Dental Research Journal

Original Article

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

Ankur Dua, Deepti Dua

Department of Restorative Dentistry and Endodontics, Ibn Sina National College of Medical Studies, Jeddah, Kingdom of Saudi Arabia

Received: June 2013
Accepted: November 2013

Address for correspondence:
Dr. Ankur Dua,
Department of Restorative Dentistry and Endodontics, Ibn Sina National College of Medical Studies, Al Mahjar Street, Jeddah 21418, Kingdom of Saudi Arabia.
E-mail: ankurdua@gmail.com

ABSTRACT

Background: The purpose of this study was to compare the efficacy of EndoVac irrigation system and side-vented closed ended needle (Max-I probe) in removing smear layer from root canals at 1 mm and 3 mm from working length using ProTaper rotary instrumentation.

Materials and Methods: A total of 50 freshly extracted maxillary central incisors were randomly divided into two groups after complete cleaning and shaping with ProTaper rotary files. In one group, final irrigation was performed with EndoVac system while in other group, final irrigation was done with a 30 gauge Max-I probe. 3% sodium hypochlorite (NaOCl) and 17% ethylenediaminetetracetic acid were used as final irrigants in all teeth. During instrumentation, 1 ml of 3% NaOCl was used for irrigation after each rotary instrument in the similar manner as in final irrigation. After instrumentation and irrigation, teeth were sectioned longitudinally into buccal and palatal halves and viewed under scanning electron microscope for evaluation of smear layer. Statistical analysis was performed using Kruskal-Wallis and Mann-Whitney U-test. ($P < 0.05$)

Results: At 3 mm level, there was no significant difference between two groups. At 1 mm level, EndoVac group showed significantly better smear layer removal compared with Max-I probe ($P = 0.0001$).

Conclusion: EndoVac system results in better smear layer removal at 1 mm from working length when compared to Max-I probe irrigation.

Key Words: EndoVac, Max-I probe, root canal irrigation, scanning electron microscope, smear layer

INTRODUCTION

Successful endodontic treatment depends amongst other factors on the effective removal of smear layer from root canals through chemo-mechanical instrumentation.[1] Various root canal irrigants have been introduced and most of them have satisfactory properties. Past studies have shown that combination of 5.25% sodium hypochlorite (NaOCl) and 17% ethylene diamine tetraacetic acid (EDTA) is quite effective in flushing out debris and smear layer from root canals.[1,2] However, none of the irrigants with the conventional irrigation system are effective in cleaning the apical 1 mm of root canal, which has maximum anatomical areas that are the most difficult and critical to debride.[3-6]

Many problems are associated with the conventional irrigation systems used. The irrigant is delivered with a syringe and needle and is expressed under positive pressure into the canals. It has been shown that the irrigant doesn't go more than 1 mm beyond the needle tip, so the apical few millimeters are never irrigated.[7,8] To make the irrigant reach the apical 1-2 mm, needle should go close to the working

Access this article online

Website: http//:drj.mui.ac.ir

length,[9] which in turn increases the risk of apical extrusion of irrigant. The commonly used irrigant, NaOCl is very toxic to the surrounding tissues and causes acute symptoms if forced beyond the apex.[10]

The mechanical cleaning and shaping has also improved with rotary Ni-Ti files. However, it was found that debris is always present in the apical 1 mm.[11,12] This is because the irrigant never reaches the apical most few millimeters.

Various newer irrigation systems have been introduced to increase the mechanical flushing action of irrigants for better removal of smear layer, which was not possible with conventional syringe irrigation with needles and cannulas. Recently, a 30 G irrigation needle covered with a brush (NaviTip FX) (Ultradent Products Inc, South Jordan, UT, USA) was introduced.[13] There have been machine assisted agitation systems (CanalBrush) (Coltene/Whaledent GmbH + Co. KG, Germany), Quantec-E irrigation system which allows for continuous irrigation agitation during rotary instrumentation. However, the literature shows no significant difference in smear layer removal with these systems when compared with syringe needle irrigation.[13] There has been continuous quest to introduce irrigation systems that can allow irrigant to reach the apical few millimeters. The EndoVac system is another new irrigation system which uses negative pressure to draw the irrigant down the canal to the apex and claims to deliver the irrigant in the apical 1-2 mm without any risk of perfusion of irrigant beyond the apex.[14]

Max-I probe is a needle with a closed end and a side-port, which is said to deliver the irrigant in the apical third without the risk of perfusion beyond the apex.[9] A 30 gauge Max-I probe was used in the present study.

