ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

"EVALUATION OF MANUAL DYNAMIC ACTIVATION, PASSIVE ULTRASONIC IRRIGATION AND CANALBRUSH ON SMEAR LAYER REMOVAL - A SCANNING ELECTRON MICROSCOPIC STUDY."

***Narmatha VJ[1], Sophia Thakur[2]**

1. Assisstant Professor, Faculty of dentistry, Melaka Manipal Medical College, Manipal, Karnataka

2. Professor, Bapuji Dental College and Hospital, Davangere, Karnataka

Manuscript Info

Manuscript History:

Received: 11 January 2015
Final Accepted: 22 February 2015
Published Online: March 2015

Key words:
Smear layer, Ultrasonic, Irrigation, Root canal, SmearClear, Sodium hypochlorite, root canal instrumentation

Corresponding Author

Narmatha VJ

Abstract

The aim of the study was to compare the efficiency of smear layer removal using Manual Dynamic Activaton, Passive Ultrasonic Irrigation and Roeko Canal brush with the conventional syringe irrigation using scanning electron microscope, and to evaluate the effect of various agitation techniques in improving the efficacy of SmearClear (17% EDTA with surfactant) and 10% citric acid.

Materials and methods: Seventy single rooted teeth with single canal were decoronated to obtain a standardized root length of 16 mm. All the specimens were cleaned and shaped using ProTaper rotary system. Intermittent irrigation of the canal was done using 0.5 ml of 3% NaOCl between each file use .The prepared teeth were randomly divided into four groups with three different irrigant agitation protocols: Group 1: Control, Group 2: Manual Dynamic Activation , Group 3: Passive Ultrasonic Irrigation and Group 4:Canal brush activation. Each of these groups were divided into 2 subgroups with two chelating i.e. SmearClear and 10% citric acid. After these procedures the specimens were prepared for scanning electron microscopic examination and evaluated for the presence of smear layer using the 5 point smear layer removal scoring system.

Results: There was a statistically significant difference in the smear layer removal efficacy of the irrigant agitation techniques with Passive Ultrasonic irrigation showing the highest efficacy followed by Canal Brush irrigation and Manual Dynamic Activation. SmearClear has a better smear layer removal efficacy in comparison with 10% citric acid.

Conclusion: Passive Ultrasonic irrigation produced cleaner canal walls devoid of smear layer when compared to Canal Brush activation and Manual Dynamic activation.

INTRODUCTION

The essence of endodontic therapy involves treating vital and necrotic dental pulps so that patients can retain their natural teeth in function and esthetics. Although successful therapy depends on many factors, one of the most important steps in any root canal treatment is canal preparation.[1]

Studies have shown that mechanical instrumentation of the root canal leaves a smear layer covering the root canal walls. This layer consists of organic and inorganic substances derived from ground dentin and predentin,

pulpal remnants, odontoblast processes; and, in cases of infected root canals, bacteria.[2,3] The presence of microorganisms within the smear layer and dentinal tubules is well documented.[4,5] The smear layer hinders the optimal penetration of antimicrobial agents into dentinal tubules and hence blocks the effects of disinfectant in them.[6,7] It can act as a barrier between filling materials and the canal wall and therefore compromise the formation of a satisfactory seal. It is a loosely adherent structure and a potential avenue for leakage and bacterial contaminant passage between the root canal filling and the dentinal walls.[8-10]Although not substantiated in clinical trials, the removal of the smear layer before root filling would appear to be prudent and would facilitate root canal filling.

To date no single irrigant has been demonstrated to be capable of dissolving both organic and inorganic parts of dentin. Sodium hypochlorite (NaOCl), in concentrations of 0.5% to 5.25%, is the irrigant of choice for root canal disinfection. But, when used alone, is ineffective in smear layer removal.[11]

Hence, the alternating use of 17%EDTA and sodium hypochlorite (NaOCl) has been recommended for the efficient removal of the smear layer. [12-14]

Recently, a new product containing 17% EDTA solution along with cetrimide and additional proprietary surfactants has been launched by SybronEndo (Orange, CA) under the brand name SmearClear. This endodontic irrigant is advertised as being specifically designed for smear layer removal and root canal cleansing, and little published data are available about its performance.[15-17]

Citric acid may also be used for smear layer removal. Concentrations ranging from 1% to 50% have been investigated. [18-21] Wayman et al[20] showed that the use of 10% citric acid and 2.5% NaOCl is a very effective approach for smear layer removal.

The literature reports show that regardless of the instrumentation and irrigation techniques, the effectiveness of irrigating solutions remains limited in the apical one third of the prepared canal.[11] This is particularly true for curved root canals and even on single rooted teeth. Therefore the improvement of irrigating protocols is essential during root canal treatment in order to achieve better cleaning efficacy especially in very complex apical area.

