AL-AZHAR
Dental Journal
For Girls

The Official Publication
of The Faculty of Dental
Medicine For Girls,
Al-Azhar University
Cairo, Egypt.

Print ISSN 2537-0308 • Online ISSN 2537-0316

ADJ-for Girls, Vol. 9, No. 1, January (2022) — PP. 73:81

Efficacy of Apple Vinegar as Root Canal Irrigant in Removing Smear Layer in Curved Canals Using EndoVac Irrigation System

Nada F. Mohamed[1*], Mohsen Nour El Dein[2], Heba Abdelkafy[3]

Codex : 09/22.01

azhardentj@azhar.edu.eg

http://adjg.journals.ekb.eg

DOI: 10.21608/adjg.2021.73464.1356

Restorative Dentistry
(Removable Prosthodontics, Fixed Prosthodontics, Endodontics, Dental Biomaterials, Operative Dentistry)

ABSTRACT

Purpose: To evaluate the efficacy of Apple Vinegar irrigating solution using EndoVac system in removing the smear layer from root canals. **Materials and Methods**: Fifty extracted permanent mandibular first molar teeth with curved mesiobuccal root canals of 5°-20° curvature range were prepared using ProTaper Gold rotary files. Then, they were divided into three groups, two equal main groups with 20 teeth for each (Group I & Group II) plus one control group (10 teeth), based on the final irrigating solution used. Group I; was rinsed with 17% EDTA, Group II; with Apple vinegar, and the Control group with sterile saline. All groups were further subdivided into two equal subgroups (A&B) according to irrigating device where Subgroup A: conventional irrigation, and Subgroup B: EndoVac irrigation system. All teeth were prepared for smear layer examination using a scanning electron microscope. **Results**: There was no statistically significant difference between Apple Vinegar and 17% EDTA groups at all root canal levels with either conventional or EndoVac irrigation. However, at the apical level, EndoVac irrigation system was superior to conventional technique when apple vinegar was the irrigant used with a statistically significant difference (p=0.029). **Conclusion:** Apple vinegar is as effective as 17% EDTA in smear layer removal from the root canal when used as a final rinse. EndoVac irrigation can help in smear layer removal from intraradicular dentin, especially at the apical root level. **Recommendations**: Further studies can be done comparing EndoVac system with more recent irrigating devices using apple vinegar as a final rinse.

KEYWORDS

Apple vinegar,
EndoVac, Smear layer.

* Paper extracted from Master thesis titled 'Efficacy of Apple Vinegar as Root Canal Irrigant in Removing Smear Layer in Curved Canals Using EndoVac Irrigation System'.

1. Dentist at Ministry of Health, Egypt.
2. Professor of Endodontic department Faculty of Dental Medicine for Girls Al-Azhar University.
3. Lecturer of Endodontic department Faculty of Dental Medicine for Girls Al-Azhar University.

* Corresponding author email: nadafikry2015@gmail.com

INTRODUCTION

Endodontic root canal treatment is based on thorough cleaning and shaping of the root canal system. This process requires preparation of the root canal system which leads to formation of a granular amorphous layer covering the dentin known as the smear layer [1]. The formed smear layer will block the dentinal tubules openings and cover the root canal walls which will make it liable for bacterial infection. Moreover, the smear layer may affect the introduction of substances that are used for root canal treatment as irrigants and intracanal medicaments preventing them from penetrating deeply into the dentinal tubules. Additionally, it can prevent obturating materials from making a good seal with the canal wall [2]. Thus, smear layer removal is a necessary process in endodontic root canal treatment[3].

A wide variety of irrigation solutions are being used during root canal treatment, commonly Sodium Hypochlorite (NaOCl) which has tissue dissolving ability, antimicrobial action, and low cost [4,5]. In addition to EDTA which has the ability to remove smear layer from the root canal. Using NaOCl alternating with 17% EDTA irrigation can help in root canal disinfection and smear layer removal [6,7]. On the other hand, EDTA solution has some drawbacks as it can harm the periapical tissue and cause dentinal erosions [8,9].