The present *in-vitro* study is an attempt to compare the efficacy of EndoVac irrigation system to Max-I probe irrigation in removal of smear layer from root canals at 1 mm and 3 mm from working length using ProTaper rotary instrumentation.

MATERIALS AND METHODS

A total of 50 freshly extracted intact, non-carious, human permanent maxillary incisor teeth were selected for the study. Teeth with straight and single patent root canal and without any anatomical variations, no visible root caries and no signs of external or internal resorption and with completely formed apices were used in the study. Pre-operative radiographs were taken, which were screened and any teeth that did not meet the required criteria were excluded from the study. The external surfaces of the teeth were debrided using ultrasonic scalers and stored in sterile saline solution at room temperature. Each tooth was numbered on the buccal and palatal surfaces of the root. A flat occlusal surface was made as a reference for determining working length and pulp chamber of each tooth was accessed. A #15 K-file (Kendo, VDW, Germany) was then introduced into the root canal until its tip was just visible at the apical foramen. The working length for the preparation was determined by deducting 1 mm from the length recorded when the file was just visible at the apex of root. Root apices were covered with sticky wax to create closed end canal model that more accurately simulates *in-vivo* situations by creating vapor-lock effect. Cleaning and shaping of all teeth was done by using Gates Glidden drills and ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) rotary files. Coronal portion of the canal was flared using Gates-Glidden drills 1-3. ProTaper rotary files were used for preparation of middle and apical third. All teeth were enlarged to master apical file size of 50 by using F5 file of Protaper rotary system to minimize the confounding factor of differences in remaining tissue after mechanical preparation. To ensure patency, recapitulation to working length was done after instrumentation with a #50 K file. During instrumentation, 1 ml of 3% NaOCl (Vishal Dentocare, Ahmedabad, India) was used at each change of file. In case of EndoVac system, the master delivery tip was use to replenish the pulp chamber while a 30G Max-I probe was used in Group B. A conventional needle replenished the irrigant in pulp chamber in control group. Samples were randomly divided in 3 groups depending on the type of irrigation system used for final irrigation.

Group A (positive control): No final irrigation was done after instrumentation was completed (n = 10).

Group B: Final irrigation was done using 30 G MAX-I probe (Dentsply Rinn, York, PA, USA) and a syringe. After instrumentation was completed, 30 s of irrigation was done with 3 ml of 17% EDTA (Canalarge, Ammdent, India) keeping the needle just short of binding point but no closer than 2 mm from working length. Then 3 cycles of irrigation was done using 3% NaOCl, 17% EDTA and 3% NaOCl. The irrigation needle was placed at working length,

irrigation with NaOCl for 30 s was accomplished. The irrigant was then left undisturbed in the canal for 60 s. This was followed by irrigation with EDTA for 30 s and then left undisturbed for 60 s. The last irrigant was NaOCl using the same method for same amount of time. A small (1-2 mm), constant apico-coronal movement of the needle was maintained during expression of irrigant by moving the needle from full working length to 2 mm short of working length and then back to full working length (n = 20).

Group C: Final irrigation was done using EndoVac (Discus Dental Smart Endodontics, USA) irrigation system. After instrumentation was completed, 30 s of irrigation was done with 1 ml 17% EDTA using macrocannula. This was done by using the EndoVac delivery/evacuation tip at the canal orifice while the macrocannula was constantly moved up and down in the canal from the point where it started to bind to the point just below the canal orifice. Then 3 cycles of microirrigation was done by using 3 ml each of 3% NaOCl, 17% EDTA and 3% NaOCl. During a cycle of microirrigation, the pulp chamber was maintained full of irrigant while microcannula was placed at working length for 6 s and then moved in apico-coronal direction until 30 s had elapsed. The irrigant was then left undisturbed for 60 s. This completed one microirrigation cycle. Similarly the other two cycles of microirrigation were performed (n = 20).