Currently, technological advances since the last decade have unraveled various irrigant agitation systems to improve the final irrigation before obturation.[11]

Studies have shown that a fully tapered, well fitting gutta percha master cone could be used in a well prepared canal as a cost effective mechanical agitator. A gentle pumping with short vertical strokes has been shown to promote disinfection.[22,23] These vertical strokes of 2 to 3 mm, produce effective hydrodynamic effect and significantly improve the displacement and exchange of any given reagent.[11]

Roeko Canal brush (Coltene Whaledent , Langenau, Germany) is an endodontic microbrush that has recently been made commercially available. This highly flexible microbrush is molded entirely from polypropelene and might be used manually with a rotary action. However, it is more efficacious when attached to contra angle hand piece running at 600 rpm.[11,24] The use of this brush with an irrigant removed debris effectively from simulated canal extensions and irregularities.[25]

Passive ultrasonic irrigation has shown promising results on debris and smear layer removal from the root canal systems. The term PUI was coined by Weller et al[26] to describe an irrigation scenario where there was no instrumentation, planning or contact of the walls with and endodontic file or an instrument.[27] With this non cutting technology, the potential to create aberrant shapes within the root canal was reduced. During PUI, the energy is transmitted from an oscillating file or a smooth wire to the irrigant in theroot canal by means of ultrasonic waves. The latter induces acoustic streaming and cavitation of the irrigant.[28-30]

The lack of scientific data comparing the combination of these chemo-mechanical techniques, have prompted the need for a study to eliminate the doubts clinically and in literature and evaluate Manual Dynamic, Passive Ultrasonic and CanalBrush Irrigation in comparison with the conventional irrigation system in improving the current modalities of smear layer removal.

MATERIALS AND METHODS

Seventy extracted single rooted human teeth with single canal were collected and stored in 1% thymol. The following were the selection criteria for the samples of the study.

INCLUSION CRITERIA

- Single rooted human teeth with single canal[31]

EXCLUSION CRITERIA

- Teeth with any developmental anomalies
- Open apex and internal resorption
- Presence of caries

- Root fissures and fractures

METHODOLOGY

I. Sample selection and decoronation

- Seventy extracted single rooted human teeth with single canal and mature root apices, extracted for orthodontic reasons, were collected and stored in 1% thymol. The presence of a single canal was verified with two digital radiographs in a mesiodistal and a buccolingual direction.The teeth were decoronated to obtain a standardized root length of 16 mm.

II. Root canal instrumentation

- After gross removal of pulpal tissue, apical patency was established using a 10 k file and the working length was obtained by deducting 1 mm from the length recorded, when the tip of the # 10 K file was just visible at the apical foramen. The apical foramen was sealed using warm modeling wax to prevent the irrigants escaping through the apex in order to simulate in vivo conditions.[32]All the specimens were cleaned and shaped using Protaper Universal Rotary file system with crown down pressure less technique with apical preparation done with hand files. All the canals were prepared so that the finished size of each apical foramen was 0.30mm in diameter. Intermittent irrigation of the canal was done using 0.5 ml of 3% NaOCl between each file use.

III. Irrigant agitation protocols

- The prepared teeth were randomly divided into four groups.

CONTROL GROUP(n=10): **STATIC IRRIGATION** with 3 ml of 3% NaOCl

GROUP A(n=20):**MANUAL DYNAMIC IRRIGATION** group

*SUBGROUP A1:*SmearClear

1ml of SmearClear for 1min followed by activation with a gutta percha cone for 1min using 100 push-pull strokes per minute[22] + 3ml of 3% NaOCl[32]

SUBGROUP A2:10% Citric acid

1ml of 10% Citric acid followed by activation with a gutta percha cone for 1min using 100 push-pull strokes per minute + 3ml of 3% NaOCl

GROUP B (n=20) : **PASSSIVE ULTRSONIC IRRIGATION** group

SUBGROUP B1:SmearClear/ultrasonic activation

1ml of SmearClear for 1min followed by ultrasonic activation[33] + 3ml of 3% NaOCl

SUBGROUP B2:10% Citric acid /ultrasonic activation

1ml of 10% Citric acid followed by ultrasonic activation + 3ml of 3% NaOCl

GROUP C(n=20):**CANALBRUSH ACTIVATION** group

SUBGROUP C1:SmearClear

1ml of SmearClear for 1 min + 30 sec activation with Roeko CanalBrush[24] + 3 ml of 3% NaOCl

SUBGROUP C2:10% Citric acid

1ml of 10% Citric acid followed by 30 sec activation with Roeko CanalBrush + 3 ml of 3% NaOCl

After the procedure is completed the specimens were rinsed with saline and dried with paper points.

IV. Sample preparation for SEM and SEM evaluation

After instrumentation the teeth were grooved vertically on the buccal and lingual surfaces using a water-cooled diamond bur taking care to avoid penetrating the root canal.The teeth were split along the long axis in a buccolingual direction using a surgical chisel. These specimens were mounted on a metallic stub and sputter coated with 20nm layer of gold. A magnification of X1500 was used to evaluate the apical and middle third of the root canal.

The SEM images were analyzed using the following 5-point scoring system.