The disadvantages of such solutions urge researchers to find a better substance that is biocompatible and has less tissue damage effect. For example, apple cider vinegar, which is an organic solution with antimicrobial properties, can aid in the removal of the smear layer and decreases dentinal microhardness [10]. Apple vinegar showed comparable results to EDTA in many studies when used as a secondary solution during the process of root canal preparation [11,12].

The root canal is considered as a closed-end channel and it is believed that its apical part can form a vapor lock effect during irrigation where the gas is being held in place with subsequent affection of irrigation quality [13-15]. Hence came the importance of creating negative pressure to ensure adequate disinfection and cleaning of the apical root part. One of the new devices, that can achieve the required negative pressure, is the EndoVac irrigation system. This system induces negative pressure at the apical part of the root canal whereby the irrigation solution is directed down the canal and subsequently back up via a small special cannula [8,16-18]. EndoVac system is effective in removing debris and necrotic pulp tissues accumulated during root canal instrumentation with less risk of periapical extrusion than the conventional irrigation method. Thus, the purpose of this study was to evaluate the ability of EndoVac system using apple vinegar in removing the smear layer in curved canals.

MATERIAL AND METHODS

Teeth selection and root canal preparation:

In the present study, anonymous extracted teeth were collected. Fifty permanent mandibular first molars with curved root canals were selected. Teeth extraction was performed because of the presence of periodontal disease. The selected teeth have mature crack-free apices, and their mesial roots have two separate canals and apical foramina for each with an average root length of 15-16 mm and 5°-20° curvature range. Research ethics committee approval was obtained from Faculty of Dental Medicine for girls –Al Azhar University (code: REC-EN-21-03).

At first, a conventional access cavity was done then mesiobuccal canal patency was checked using a size 10 K-file extended down to the canal until it was just detected at the apex. This was followed by estimating the working length by deducting 1 mm from the whole length. Schneider's technique was used to measure the mesiobuccal root canal curvature degree [19,20].

Then root canal instrumentation was done using ProTaper Gold rotary Ni-Ti files (Dentsply Maillefer, Ballaigues, Switzerland) Sx file was used initially reaching to file F4 as the master apical file (MAF), as instructed by the manufacturer, to obtain the required space for the microcannula of EndoVac

irrigating system and subsequently achieving the full working length and ensuring a better cleansing outcome [21,22].

During root canal preparation, particularly after each instrument use, 2ml/1min of 2.6% sodium hypochlorite (NaOCl) solution (Alex. Detergents and Chemical Co., Egypt) that is freshly prepared to dissolve any remaining organic tissue. A 27-gauge Navi-Tip flexible irrigation needle (DiaDent Group Int., Korea) was introduced deep into the root canal without binding to inject NaOCl irrigating solution. A total amount of 14 ml of irrigation was used.

Samples grouping:

The 50 tested samples were divided into two equal main groups with 20 teeth for each (Group I & Group II) plus one control group (10 teeth) according to the final irrigating solution used. Group I: irrigated with 17% EDTA (Amrit Chem & Min. Ag, Mohali, India), Group II: irrigated with Apple vinegar (commercial), and Control group: irrigated with sterile saline. All groups were further subdivided into two equal subgroups (subgroup A&B) according to the used irrigating device. Subgroup A (Conventional irrigation): irrigated with 5ml/3 min of the assigned final rinse using a 27gauge side vent irrigating needle, where the needle was inserted 2 mm shorter than the working length without binding followed by canal irrigation with 5 ml distilled water and drying with paper points[23-25]. Subgroup B (EndoVac irrigation): the final rinse (5ml/70 sec) was done using EndoVac irrigating system (Discus DentalR, Smart Endodontics, Culver City (CA)) guided by the manufacturer's recommendations [26].

Once the irrigant was introduced by Master Delivery tip (MDT) which is positioned just inside the access opening, its flow was directed against the axial wall in order to create a constant flow of irrigation solution and to avoid its overflow. The macrocanula was used along with the MDT to pressure wash the coronal two-thirds of the root canal. During the procedure, the macrocannula was directed up and down in the canal for 30 seconds. The canal space was then left with irrigant in place for 60 seconds. Then Microirrigation stage was done in 3 cycles where the pulp chamber was flooded with irrigant and the microcannula was placed to full working length in each cycle.