The canals were dried with absorbent paper points and the entrance to each of the canals was protected with a cotton pellet to prevent penetration of the dentinal debris into the canals during decoronation. A #15 K-file with rubber stopper set at working length was placed on external surface of the tooth and working length was marked with scalpel. Teeth were then marked at 1 mm and 3 mm from working length with a scalpel. Using diamond discs with water, the crown was removed at cement enamel junction and deep grooves were made on the buccal and palatal surfaces of the roots without perforating the canal. The roots were then split longitudinally using a chisel. One half of each root was selected for examination under scanning electron microscope (SEM) (Cambridge, Sterioscan 360, Cambridge, UK).

After assembly on coded stubs, the specimens were gold sputtered and examined under a SEM. The dentinal wall of the apical 1 mm and 3 mm was observed for the presence/absence of smear layer. Photomicrographs were taken of the canal walls at 1 and 3 mm from the working length of each specimen at ×1000 magnification. These photomicrographs were evaluated individually by an examiner, who was blind to the irrigation regimens and scores were attributed according to the following scoring criteria developed by Mayer *et al*. in 2003.[7]

Smear layer

Score 1: All dentinal tubules are open and no smear layer present.

Score 2: Some dentinal tubules are open and others covered by thin smear layer.

Score 3: A few dentinal tubules are open and others covered by thin homogenous smear layer.

Score 4: All dentinal tubules are covered by a homogenous smear layer without any open tubules visible.

Score 5: Thick homogenous layer completely covering the canal walls.

Attributed scores were tabulated and submitted to statistical analysis. Mann-Whitney U test and non-parametric tests such as Kruskal-Wallis test were used for comparisons between the various groups ($P < 0.05$).

RESULTS

Table 1 shows mean and standard deviation for three groups at 1 mm and 3 mm levels. The control group shows highest smear layer scores at both 1 mm and 3 mm from working length [Table 1]. At 3 mm level, there was no significant difference between EndoVac and Max-I group in removal of smear layer from root canals (P = 0.5416) [Table 2]. However, at 1 mm level, EndoVac system showed significantly cleaner root canals when compared to needle irrigation (P = 0.0001) [Table 3]. Figures 1-3 show representative SEMphotographs for groups A, B and C respectively at 1 mm and 3 mm level.

Table 1: Mean and standard deviation of smear layer score at 1 mm and 3 mm from working length in groups A, B, C

Groups	1 mm			3 mm		
	Means	SD	Median	Means	SD	Median
A	5.00	0.00	5	5.00	0.00	5
B	3.80	0.79	4	1.20	0.42	1
C	1.20	0.42	1	1.10	0.32	1

A: Control; B: Max-I probe; C: EndoVac system; SD: Standard deviation

Table 2: Pair wise comparison of three groups A, B, C with respect to smear layer scores at 3 mm by Mann-Whitney U-test

Groups	Means	SD	Median	Sum of ranks	U value	Z value	*P* value
A	5.00	0.00	5.00	65.00	0.00	−3.3968	0.0007*
B	1.20	0.42	1.00	55.00			
A	5.00	0.00	5.00	65.00	0.00	−3.5355	0.0004*
C	1.10	0.32	1.00	55.00			
B	1.20	0.42	1.00	110.00	45.00	−0.6104	0.5416
C	1.10	0.32	1.00	100.00			

*$P < 0.05$. SD: Standard deviation

Table 3: Pair wise comparison of three groups (A, B, C) with respect to smear layer scores at 1 mm by Mann-Whitney U-test

Groups	Means	SD	Median	Sum of ranks	U value	Z value	*P* value
A	5.00	0.00	5.00	60.00	5.00	−2.6348	0.0084*
B	3.80	0.79	4.00	60.00			
A	5.00	0.00	5.00	65.00	0.00	−3.3968	0.0007*
C	1.20	0.42	1.00	55.00			
B	3.80	0.79	4.00	155.00	0.00	−3.9399	0.0001*
C	1.20	0.42	1.00	55.00			

*$P<0.05$. SD: Standard deviation

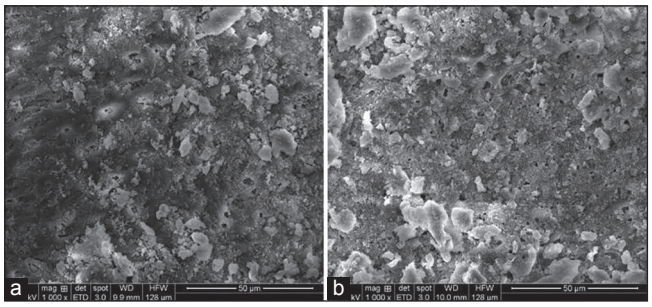

Figure 1: Representative scanning electron microscope photographs (a) Group A (positive control) at 1 mm from working length (b) Group A (positive control) at 3 mm from working length