Scores	Criteria
1	No smear layer and dentinal tubules open
2	Small amounts of scattered smear layer and dentinal tubules open

3	**Thin smear layer and dentinal tubules partially open (characteristic image of crescent)**
4	**Partial covering with thick smear layer**
5	**Total covering with thick smear layer**

RESULTS

Table 1 shows the mean ± standard deviation, median and range of the smear layer scores obtained in all the groups. On comparison of the smear layer scores of the individual groups with the control group with the Mann Whitney test highly statistically significant p values ($p < 0.001$) were obtained which are shown in the table clearly. Group A1 and A2 showed p values of 0.004 and 0.002 respectively which were statistically significant in comparison with the control group. Whereas groups B1, B2, C1, C2 showed p values < 0.001 , which were statistically highly significant.

Table 2 shows the statistical comparison of the smear layer scores with two different irrigant solutions i.e SmearClear and 10% citric acid regardless of the agitation technique used.

On comparison of the smear layer scores of the two subgroups of group A [Grp A1:Manual dynamic activation + SmearClear, Grp A2: Manual dynamic activation + 10% citric acid], p value of 1.00 has been obtained which is statistically insignificant. However, the mean smear layer score of the Grp A1 is lesser when compared to Grp A2, i.e. 2.97 and 3 respectively.

On comparison of the scores of subgroups in the group B, [Grp B1: Passive Ultrasonic irrigation + SmearClear , Grp B2: Passive ultrasonic irrigation + 10% citric acid], a statistically significant difference has been obtained.($p = 0.02$).

The statistical comparison of the subgroups of group C ,[Grp C1: Canal Brush + SmearClear, Grp C2: Canal Brush + 10% citric acid] has shown a p value which is statistically insignificant.($p > 0.05$). However, the average score obtained in group C1 is lower than that in the group C2.

Hence, in the present study it has been shown that SmearClear has a better smear layer removal efficacy in comparison with 10% citric acid. However the difference is not statistically significant ($p > 0.05$) except in the group B.

Table 3 shows the statistical comparison of the smear layer scores among the three final irrigation techniques i.e. Grp A: Manual Dynamic Activation, Grp B: Passive ultrasonic irrigation and Grp C: Canal Brush agitation.

The comparison of the average scores of Grp A1 and B1 with Mann Whitney Test showed a p value of 0.001, which is statistically highly significant. However the comparison of the scores of Grps A1 with C1 and Grp B1 with C1 showed p values of 0.003 and 0.05 respectively, which were statistically significant.

On comparison of group A2 with group B2 and C2, p values of 0.02 and 0.05 were obtained respectively which are statistically significant. Whereas, the difference obtained on comparison of the groups B2 and C2 was not statistically significant.($p = 0.88$)

Graph 1 shows the average smear layer score among the different final irrigation regimens.

Graph 2 shows the comparison of the smear layer scores among the different final irrigation techniques with smear clear as the irrigant.

Graph 3 shows the comparison of the smear layer scores among the different final irrigation techniques with citric acid as the irrigant.

TABLE 1

COMPARISON OF THE MEAN± STANDARD DEVIATION SMEAR LAYER SCORE OF THE DIFFERENT FINAL IRRIGATION REGIMENS WITH THE CONTROL

	MEAN±SD	MEDIAN	RANGE	Comparison with control*

CONTROL		3.47 ± 0.28	3.33	3.00 - 4.00	-
A MDA£	A1	2.97 ± 0.33	3.00	2.33 - 3.33	0.004 S
	A2	3.00 ± 0.29	3.00	2.33 - 3.33	0.002 S
B PUI€	B1	1.87 ± 0.36	2.00	1.33-2.33	< 0.001 HS
	B2	2.43 ± 0.52	2.33	1.67-3.33	< 0.001 HS
C CBϕ	C1	2.27 ± 0.44	2.33	1.67 – 3.00	< 0.001 HS
	C2	2.40 ± 0.66	2.33	1.67 – 3.33	< 0.001 HS

* MANN- WHITNEY TEST, £- MANUAL DYNAMIC ACTIVATION, €- PASSIVE ULTRASONIC IRRIGATION,
ϕ- CANAL BRUSH AGITATION

TABLE 2
STATISTICAL COMPARISON OF THE SMEAR LAYER SCORES WITH TWO DIFFERENT IRRIGANT SOLUTIONS

		A1/B1/C1	A2/B2/C2	SIGNIFICANCE OF DIFFERENCE*
GROUP A	MEAN ± SD	A1-SMEAR CLEAR 2.97 ± 0.33	A2-CITIRC ACID 3.00± 0.29	A1 /A2 P = 1.00 NS
GROUP B	MEAN ± SD	B1-SMEAR CLEAR 1.87 ± 0.36	B2-CITRIC ACID 2.43 ± 0.52	B1/B2 P = 0.02 S
GROUP C	MEAN ± SD	C1-SMEAR CLEAR 2.27 ± 0.44	C2- CITRIC ACID 2.40 ± 0.66	C1/C2 P = 0.76 NS