The three cycles were done as follows

- The first cycle of irrigation was done using 5 ml of NaOCl active irrigation over 30 seconds followed by pulling the microcannula out of the canal while there is a sufficient amount of irrigant to make sure that the canal remained totally filled with the irrigant throughout the whole cycle and that no air was introduced into the canal space. NaOCl solution was then kept filling the canal for one minute.
- In the second cycle, 5 ml of each irrigant was used for its specific group for 10 seconds of active irrigation then left for 60 seconds in the canal.
- In the third cycle, the same steps in the first cycle were repeated. Once the 3 cycles were finished, the microcannula was kept at the working length for some time until the excess fluid was removed. Then canal irrigation followed using 5ml of sterile distilled water and finally, the canal was dried with paper points [26].

Scanning electron microscope (SEM) preparation:

All specimens were decoronated then mesiobuccal roots were grooved longitudinally on both buccal and lingual surfaces with a diamond disk without affecting the root canals' integrity. Then a hammer and chisel were used to cut each sample into two halves, while the one showing full canal length with fewer irregularities was the selected sample. To estimate the root thirds, a digital caliper was used to measure the length of every hemisected sample from the apex to the cementoenamel junction. This was followed by marking the points to be scanned which are corresponding to the midpoint of the coronal, middle, and apical thirds starting from the apex. These areas were scanned by Environmental SEM Model Quanta 250 FEG (Field Emission Gun), with an accelerating voltage of 30 K.V.

Photomicrographs were magnified (X 2000) for the smear layer score at all parts of the canals. The smear layer score was estimated utilizing a numerical evaluation scale[27].

Statistical analysis

The mean and standard deviation values were calculated for each group in each level. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests and showed non-parametric (not normal) distribution.

Kruskal Wallis test was used to compare between more than two groups in non-related samples Mann Whitney was used to comparing between two groups in non-related samples. For comparing more than two groups in related samples, Friedman test was used. Wilcoxon t-test was used to compare two groups in related samples.

The significance level was set at P≤0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Comparison of smear layer scores between irrigants at each root level:

There was no statistically significant difference between the mean scores of smear layer produced by group I (17% EDTA) and group II (Apple Vinegar) at all levels with either conventional irrigation or EndoVac irrigation system. However, there was a statistically significant difference between both experimental groups (I, II) and control group table (1) and figure (1).

Table (1) *The mean and standard deviation (SD) of smear layer scores in different subgroups using EDTA, Apple vinegar, saline at coronal, middle, and apical thirds.*

Device	Root level	Group I (EDTA)		Group II (Apple Vinegar)		Control group (Saline)		*p-value*
		Mean	SD	Mean	SD	Mean	SD	
Conventional	Coronal	1.6	0.84	1.8	0.79	4.4	0.55 [a,b]	0.002*
Endo-VAC	Coronal	1.5	0.71	1.6	0.7	4	0 [a,b]	0.001*
p-value		0.863ns		0.565ns		0.134ns		
Conventional	Middle	2.3	0.82	2.2	0.63	4.8	0.45 [a,b]	<0.002*
Endo-VAC	Middle	2	0.67	1.8	0.63	4.6	0.55 [a,b]	0.001*
p-value		0.439ns		0.168ns		0.513ns		
Conventional	Apical	3.2	0.92	3.2	0.63	5	0 [a,b]	0.003*
Endo-VAC	Apical	2.5	0.71	2.4	0.84	4.8	0.45 [a,b]	0.002*
p-value		0.068ns		0.029*		0.317ns		
Conventional	Total	2.37	1.07	2.4	0.89	4.73	0.46	
Endo-VAC	Total	2	0.79	1.93	0.79	4.47	0.52	

ns*; non-significant (p>0.05)* **; significant (p≤ 0.05)*

a*: there is a significant difference with group I.* **b***: there is a significant difference with group II.*