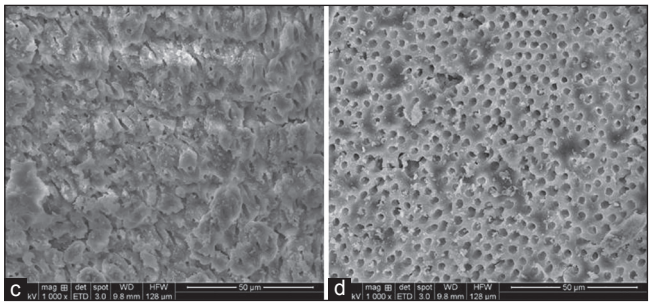

Figure 2: (c) Group B (Max-I probe) at 1 mm from working length (d) Group B (Max-I probe) at 3 mm from working length

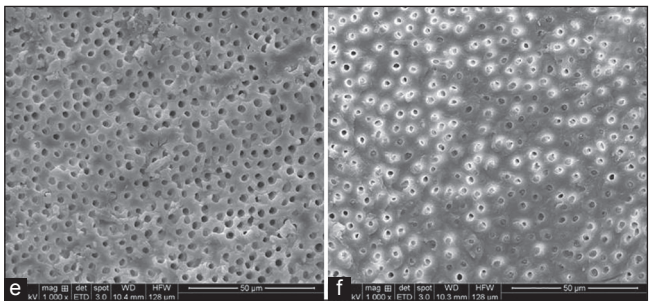

Figure 3: (e) Group C (EndoVac system) at 1 mm from working length (f) Group C (EndoVac system) at 3 mm from working length

DISCUSSION

The ultimate goal of root canal preparation is canal debridement to promote apical healing.[15] After biomechanical preparation, a layer of debris composed of organic and inorganic material is formed on root canal walls, obliterating the dentinal tubule entrances and root canal ramifications.[16] The smear layer may prevent or delay considerably the penetration of antimicrobial agents into the dentinal tubules[17] as well as interfere with the adhesion of root canal sealers to the canal walls, thus compromising the quality of obturation.[18,19] Various methods have been employed to eliminate debris and smear layer from root canal; however, none of the methods employed completely eliminate smear layer from apical 1 mm of root canal.[20-22]

NaOCl is the most widely used chemical solution in the biomechanical preparation of root canal system.[23] However, despite its excellent antimicrobial activity and capacity of dissolving organic materials, this solution alone does not effectively remove the smear layer.[23,24] The association of EDTA and NaOCl solutions has proved to be effective in removing smear layer.[3] EDTA acts upon the inorganic components of the smear layer while NaOCl dissolves the collagen, leaving the entrances to the dentinal tubules more open and exposed. Studies have shown that the use of a high volume final flush with 17% EDTA followed by NaOCl effectively removes the smear layer.[25] However, none of the irrigants with the conventional irrigation system are effective in cleaning the apical one-third of root canal.[2]

Various irrigation systems have been developed, which claim to work effectively in apical third of root canal.[13]

In the present study, both EndoVac system and Max-I probe allowed for better smear layer removal

from the root canal when compared with the control group. EndoVac system produced significantly cleaner canals at 1 mm from working length compared with Max-I probe. This can be attributed to the design of EndoVac microcannula and the placement of the 12 suction holes along the side of the last 0.07 mm of the microcannula. As the apical size increases, there are decreased chances of these holes contacting the root canal wall and becoming blocked. The larger area surrounding the microcannula also allows for increased volume of irrigant to the microcannula tip and a resulting increase in volume.[26]