*MANN- WHITNEY TEST

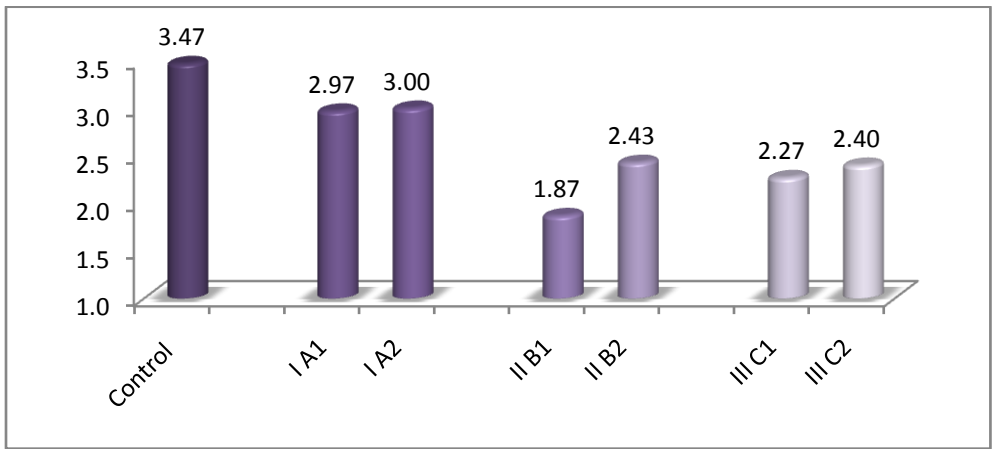
TABLE 3
STATISTICAL COMPARISON OF THE SMEAR LAYER SCORES AMONG THE THREE FINAL IRRIGATION TECHNIQUES

GROUPS	SUBGROUPS	MEAN ± SD	SUBGROUP	MEAN ± SD
GROUP A MDA	A1	2.97 ± 0.33	A2	3.00 ± 0.29
GROUP B PUI	B1	1.87 ± 0.36	B2	2.43 ± 0.52

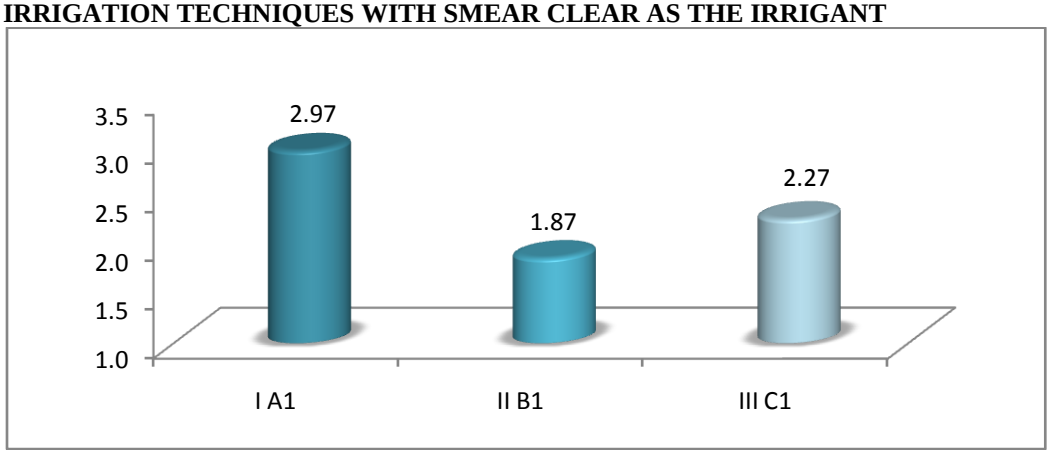
GROUP C CANAL BRUSH	C1	2.27 ± 0.44	C2	2.40 ± 0.66
Kruskal wallis – ANOVA*	H = 17.90 P < 0.001 HS		H= 6.23 P < 0.05 S	
Difference between groups** (p values)	A1- B1	P < 0.001 HS	A2 – B2	P = 0.02 S
	A1 – C1	P = 0.003 S	A2 – C2	P = 0.05 S
	B1 – C1	P = 0.05 S	B2 – C2	P = 0.88 NS