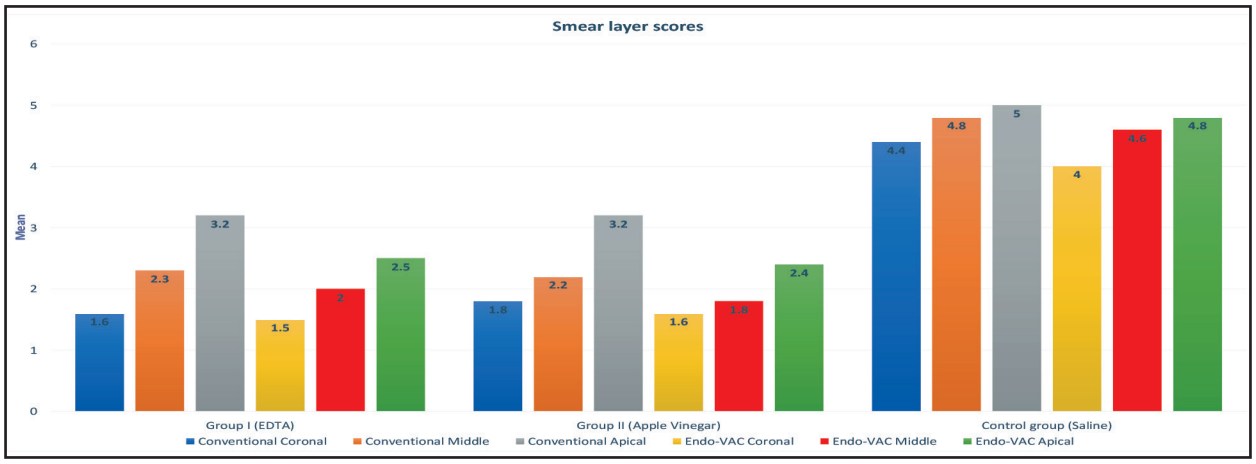

Figure (1) Bar chart representing the mean value of smear layer scores in different subgroups using EDTA, Apple vinegar, Saline at coronal, middle, and apical levels.

Comparison of smear layer scores between devices within each group at each root level:

No statistically significant difference was detected between different irrigating techniques (conventional irrigation and EndoVac irrigation system). However, at the apical level, there was a significant difference between them when apple vinegar was used as a final rinse (p=0.029) table (1) and figures (1,2).

Comparison of smear layer scores among the root canal levels within each group

The apical level showed the highest statistically significant mean smear layer scores compared to the middle and coronal levels. However, there was no statistically significant difference between the middle and coronal levels regardless of the irrigant used, table (1) and figure (1).