Another factor that supports the better cleaning efficacy of EndoVac in apical 1 mm from working length when compared with Max-I probe is the vapor lock effect. The presence of apical vapor lock created by the organic decomposition of NaOCl into a bubble of carbon dioxide and ammonium adversely affects debridement efficacy when using positive pressure system.[27] In the closed system, irrigant extrusion beyond 1-1.5 mm of a side-venting needle could generate a liquid film along the air bubble-canal wall interface.[28] The fluid stagnation in this "dead water zone" (apical area where the solutions are not exchanged by irrigation) fails to provide adequate irrigant replacement, resulting in gross debris retention in this region. Furthermore, irrigation with an acidic or calcium chelating agent creates a demineralized collagen matrix on the surface of radicular dentin on removal of the smear layer.[29] In the absence of strong turbulent fluid flow, debris particles could be trapped by this porous interlacing fibrillar network as they were displaced by the irrigant toward the orifice.[27] The design of micro-cannula eliminates this vapor-lock effect, thus allowing apical exchange of irrigants. Moreover, macrocannula removes as much debris as possible before microcannula is used, thus allowing better action of the latter and preventing the chances of blockage of the micro-cannula.

At 3 mm level, both Max-I probe and EndoVac showed statistically insignificant difference since both the systems were able to deliver irrigant at this level due to the sufficient apical enlargement in our study. This can also be attributed to the design of the Max-I probe. The dispersal of the irrigating solution through the side-port in the cannula of Max-I probe creates an upward turbulent motion around and beyond the end of the probe, which thoroughly irrigates the root canal preparation and also prevents solution and debris from being expressed through the periapical foramen. These results were in accordance with other studies, which concluded that side-vented needles were effective in coronal and middle thirds debridement.[30]

However, our study did not include irrigation with EndoVac system and Max-I probe in curved and narrow canals. EndoVac system requires a minimum canal shape of at least a #35 instrument with a 4% taper, or with a non-tapered system like lightspeed, a size #45 at full working length since the microcannula's diameter is 0.32 mm.[31] As widely demonstrated in the literature, root canal apical diameters are frequently equal to if not greater than 0.35 mm. Thus in theory, there should be few canals where positioning the microcannula at full working length would not be practical. In these cases, the use of non-tapered instruments such as lightspeed LSX become invaluable.[32] In long canals like those typically found in the upper canines, a 31 mm microcannula can be used.

Thus, further studies should emphasize on smear layer removal efficacy of these irrigation systems in canals which cannot be prepared to large apical sizes.

The results of the present study showed that EndoVac irrigation system is an effective root canal irrigation system for the removal of intracanal debris and smear layer in apical area. Nevertheless, these *in vitro* results cannot be extrapolated to *in vivo* situations. Hence, further research is required and more *in vivo* studies need to be done to evaluate this method of irrigation.

CONCLUSION

Within the limitations of the present study, it could be concluded that both irrigation systems (EndoVac and Max-I probe) are effective in removal of smear layer at 3 mm level. However, the apical negative pressure system (EndoVac) used in the study is significantly more effective than the side-vented closed ended needle (Max-I probe) in removal of smear layer at apical 1 mm level.

ACKNOWLEDGMENTS

The authors deny any conflicts of interest. The authors would like to thank Dr. Beena Rani Goel for providing the EndoVac system for this study. We also wish to thank Mr. Gurulingam, Indian Institute of Science, Bangalore for technical assistance and Mr. Shivalingappa Javali for assistance in statistical analysis.