*Kruskal-Wallis ANOVA
**Mann – Whitney Test

GRAPH 1:AVERAGE SMEAR LAYER SCORE AMONG THE DIFFERENT FINAL IRRIGATION REGIMENS

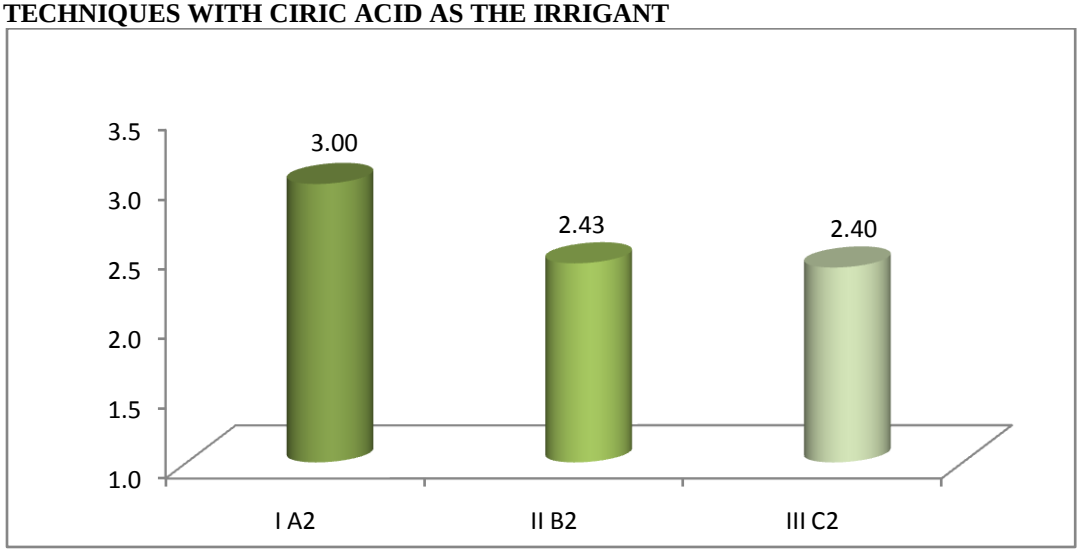


GRAPH 2: COMPARISON OF THE SMEAR LAYER SCORES AMONG THE DIFFERENT FINAL IRRIGATION TECHNIQUES WITH SMEAR CLEAR AS THE IRRIGANT



GRAPH 3

COMPARISON OF THE SMEAR LAYER SCORES AMONG THE DIFFERENT FINAL IRRIGATION TECHNIQUES WITH CIRIC ACID AS THE IRRIGANT



DISCUSSION

The endodontic community is unanimous concerning the fact that although mechanical instrumentation reduces the bacteria from the root canals by approximately 50%, disinfecting irrigants are needed to eliminate the microbiota in locations where instruments cannot access.[34, 35]

Consequently, a plethora of irrigant agitation techniques have been proposed to increase the efficacy of the irrigant solutions. Some of these techniques include manual agitation with hand files, manual agitation with gutta percha cones, mechanical agitation with plastic instruments and sonic and ultrasonic agitation.[11]

Various irrigants are used in endodontic practice for their chemical and therapeutic effects.

Sodium hypochlorite (NaOCl) is considered to be of the highest standard for irrigation of root canals. Differing concentrations of NaOCl i.e., 0.5%, 1.0%, 2.5%, and 5.25%, have been shown to be equally efficacious in the disinfection of necrotic root canals as well as removal of loose superficial debris.[36,37] Therefore, 3 % NaOCl was used with the conventional syringe in this study which served as the negative control group.

Although sodium hypochlorite appears to be the most desirable single endodontic irrigant, it cannot dissolve inorganic dentin particles. In order to address this issue, demineralizing/chelating agents such as ethylenediamine tetraacetic acid (EDTA) and citric acid have been introduced.

Smear Clear is a commercially available 17% EDTA solution with a cationic (cetrimide) and an anionic surfactant. Dunavant et al[15] have evaluated the this product *in vitro*. They compared efficacy of SmearClear to the conventional NaoCl, 2% Chlorhexidine, REDTA and BioPure MTAD against E faecalis biofilms. The authors found that SmearClear had greater efficacy than chlorhexidine, REDTA and BioPure MTAD. These results may be attributed to the cetrimide present in SmearClear, which is a quarternary ammonium compound and a cationic detergent that is effective against gram positive and gram negative microorganisms. With respect to smear layer removal, it has been shown in various studies that SmearClear is similar in efficacy to different concentrations of EDTA.[16,17]

Citric acid may also be used for smear layer removal in concentrations ranging from 1% to 50%.[18-21] However, Di Lenarda et al[21] reported no or negligible difference in smear layer removal with citric acid and EDTA. Similar results were found in a study conducted by Khedmat et al wherein the application of 10% citric acid for 1 min followed by 3 ml of 5.25% NaOCl was not sufficient to completely remove the smear layer, especially in the apical third. [38]

The present study has therefore been performed to know the smear layer removal efficacy of SmearClear and 10% citric acid and the effect of three different agitation techniques namely, Manual Dynamic activation, Passive Ultrasonic irrigation and Canal brush agitation in improving its efficacy in comparison to the conventional syringe irrigation with NaOCl.

Manual dynamic activation, is a gentle pumping of well fitting gutta percha cone with short vertical strokes, has been shown to produce effective hydrodynamic effect and promote disinfection by displacement and exchange of any given reagent.[11] In the present study, it was seen that MDA had a significant difference in the smear

layer scores in comparison with the conventional syringe irrigation system.($p < 0.005$) Several factors could have contributed to the positive results of manual dynamic activation : (1) the pull- push motion of a well fitting gutta percha point in the canal might generate higher intracanal pressure changes during pushing movements , overcoming the inherent *vapor lock effect*, seen in the apical third of the canal, leading to more effective delivery of irrigant to the untouched canal surfaces. (2) the push- pull motion of the gutta percha point probably acts by physically displacing, folding and cutting of fluid under viscously dominated flow in the root canal system. The latter probably allows better mixing of the fresh unreacted solution with the spent, reacted irrigant.