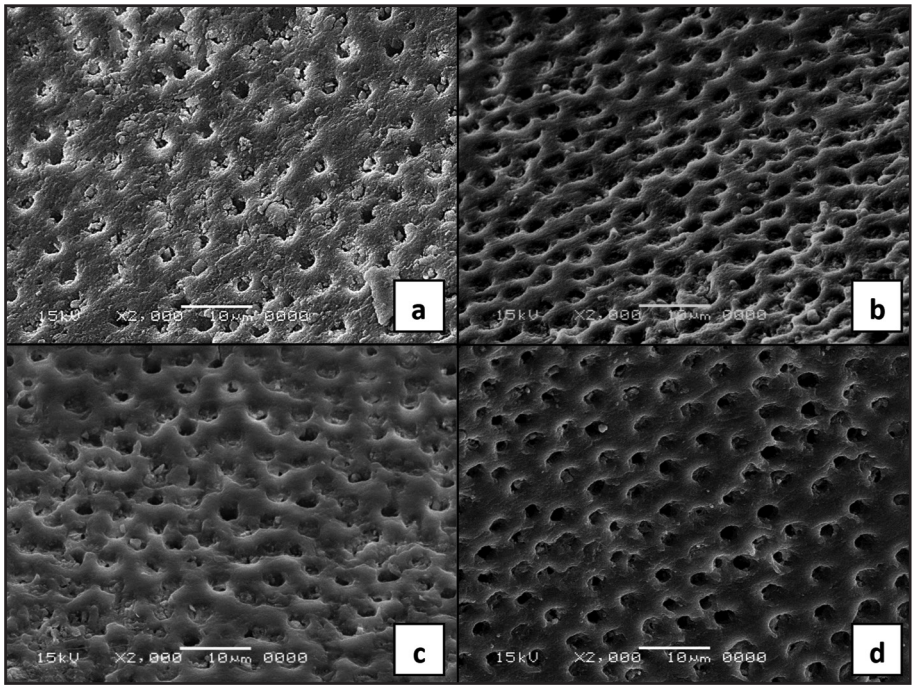

Figure (2) Scanning photomicrograph of the apical level of a root canal rinsed with: (a) 17% EDTA by conventional irrigation, (b) 17% EDTA by Endo vac irrigation system, (c) apple vinegar by conventional irrigation, and (d) apple vinegar by Endo vac irrigation system.

DISCUSSION

There are some criteria for the ideal endodontic irrigant, for example, being biocompatible, having antibacterial action, can dissolve organic tissues, and has the ability to remove the smear layer. Unfortunately, there is no such irrigant that has all these criteria combined or can act at the same time on both organic and inorganic parts of the smear layer. Hence, the combination of two or more irrigant solutions is required to obtain a good root canal cleaning outcome. A very popular example of this combination is sodium hypochlorite used alternatively with EDTA which proved to be effective to remove the smear layer [28,29]. Recently, many researches were done seeking an effective chelating agent that is more biocompatible compared to EDTA[17,23].

Apple vinegar was selected in this study for its advantages as it possesses; chelating capacity, antibacterial action, biocompatibility, cost-effectiveness, and possible anti-inflammatory role [30]. Moreover, it was found that a 3-minute contact time of 5 ml 17% EDTA irrigation solution is effective in smear layer removal [24,25]. Likewise, apple vinegar irrigation for 3 minutes was effective in smear layer removal [23-25].

Many techniques are used to introduce the irrigation solution into the root canal. Irrigation with metal needles is the traditional method used. The needle is difficult to control, and studies have shown that it is less effective in the apical third of the root canal. EndoVac is a recent irrigation device that has a special thin needle connected to suction that creates a negative apical pressure whereby the irrigant reaching the pulp chamber is sucked down the root canal and back up again [8,31]. In the present study, both EndoVac and conventional needle were used in association with different irrigation solutions (EDTA and apple vinegar). These different methods were checked for the root canal cleaning ability.

Regarding the effect of irrigant on smear layer scores; there was no statistically significant difference observed between the mean smear layer scores produced by 17% EDTA and apple vinegar irrigation at all root canal thirds. These results came in agreement with a previous study where apple vinegar proved to be an effective irrigant in smear layer removal [32]. This might be attributed to the apple vinegar acid component, especially malic acid[33].

In disagreement with results of the present study, one research stated that apple vinegar was significantly less effective than EDTA in smear layer removal. This might be attributed to the nature of the teeth selected where canine teeth with straight root canals were tested and using distilled water rather than NaOCl for irrigation during root canal instrumentation [34].

Regarding the effect of irrigating techniques on smear layer scores**;** statistical data showed no significant difference between the conventional and EndoVac irrigation techniques at all root levels when 17% EDTA was used as a final irrigant. This was consistent with other study reported that EndoVac irrigation system and conventional irrigation have a comparable smear layer removal efficiency all over the root levels when EDTA was used as a final irrigant [17]. However, it was noticed that using the EndoVac irrigation system in this study has led to better root canal cleanliness with lower mean smear layer scores, compared to the conventional needle irrigation method.

When apple vinegar was the irrigation solution, EndoVac irrigation system has shown lower smear layer scores with no statistically significant difference between EndoVac and conventional methods except for the apical level where there was a statistically significant difference between the two techniques (conventional and EndoVac).