REFERENCES

1. Crumpton BJ, Goodell GG, McClanahan SB. Effects on smear layer and debris removal with varying volumes of 17% REDTA after rotary instrumentation. J Endod 2005;31:536-8.
2. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod 1987;13:147-57.
3. 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;38:285-90.
4. Khedmat S, Shokouhinejad N. Comparison of the efficacy of three chelating agents in smear layer removal. J Endod 2008;34:599-602.
5. Senia ES, Marshall FJ, Rosen S. The solvent action of sodium hypochlorite on pulp tissue of extracted teeth. Oral Surg Oral Med Oral Pathol 1971;31:96-103.
6. Baker NA, Eleazer PD, Averbach RE, Seltzer S. Scanning electron microscopic study of the efficacy of various irrigating solutions. J Endod 1975;1:127-35.
7. Mayer BE, Peters OA, Barbakow F. Effects of rotary instruments and ultrasonic irrigation on debris and smear layer scores: A scanning electron microscopic study. Int Endod J 2002;35:582-9.
8. Ram Z. Effectiveness of root canal irrigation. Oral Surg Oral Med Oral Pathol 1977;44:306-12.
9. Kahn FH, Rosenberg PA, Gliksberg J. An *in vitro* evaluation of the irrigating characteristics of ultrasonic and subsonic handpieces and irrigating needles and probes. J Endod 1995;21:277-80.
10. Witton R, Henthorn K, Ethunandan M, Harmer S, Brennan PA. Neurological complications following extrusion of sodium hypochlorite solution during root canal treatment. Int Endod J 2005;38:843-8.
11. Jeon IS, Spångberg LS, Yoon TC, Kazemi RB, Kum KY. Smear layer production by 3 rotary reamers with different cutting blade designs in straight root canals: A scanning electron microscopic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:601-7.
12. 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.
13. Gu LS, Kim JR, Ling J, Choi KK, Pashley DH, Tay FR. Review of contemporary irrigant agitation techniques and devices. J Endod 2009;35:791-804.
14. Nielsen BA, Craig Baumgartner J. Comparison of the EndoVac system to needle irrigation of root canals. J Endod 2007;33:611-5.
15. Bystrom A, Happonen RP, Sjogren U, Sundqvist G. Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. Endod Dent Traumatol 1987;3:58-63.
16. Orstavik D, Haapasalo M. Disinfection by endodontic irrigants and dressings of experimentally infected dentinal tubules. Endod Dent Traumatol 1990;6:142-9.
17. Lynne RE, Liewehr FR, West LA, Patton WR, Buxton TB, McPherson JC. *In vitro* antimicrobial activity of various medication preparations on *E. faecalis* in root canal dentin. J Endod 2003;29:187-90.
18. Shahravan A, Haghdoost AA, Adl A, Rahimi H, Shadifar F. Effect of smear layer on sealing ability of canal obturation: A systematic review and meta-analysis. J Endod 2007;33:96-105.
19. 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;25:123-5.
20. Moodnik RM, Dorn SO, Feldman MJ, Levey M, Borden BG. Efficacy of biomechanical instrumentation: A scanning electron microscopic study. J Endod 1976;2:261-6.
21. Moorer WR, Wesselink PR. Factors promoting the tissue dissolving capability of sodium hypochlorite. Int Endod J 1982;15:187-96.
22. Abed AM, Farhad SZ, Farhad A, Barekatain M, Mafi M, Abooie MS. Debris and smear layer removal efficacy and changes in morphology of dentinal tubules after using citric acid, tetracycline-hydrochloride and mixture of tetracycline and acid and detergent. Dent Res J (Isfahan) 2013;10:232-7.
23. 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;34:1541-4.
24. Pérez-Heredia M, Ferrer-Luque CM, González-Rodríguez MP. The effectiveness of different acid irrigating solutions in root canal cleaning after hand and rotary instrumentation. J Endod 2006;32:993-7.
25. 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;9:137-42.
26. Brunson M, Heilborn C, Johnson DJ, Cohenca N. Effect of apical preparation size and preparation taper on irrigant volume delivered by using negative pressure irrigation system. J Endod 2010;36:721-4.
27. Tay FR, Gu LS, Schoeffel GJ, Wimmer C, Susin L, Zhang K, *et al*. Effect of vapor lock on root canal debridement by using a side-vented needle for positive-pressure irrigant delivery. J Endod 2010;36:745-50.
28. Liao Q, Zhao TS. Modeling of Taylor bubble rising in a vertical mini noncircular channel filled with a stagnant liquid. Int J Multiphase Flow 2003;29:411-34.
29. Tay FR, Gutmann JL, Pashley DH. Microporous, demineralized collagen matrices in intact radicular dentin created by commonly used calcium-depleting endodontic irrigants. J Endod 2007;33:1086-90.
30. Uroz-Torres D, González-Rodríguez MP, Ferrer-Luque CM. Effectiveness of the EndoActivator System in removing the smear layer after root canal instrumentation. J Endod 2010;36:308-11.
31. Schoeffel GJ. The EndoVac method of endodontic irrigation: Part 4, Clinical use. Dent Today 2009;28:64, 66-7.
32. Baugh D, Wallace J. The role of apical instrumentation in root canal treatment: A review of the literature. J Endod 2005;31:333-40.

How to cite this article: Dua A, Dua D. 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. Dent Res J 2015;12:38-43.
Source of Support: Nil. **Conflict of Interest:** None declared.