The present study is the first of its kind in which Manual Dynamic activation has been used along with SmearClear and 10 % citric acid. The addition of Manual Dynamic activation to SmearClear produced significantly cleaner canal walls compared to the control group ($p= 0.004$). Similarly the agitation of 10% citric acid by MDA produced significantly lesser smear layer scores compared to the control group. However, the difference between group A1(MDA+ SmearClear) and A2(MDA+ 10% citric acid) was not statistically significant.

The concept of using ultrasonic devices in endodontics was first introduced by Richman in 1957. Two types of ultrasonic irrigation have been described in the literature: one where irrigation is combined with simultaneous ultrasonic instrumentation (UI) and another without simultaneous instrumentation, so called passive ultrasonic irrigation (PUI). Passive ultrasonic irrigation was first described by Weller et al in 1980.[26]In the present study, PUI has been used as one of the methods of irrigant agitation.

PUI relies on the transmission of acoustic energy from an oscillating file or smooth wire to an irrigant in the root canal as described by Ahmad et al.[28] The energy is transmitted by means of ultrasonic waves and can induce acoustic streaming and cavitation of the irrigant. After the root canal has been shaped upto the master apical file, a small file of size 15 is introduced in the centre of the root canal, as far as the apical region. The root canal is then filled with an irrigant solution and the ultrasonically oscillating file activates the irrigant. As the root canal has already been biomechanically prepared, the file can move freely and the irrigant can penetrate more easily into the apical part of the root canal system. Because of the active streaming of the irrigant its potential to contact a greater surface area of the canal wall is enhanced. This seems to improve the efficacy of irrigation solutions in removing organic and inorganic debris from the root canal walls. A possible explanation for the improved action is that a much higher velocity and volume of irrigant flow is created in the canal during PUI.[28,29]

In this study, the use of Passive Ultrasonic irrigation was demonstrated to be the better mode of agitation, irrespective of the irrigant used, compared to Manual Dynamic activation and Canal Brush activation. Following Passive ultrasonic agitation, a better removal of smear layer was noticed, which subsequently revealed the least smear layer scores in the SEM micrographs. The smear layer scores show a highly statistically significant difference when compared to conventional syringe irrigation.($p< 0.001$)

The addition of ultrasonics to EDTA has been previously reported in literature. Kuah et al demonstrated the in vitro effectiveness of 17% EDTA with and without ultrasonics on smear layer removal was evaluated. One hundred and five extracted premolars randomly divided into seven groups were instrumented with different final irrigating protocols: group(Sal3US), saline for 3 minutes with ultrasonics; groups B (Na3) and C (Na3US), 1% sodium hypochlorite forminutes without and with ultrasonics, respectively; groups D (ED3) and E (ED3US), 17% EDTA for 3 minutes without and with ultrasonics, respectively; and groups(ED1) and G (ED1US), 17% EDTA for 1 minute without and with ultrasonics, respectively. Specimens were examined under scanning electron microscope and scored for smear layer and debris removal. Statistical analysis showed that groups with EDTA and ultrasonic irrigation, groups E (ED3US) and G (ED1US), had significantly more specimens with complete smear layer and debris removal. There was no significant difference between groups E (ED3US) and G (ED1US). It was concluded that a 1-minute application of combined use of EDTA and ultrasonics efficient for smear layer and debris removal in the apical region of the root canal.[33]

In the present study a one minute application of SmearClear along with ultrasonic agitation was used which produced similar results as that of the previous studies. In this study, ultrasonics was used only after the completion of instrumentation to fully use the principle of acoustic streaming. A low-power setting was used to avoid planing of the canal walls.[28]

The addition of ultrasonic to SmearClear (Group B1) and 10% citric acid (Group B2) produced smear layer scores which were highly significant when compared to the control group. Hence the results of the present study are in corroboration to the previous studies. The combination of ultrasonics and SmearClear produced the least smear layer scores in the study ranging from 1.33- 2.33. This can be attributed to the phenomenon of acoustic streaming and also the composition of SmearClear, which contains an additional surfactant to improve the wetting of the smeared canal walls.

Canal brush (Coltene Whaledent , Langenau, Germany) is an endodontic microbrush that has been made commercially available since 2007. This highly flexible microbrush is molded entirely from polypropelene and might be used manually with a rotary action. However, it is more efficacious when attached to contra angle hand piece running at 600 rpm.[11, 24] The use of this brush with an irrigant removed debris effectively from simulated canal extensions and irregularities.[25] In the present study, canal brush agitation was used in combination with SmearClear and 10% citric acid. The results show that these irrigation protocols produced significantly lower smear layer scores when compared to the control i.e. conventional syringe irrigation.($p<0.001$).