The efficacy of EndoVac irrigation system might be due to the particular way it works. The microcannula can go deeper into the root canal

whereby irrigant solution is being pulled down the canal then sucked by the negative pressure created from the suction unit. Before using the microcannula, the macrocannula can be used to remove the larger debris particles to avoid its clogging [26]. Moreover, EndoVac system can ensure continuous irrigation throughout the working length with a constant flow of fresh irrigation solution [17,35]. In addition, these could be due to the need of increasing value of apical preparation size which is required for the microcannula to reach the full working length. Increasing the apical size will give a lower possibility of occlusion for the microcannula holes and subsequently more contact with the root canal wall and a better irrigation quality [35,36].

Some studies concluded that the efficiency of EndoVac system in removing the smear layer was better than the conventional irrigation at 1 mm from the working length which is consistent with this study [14,37,38]. While in disagreement with the present study, another research concluded that EndoVac irrigating system results are comparable to that of conventional irrigation at the apical level. This might be attributed to the small Navi tip used (30 gauge) [17].

Statistical data collected from this study regarding the effect of root canal level on smear layer scores have shown a significant difference between the mean smear layer scores of coronal, middle, and apical root levels regardless of other variables. The highest mean scores were observed at the apical level compared to other levels. While there was no statistically significant difference between the coronal and middle thirds. These results agree with other studies that ensured the lower efficacy of irrigation methods in cleaning the apical third [39,40].

The higher mean scores of the apical part of the root canal are due to the more difficulty to clean that level compared to coronal and middle levels that have larger canal sizes and hence, a better quality of irrigation [40]. Besides having a narrower canal diameter, the apical level has dentin that shows more sclerosis, and its dentinal tubules are less in diameter. Therefore, less amount of irrigation solution will reach the apical level with more smear layer left behind [25].

On the other hand, the results of this study were in disagreement with one study which stated that EDTA was equally efficient in smear layer removal from all root canal thirds. This might be due to testing a straight single root canal, unlike the present study which tested curved root canals, and the longer time of irrigation,5 minutes, as a final rinse which shall increase the efficiency of irrigation [41].

CONCLUSION

1. Apple vinegar irrigation is effective in the removal of smear layer from dentinal tubules with comparable results to 17% EDTA irrigation when used as a final rinse.
2. The Endo Vac system is a good root canal irrigation tool for smear layer removal purposes especially at the apical level and when Apple vinegar is used as a final rinse.

RECOMMENDATIONS

Further studies can be done comparing Endo Vac irrigating system with more recent irrigating devices using apple vinegar as a final rinse.

ACKNOWLEDGMENT

This paper results and the research behind it would not have been possible to be completed without the support of The Regional Center for Mycology and Biotechnology at Al-Azhar University.

CONFLICT of INTEREST

None declared.

FUNDING

No funding was received for this study.

