison of cleaning efficiency

Irrigant	Coronal	Middle	Apical
	Mean Rank	Mean Rank	Mean Rank
Sodium hypochlorite	51.50	56.50	68.65
EDTA + Sodium hypochlorite	32.88	38.50	42.70
Sodium hypochlorite + Citric acid	34.97	41.50	42.30
P value	0.033*	0.004*	<0.001*

*-significant ($p<0.05$),

Discussion

In the present study, the effectiveness of the EndoVac system, and the Endovac, needle irrigation and irrigants NaOCl, EDTA & Citric acid about smear layer removal is analyzed. The SR is produced on root canal walls during the process of root canal preparation. Although there has been no consensus on the subject, it is suggested that this layer should be removed to provide better disinfection of canal and root canal sealer adaptation. [1,13] Removal of the SR can be accomplished by the effective irrigation techniques with the use of irrigation solutions that dissolve both organic and inorganic components of the layer.[14] The ability to clean the root canal efficiently depends on both the method and the irrigation solutions used. The various irrigating solutions like NaOCl, EDTA, and Citric acid are used in the study with the supporting results of Teixeira et al. [20]. Study which showed that the alternate use of EDTA and NaOCl is an efficient method for removal of the organic and inorganic parts of smear layer. Citric acid may also be used for the smear layer removal that is supported by the study of Di Lenarda et al., Which showed no or a negligible difference in smear layer removal obtained by citric acid and EDTA.[21] Final irrigation groups with 17% EDTA followed by 5% NaOCl and 10 % citric acid followed by 5% NaOCl showed better results than irrigation with 5%NaOCl alone, which is following the previous studies.[22,23] Endovac provided the best results in the apical third when compared to Endoactivator and needle irrigation. Concerning smear layer removal, this is following the other studies. [24,25] EndoActivator works on the principle of hydrodynamic agitation of irrigant, but acoustic micro streaming can only occur in a liquid phase. Therefore, once a sonic activated tip leaves the irrigant and enters the apical vapor lock, acoustic micro streaming and cavitation become physically impossible.[24] For the EndoVac group, the effectiveness of the EndoVac system in producing clean canals might be attributed to its apical negative pressure approach.[26] The apical negative pressure pulls the irrigant down the canal walls towards the apex, creating a rapid turbulent current force towards the terminus of the micro cannula. The orifices of the micro cannula evacuate debris from the closed end of the canal systems. This mechanism helps to overcome the vapor lock, thus enabling effective irrigation.[26] contradictory results to the study have Endoactivator performed the best cleansing action in all root canal thirds according to Raffaella Castagnola et al.[27] The cleansing action of Endovac is similar to Endoactivator at the coronal and middle third of the root canals, which is following the studies [24,25] contradictory to this study is Endoactivator performed the best cleansing action in all root canal third.[27] The EndoVac system removed more smear layer in the apical, middle, and coronal third than conventional irrigation ($p < 0.05$). Needle irrigation is following the author[27] because the flushing action of syringe irrigation is relatively weak and is dependent not

only on the anatomy of the root canal but also on the depth of placement and the diameter of the needle. It has been shown that irrigants can only progress 1 mm beyond the tip of the needle[28] present study results are in partial agreement with Abarajithan et al.[29] They found significant differences [$p < 0.05$] in the reduction of the smear layer only in the apical third of teeth rinsed with the EndoVac system compared with conventional irrigation. However, no significant difference was reported in the coronal and middle thirds. Concerning the smear layer removal the performance of Endoactivator is better than needle irrigation in the coronal and middle third but showed similar results at apical third this is in partial agreement with the results of coinciding with the results of uroj torres. [30]

Conclusion

1. None of the irrigation system or solution eradicates smear layer.
2. Endovac performed better in the apical third when compared to Endoactivator and needle irrigation regarding the smear layer removal.
3. Endoactivator showed comparable performance to Endovac in the coronal and middle thirds.
4. Needle irrigation method has the least overall smear layer removal efficacy.
5. Among the irrigation solutions, NaOCl alone has the least smear layer removal efficacy when compared to and NaOCl+Citric acid, NaOCl+EDTA irrigation sequence groups.
6. NaOCl+ Citric acid irrigation sequence comparable efficacy of smear layer removal to the NaOCl+EDTA irrigation sequence.