The apical preparation for all the specimens was done upto F3 ProTaper Rotary file which was appropriate to advance the brush into the canals easily. Findings similar to the present study were reported by Garip Y and coworkers in an in vitro study wherein it was concluded that irrigating with brushing tended to produce cleaner canal walls.[24]

In the present study, the CanalBrush was used with a circumferential and 2- to 3-mm up-and-down motion for 30 seconds, in a slow-speed handpiece. Different results may be obtained if the brush was used for a longer period of time. Modifications to the brush may also increase its effectiveness in cleaning canal walls. The availability of the CanalBrush in different sizes would make it possible to use the brush more effectively in larger root canal systems and would allow more of the brush to contact the canal walls during brushing.

The mechanical properties and dimensional characteristics of this brush have been evaluated. The Canal Brush is standardized and can be used without risk of fracture in curved canals.[43] The samples in the present study were all single-rooted human teeth with straight canals, which is a limitation of this study. None of the brushes fractured, but deformations were observed.

In the current study, **scanning electron microscope** has been used to evaluate the smear layer. Boyde, Switsur and Stewart (1963) appear to have been among the first to describe in greater detail, the nature of the surface deposits in situ using the Scanning electron microscope. Since then SEM has been one of the most efficient methods of evaluation of smear layer.[44] The 5 point scoring system used in the present study is a modification of the scale described by Hulsmann et al.[45] This system lacked sensitivity in the best scores and hence was modified by Caron G et al.[32]

The smear layer is the prime encumbrance to the endodontist's dream of achieving a fluid tight three dimensional seal. The present study has unveiled the significance of the contemporary irrigant agitation techniques and their efficacy in removal of the smear layer. However, it is for the clinician to pick the right device intended for the situation and use it efficiently to accomplish the task of prolonging the longevity of each diseased tooth in the stomatognathic system.

CONCLUSION

Within the limitations of this study, it can be concluded that,

- SmearClear and 10% citric acid produces better removal of smear layer from prepared root canals compared to 3% NaOCl.
- Passive Ultrasonic agitation of SmearClear produces the cleanest canal walls compared to Manual Dynamic activation and Canal Brush agitation
- Canal Brush agitation and Manual Dynamic activation can be used effectively as irrigant agitation techniques compared to conventional syringe irrigation
- Canal Brush agitation produced significantly cleaner canal walls compared to Manual Dynamic activation

REFERENCES

1. Peters OA Current challenges and concepts in the preparation of root canal systems: a review. J Endod. 2004; 30(8):559-67.
2. McComb D, Smith DC.A preliminary scanning electron microscopic study of root canals after endodontic procedures. J Endod. 1975; 1(7):238-42.
3. Mader CL, Baumgartner JC, Peters DD Scanning electron microscopic investigation of the smeared layer on root canal walls. J Endod. 1984; 10(10):477-83.
4. Baker N, Eleazer P, Averbach R, et al. Scanning electron microscopic study of the efficacy of various irrigating solutions. J Endod 1975; 1:27–35.
5. Sen BH, Wesselink PR, Türkün M. The smear layer: a phenomenon in root canal therapy. Int Endod J. 1995; 28 (3):141-8.