REFERENCES

1. Violich D R, Paul N C. The smear layer in endodontics. Int J Endod. 2010; 43:2-15.
2. Buurma H A, Buurma B J. The effect of smear layer on bacterial penetration through roots obturated using zinc oxide eugenol-based sealer. BMC Oral Health.2020; 20: 1-88.
3. Alamoudi RA. The smear layer in endodontic: To keep or remove – an updated overview. Saudi Endod J 2019;9:71-81.
4. Sharma S, Farooq R, Purra A R, Ahanger F A, Bhagat P. Comparative Evaluation of Smear Layer Removal Efficacy of Different Final Irrigating Solutions: A Scanning Electron Microscopic Study. JAMDS.2020;8: 2348-6805.
5. Prabhakaran P, BallagereAM. A scanning electron microscope evaluation of efficacy of sodium hypochlorite and Allium sativum in smear layer removal in root canals with the use of modified evacuation system: An ex vivo study. J Conserv Dent. 2018; 21: 401-7.
6. Himmatrao P, Patil, Nitin MG, Janardan SK, Mathew RS, Balasaheb. Efficacy of new irrigating solution on smear layer removal in apical third of root canal: A scanning electron microscope study.JConserv Dent. 2018; 21:190-3.
7. Patel MC, Bhatt RA, Joshi KR, Vaghela LL. Evaluation and comparison of smear layer removal potency of three different irrigation regimes – A stereomicroscopic and scanning electron microscopic study. Indian J Dent Sci 2021; 13:18-23.
8. Abdelglil SA, FaragAM, El-Hediny HA, Darrag AM. Efficacy of Endo Vac system and needle irrigation on root canal debridement. J Tanta Dental. 2016; 13: 171-8.
9. Ratih D N, Enggardipta R A, Kartikaningtyas A T. The Effect of Chitosan Nanoparticle as A Final Irrigation Solution on The Smear Layer Removal, Micro-hardness and Surface Roughness of Root Canal Dentin. TODENTJ.2020; 14-19.
10. Mohanty S, Ramesh S, Muralidharan N Antimicrobial efficacy of apple cider vinegar against Enterococcus faecalis and Candida albicans: An in vitro study. J Adv Pharm Educ Res. 2017; 2:137-41.
11. Rao P S S, Karthik L,Kumar M P, Devi V G,Vasantha M, Sowmya K.Comparative evaluation of smear layer removal by EDTA, Apple Cider Vinegar and Fumaric acid when used as irrigant - an Invitro Atomic Force Microscopic study.IJDSIR.2020; 3: 280 –7.
12. Mittal A, Dadu S, Yendrembam B, Abraham A, Garg P. Comparison of new irrigating solutions on smear layer removal and calcium ions chelation from the root canal: An in vitro study. J Endod. 2018; 30: 55-61.
13. Dioguardi M, Crincoli V, Sovereto D, Caloro G A, Aiuto R et al. Effectiveness of Vapor Lock Effect Removal in Endo Training Blocks: Manual Dynamic Agitation versus Passive Ultrasonic Irrigation. Appl. Sci. 2019, 9: 24-5411.
14. Jasrotia A, Bhagat K, Bhagat N, Bhagat RK. Comparison of five different irrigation techniques on smear layer removal in apical thirds of root canals of mandibular first premolar: A scanning electron microscopic study. J Int Soc Prevent Communit Dent 2019; 9:630-6.
15. Wu, Di, Ma, Yong-zhen, Jia, Jing, Xin, Bing-chang, Wang, Da-shan, Sun, De-gang ,Wang, Ling-xiang . Removal of the root canal smear layer using Carisolv III and sodium hypochlorite, Medicine.2020; 99-20372.
16. Faus-Llácer V, Luna-Roa M, Faus-Matoses I, Ruiz-Sánchez C, Zubizarreta-Macho A, Sauro S et al.Comparative Analysis of the Smear Layer Removal Capability between EndoVac and Endoactivator Endodontic Irrigation Systems at the Root Canal System and Isthmus: A Micro-Computed Tomography Analysis. Appl. Sci. 2020; 10-7033.
17. El zayat S, Fawzy M, Bastawy H. Efficacy of Chitosan as a root canal irrigant in removing smear layer in curved root canals using endovac irrigation system (SEM study). ADJ_for Girls 2018; 5:485-94.
18. Mancini M, Cerroni L, Iorio L, Dall'Asta L, Cianconi L M. FESEM evaluation of smear layer removal using different irrigant activation methods (EndoActivator, EndoVac, PUI and LAI). An in vitro study. Springer-Verlag GmbH.2018; 22: 993–9.
19. Nagmode PS, Chavan KM, Rathi RS, Tambe VH, Lokhande N, Kapse BS. Radiographic evaluation of root canal curvature in mesiobuccal canals of mandibular molars by different methods and its correlation with canal access angle in curved canals: An in vitro study. J Conserv Dent. 2019; 22:425-9.
20. Alim B A, Berker Y G.Evaluation of different root canal filling techniques in severely curved canals by micro-computed tomography.Saudi Dent J,2020;32:200-5.
21. Dua R, Kochhar G K, Garewal R, Khanna A, Thakur A. Root Canal Irrigation Devices: An Update. Ijrhas.2018;4: 2455-7803.
22. Hanbazaza NS, Abuhaimed TS. Influence of kinematics on the cyclic fatigue of ProTaper Gold and WaveOne Gold. Saudi Endod J 2020; 10:145-51.

23. Tekin B, Demirkaya K. Natural irrigation solutions in endodontics. Gulhane Med J 2020; 62:133-8.

24. Matos, F.d.S., da Silva, F.R., Paranhos, L.R. et al. The effect of 17% EDTA and QMiX ultrasonic activation on smear layer removal and sealer penetration: ex vivo study. Sci Rep.2020; 10: 10311.