References

1. Mc Comb D, Smith DC. A preliminary scanning electron microscopic study of root canals after endodontic procedures. J Endod. 1975;1(7):238-42.
2. Yamada RS, Armas A, Goldman M, Lin PS. A scanning electron microscopic comparison of a high volume final flush with several irrigating solutions Part 3. J Endod. 1983;9(4):137-42.
3. Torabinejad M, Handysides R, Khademi AA, Bakland LK. Clinical implications of the smear layer in endodontics: a review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002;94(6):658-66.
4. Orstavik D, Haapasalo M. Disinfection by endodontic irrigants and dressings of experimentally infected dentinal tubules. Endod Dent Traumatol. 1990;6(4)142-9.
5. White RR, Goldman M, Lin PS. The influence of the smeared layer upon dentinal tubule penetration by plastic filling materials. J Endod. 1984;10(12):558-62.
6. Economides N, Liolios E, Kolokuris I, Beltes P. Long-term evaluation of the influence of smear layer removal on the sealing ability of different sealers. J Endod. 1999;25(2):123-5.
7. Kennedy WA, Walker WA 3rd, Gough RW. Smear layer removal effects on apical leakage. J Endod. 1986;12(1):21-7.
8. Drake DR, Wiemann AH, Rivera EM, Walton RE. Bacterial retention in canal walls in vitro: effect of smear layer. J Endod. 1994;20(2):78-82.
9. Clark-Holke D, Drake D, Walton R, Rivera E, Guthmiller JM. Bacterial penetration through canals of endodontically treated teeth in the presence or absence of the smear layer. J Dent. 2003;31(4):275-81.
10. Gulabivala K, Patel B, Evans G, Ng, Y-L. Effects of mechanical and chemical procedures on root canal surfaces. Endodontic Topics. 2005;10(1):103-22
11. Zehnder M. Root canal irrigants. J Endod. 2006;32(5):389-398

12. Hulsmann M, Heckendorff M, Lennon A. Chelating agents in root canal treatment: mode of action and indications for their use. Int Endod J. 2003;36(12):810-30.
13. Wayman BE, Kopp WM, Pinero GJ, Lazzari EP. Citric and lactic acids as root canal irrigants in vitro. J Endod 1979;5(9):258-65.
14. Tay FR, Gu LS, Schoeffel GJ, et al. Effect of vapor lock on root canal debridement by using a side-vented needle for positive-pressure irrigant delivery. J Endod. 2010;36(4):745–750.
15. Slowey RR. Root canal anatomy. Road map to successful endodontics. Dent Clin N Am. 1979;23(4):555-73
16. Violich DR, Chandler NP. The smear layer in endodontics: A review. Int Endod J. 2010;43(1):2-15.
17. Munoz HR, Camacho-Cuandra K. In vivo efficacy of three different endodontic irrigation systems for irrigant delivery to working length of mesial canals of mandibular molars. J Endod. 2012;38(4):445-8
18. Gu LS, Kim JR, Ling J, et al. Review of contemporary irrigant agitation techniques and devices. J Endod. 2009;35(6):791-804
19. Jensen SA, Walker TL, Hutter JW, Nicoll BK. Comparison of the cleaning efficacy of passive sonic activation and passive ultrasonic activation after hand instrumentation in molar root canals. J Endod. 1999;25(11):735-8.
20. Teixeira CS, Felippe MC, Felippe WT. The effect of application time of EDTA and NaOCl on intracanal smear layer removal: An SEM analysis. Int Endod J. 2005;38(5):285-90.
21. Di Lenarda R, Cadenaro M, Sbaizero O. Effectiveness of 1 mol L±1 citric acid and 15% EDTA irrigation on smear layer removal. Int Endod J. 2000;33(1):46-52.
22. Sedigheh Khedmat, Noushin Shokouhinejad. Comparison of the Efficacy of Three Chelating Agents in Smear Layer Removal. J Endod. 2008;34(5):599-602.
23. Ahir B, Parekh V, Katyayan MK, Katyayan PA. Smear layer removal efficacy of different irrigating solutions: A comparative scanning electron microscope evaluation. Indian J Dent Res. 2014;25(5):617-622.
24. Sanghamitra Suman, Promila Verma, Aseem Prakash-Tikku, Rhythm Bains, Vijay Kumar-Shakya. A Comparative Evaluation of Smear Layer Removal Using Apical Negative Pressure (EndoVac), Sonic Irrigation (EndoActivator), and Er: YAG laser: An In Vitro SEM Study. J Clin Exp Dent. 2017;9(8):e981-7.
25. Priyatam Karade, Rutuja Chopade, Suvarna Patil, Upendra Hoshing, Madhukar Rao, Neha Rane, et al. Efficiency of Different Endodontic Irrigation and Activation Systems in Removal of the Smear Layer: A Scanning Electron microscopy study. Iranian Endodontic Journal. 2017;12(4):414-41832.
26. Nielsen BA, Baumgartner JC. Comparison of the EndoVac system to needle irrigation of root canals. J Endod. 2007;33(5):611-5
27. Raffaella Castagnola, Carlo Lajolo, Irene Minciacchi, Gilda Cretella, Roberta Foti, Luca Marigo, et al. Efficacy of three different irrigation techniques in the removal of smear layer and organic debris from root canal wall: A scanning electron microscopy study. Giornale Italiano di Endodonzia. 2014;28(2):79-86
28. Plotino G, Pameijer CH, Grande NM, Somma F. Ultrasonics in endodontics: A review of the literature. J Endod. 2007;33(2):81-95.
29. Abarajithan M, Dham S, Velmurugan N, Valerian-Albuquerque D, Ballal S, Senthilkumar H.

Comparison of EndoVac irrigation system with conventional irrigation for the removal of intracanal smear layer: an in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;112(3):407-11.

30. Uroz-Torres D, Gonza`lez-Rodrı`quez MPR, Ferrer-Luque CM. Effectiveness of the EndoActivator system in removing the smear layer after root canal instrumentation. J Endod. 2010;36(2):308-11.