6. Goldberg F, Abramovich A. Analysis of the effect of EDTAC on the dentinal walls of the root canal. J Endod. 1977; 3:101–5
7. Haapasalo M, Ørstavik D. In vitro infection and disinfection of dentinal tubules. J Dent Res.1987; 66: 1375–9.
8. Lester KS, Boyde A Scanning electron microscopy of instrumented, irrigated and filled root canals. British Dent J 1977; 143: 359–67.
9. White RR, Goldman M, Lin PS. The influence of the smeared layer upon dentinal tubule penetration by endodontic filling materials. Part II. J Endod 1987; 13: 369–74.
10. Violich DR, Chandler NP. The smear layer in endodontics - a review. Int Endod J. 2010; 43(1):2-15.
11. Gu LS, Kim JR, Ling J, Choi KK, Pashley DH, Tay FR. Review of contemporary irrigant agitation techniques and devices. J Endod. 2009 ; 35(6):791-804
12. Zhang K, Kim YK, Cadenaro M, Bryan TE, Sidow SJ, Loushine RJ, Ling JQ, Pashley DH, Tay FR. Effects of different exposure times and concentrations of sodium hypochlorite/ethylenediaminetetraacetic acid on the structural integrity of mineralized dentin. J Endod. 2010; 36 (1) :105-9.
13. Ciucchi B, Khettabi M, Holz J. The effectiveness of different endodontic irrigation procedures on the removal of the smear layer: a scanning electron microscopic study. Int Endod J. 1989; 22:21–8.
14. Peters OA, Barbakow F. Effects of irrigation on debris and smear layer on canal walls prepared by two rotary techniques: a scanning electron microscopic study. J Endod. 2000; 26:6–10
15. Dunavant TR, Regan JD, Glickman GN, Solomon ES, Honeyman AL. Comparative evaluation of endodontic irrigants against Enterococcus faecalis biofilms. J Endod.2006; 32(6):527-31.
16. Lui JN, Kuah HG, Chen NN. Effect of EDTA with and without surfactants or ultrasonics on removal of smear layer. J Endod. 2007; 33(4):472-5.
17. da Silva LA, Sanguino AC, Rocha CT, Leonardo MR, Silva RA. Scanning electron microscopic preliminary study of the efficacy of SmearClear and EDTA for smear layer removal after root canal instrumentation in permanent teeth. J Endod. 2008; 34(12):1541-4
18. Machado-Silveiro LF, Gonzalez-Lopez S, Gonzalez-Rodriguez MP. Decalcification of root canal dentine by citric acid, EDTA and sodium citrate. Int Endod J. 2004; 37: 365–9.
19. Baumgartner JC, Brown CM, Mader CL, et al. A scanning electron microscopic evaluation of root canal debridement using saline, sodium hypochlorite, and citric acid. J Endod. 1984; 10:525–31.
20. Wayman BE, Kopp WM, Pinero GJ, et al. Citric and lactic acids as root canal irrigants in vitro. J Endod. 1979; 5:258–65.
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; 33:46–52.
22. McGill S, Gulabivala K, Mordan N, Ng YL. The efficacy of dynamic irrigation using a commercially available system (RinsEndo) determined by removal of a collagen 'bio-molecular film' from an ex vivo model. Int Endod J. 2008; 41 (7):602-8.
23. Huang TY, Gulabivala K, Ng YLA bio-molecular film ex-vivo model to evaluate the influence of canal dimensions and irrigation variables on the efficacy of irrigation. Int Endod J. 2008 ; 41(1):60-71
24. GaripY, Sazak H, Gunday M, Hatipoglu S. Evaluation of smear layer removal after use of canalbrush: an SEM study. Oral Surg Oral Med Oral Pathol 2010; 110: e62-e66
25. Weise M, Roggendorf MJ, Ebert J, Petschelt A, Frankenberger R. Four methods for cleaning simulated lateral extensions of curved root canals: a SEM evaluation. Int Endod J 2007; 40: 991–2.
26. Weller RN, Brady JM, Bernier WE. Efficacy of ultrasonic cleaning. J Endod. 1980; 6: 740–3.
27. 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; 25:735–8.
28. Ahmad M, Pitt Ford TJ, Crum LA. Ultrasonic debridement of root canals: acoustic streaming and its possible role. J Endod 1987; 13:490–9.
29. Ahmad M, Pitt Ford TR, Crum LA, Walton AJ. Ultrasonic debridement of root canals: acoustic cavitation and its relevance. J Endod. 1988; 14:486–93.
30. van der Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J. 2007; 40:415–26.
31. Paragliola R, Franco V, Fabiani C, Mazzoni A, Nato F, Tay FR, Breschi L, Grandini S. Final rinse optimization: influence of different agitation protocols. J Endod 2010 ; 36(2): 282-5

32. Caron G, Nham K, Bronnec F, Machtou P. Effectiveness of different final irrigant activation protocols on smear layer removal in curved canals. J Endod 2010; 36(8):1361-6
33. Kuah HG, Lui JN, Tseng PS, Chen NN. The effect of EDTA with and without ultrasonics on removal of the smear layer. J Endod. 2009; 35(3):393-6
34. Zehnder M, Schmidlin P, Sener B, Waltimo T. Chelation in root canal therapy reconsidered. J Endod. 2005; 31(11):817-20.
35. Dalton BC, Orstavik D, Phillips C, Pettiette M, Trope M. Bacterial reduction with nickel-titanium rotary instrumentation. J Endod. 1998; 24(11):763-7.
36. Zehnder M. Root canal irrigants. J Endod. 2006; 32(5):389–398.
37. Baumgartner JC, Cuemin PR. Efficacy of several concentrations of sodium hypochlorite for root canal irrigation. J Endod. 1992; 18: 605-612.
38. Khedmat S, Shokouhinejad N. Comparison of the efficacy of three chelating agents in smear layer removal. J Endod. 2008; 34(5):599-602.
39. Foschi F, Nucci C, Montebugnoli L, Marchionni S, Breschi L, Malagnino VA, Prati C. SEM evaluation of canal wall dentine following use of Mtwo and ProTaper NiTi rotary instruments. Int Endod J. 2004; 37 (12):832-9
40. Chow TW. Mechanical effectiveness of root canal irrigation. J Endod.1983; 9 (11):475-9.
41. Falk KW, Sedgley CM. The influence of preparation size on the mechanical efficacy of root canal irrigation in vitro. J Endod. 2005; 31(10):742-5.
42. Khademi A, Yazdizadeh M, Feizianfard M. Determination of the minimum instrumentation size for penetration of irrigants to the apical third of root canal systems. J Endod. 2006; 32(5):417-20.
43. Plotino G, Grande NM, Melo MC, Bahia MG, Somma F. Mechanical properties and dimensional characterisation of Roeko CanalBrush. Int Endod J 2009; 42:1159.
44. Cotton R Introduction :smear layer on dentin .Oper Dent 1984 ;9:1-3
45. Hülsmann M, Rümmelin C, Schäfers F. Root canal cleanliness after preparation with different endodontic handpieces and hand instruments: a comparative SEM investigation. J Endod. 1997; 23(5):301-6.