25. Chia MSY, Parolia A, Lim BSH, Jayaraman J, Porto ICCM. Effect of QMix irrigant in removal of smear layer in root canal system: a systematic review of in vitro studies. Restor Dent Endod. 2020;45: 28.

26. Endovacbrochure.Available at https: //www.kerrdental.com.

27. HülsmannM, Riimmelin C, Schafers F. Root canal cleanliness after preparation with different endodontic hand pieces and hand instrument.A comparative SEM investigation. J Endod 1997; 23: 301-6.

28. Suman S, Verma P, Prakash-Tikku A, Bains R, Kumar-Shakya V. A Com-. 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: 981-7.

29. Mohammadi Z, Shalavi S, Moeintaghavi A, Jafarzadeh H. A Review Over Benefits and Drawbacks of Combining Sodium Hypochlorite with Other Endodontic Materials. opendentj.2017;11:661-9.

30. Ratih D N, Enggardipta R A, Kartikaningtyas A T.The Effect of Chitosan Nanoparticle as A Final Irrigation Solution on The Smear Layer Removal, Micro-hardness and Surface Roughness of Root Canal Dentin. TODENTJ.2020;14:19-26.

31. Thulaseedharan S, Kabbinale P, Vallabhdas AK, Ninge Gowda VC, Chandrashekar KS, Marulappa R. In vitro comparative evaluation of effectiveness of sodium hypochlorite with conventional irrigation method versus EndoVac and ultrasonic irrigation in the elimination of Enterococcus faecalis from root canals. J Pharm Bioall Sci 2020;12,1:105-8.

32. Moness Ali AM, Raab WH. Smear layer removal efficiency using apple vinegar: An in vitro scanning electron microscope study. Am J Dent. 2019; 32:21-7.

33. Candeiro GT, Matos IB, Costa CF, Fonteles CS. Vale MS. A comparative scanning electron microscopy evaluation of smear layer removal with apple vinegar and sodium hypochlorite associated with EDTA. J Appl Oral Sci 2011; 19: 639-43.

34. Kirchhoff AL, Viapiana R, Miranda C, Sousa NetoMD,Cruz Filho AM. Comparison of the apple vinegar with other chelating solutions on smear layer and calcium ions removal from the root canal. Indian J DentRes2014; 25:370-4.

35. Schoeffel GJ.The EndoVac method of endodontic irrigation, part 2 – Efficacy.Dent Today 2008;27:86-7.

36. Silva CC, Ferreira V M D, De-Deus G, Herrera D R.Effect of Intermediate Flush Using Different Devices to Prevent Chemical Smear Layer Formation.Braz Dent J 2017; 28:447-452.

37. Dua A, DuaD.Comparative evaluation of efficacy of EndoVac irrigation system to Max-I probe in removing smear layer in apical 1 mm and 3 mm of root canal: An in vitro scanning electron microscope study. DRJ 2015; 12:38-43.

38. Kowsky DK, Naganath M. Effectiveness of different irrigation devices on the smear layer removal in the apical portion of curved root canals: A scanning electron microscopy study. Saudi Endod J 2018; 8:111-6.

39. Rathakrishnan M, Sukumaran VG, Subbiya A. Efficacy of an Innovative Irrigant on Smear Layer Removal – SEM Analysis. J Clin Diagn Res 2016; 10: 104-6.

40. Safwat HA, Nour El-deen MM, Bastawy HA. Evaluation of smear layer removal and calcium ions concentration in intraradicular dentin treated with apple vinegar. ADJ_for Girls 2017; 4: 279-87.

41. Attur K, Joy M T, Karim R, Kumar VJ A, Deepika C, Ahmed H.Comparative analysis of endodontic smear layer removal efficacy of 17% ethylenediaminetetraacetic acid, 7% maleic acid, and 2% chlorhexidine using scanning electron microscope: An in vitro study.J Int Soc Prev Community Dent. 2016; 6:160-5.