Comparative Evaluation of the Efficacy of EndoVac and Conventional Irrigating Systems in Primary Molars – An *in Vitro* Study

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Objective: *The present study was undertaken to evaluate and compare the apical extrusion of irrigant and depth of irrigant penetration into the dentinal tubules using the EndoVac irrigating system and the manual irrigation system in primary molar teeth.* ***Study design:*** *Twenty five extracted primary molars satisfying the inclusion and exclusion criteria were divided into two groups of 29 roots in each group with an equal distribution of apical foramen area. The teeth were mounted in pre-weighed glass bottles and the canals were irrigated with both the irrigating systems using 5.25% sodium hypochlorite solution mixed with acid fuchsin which enables the irrigating solution to penetrate efficiently into the dentinal tubules. The amount of irrigant extruded was recorded. The roots were sectioned at 2mm, 4mm and 6mm from the apex and examine the depth of irrigant penetration into the dentinal tubules under a stereomicroscope.* ***Results:*** *Apical extrusion of the irrigant was significantly less with the EndoVac system (1.18±1.04gms) when compared to manual irrigation system (2.3±1.55gms) (P<0.05). EndoVac irrigation system showed greater depth of irrigant penetration into the dentinal tubules (49.90±17.52mm, 32.17±12.20mm and 15.70±8.91mm) compared to the manual irrigation system (30.48±16.27mm, 14.74±9.67mm and 5.59±7.09mm) at 6mm, 4mm and 2mm respectively (P<0.05). Results showed that the depth of irrigant penetration into the dentinal tubules with both the irrigating systems was found to be significantly greater in the six mm sections compared to the four mm and two mm sections (P<0.05).* ***Conclusion:*** *The EndoVac irrigation system showed significantly greater efficacy compared to the manual irrigation system in primary molars with less amount of irrigant extrusion and better depth of irrigant penetration into the dentinal tubules.*

Key words: EndoVac Apical extrusion, irrigating syringe, irrigant penetration.

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INTRODUCTION

It has become increasingly clear that the largest portion of endodontic success depends upon the ability to remove microorganisms and prevent reinfection, though mechanical and manual root canal debridement . The variations in root canal anatomy of primary molars with widely divergent and curved roots holds the difficulty in achieving a thorough debridement of the necrotic tissue. This is usually not possible to achieve by instrumentation alone but also requires copious irrigation with a suitable irrigant that cleans the root canal system by eradicating the intraradicular microbial infection along with an appropriate biocompatible seal.[1]

Chemomechanical debridement helps in elimination of pulpal tissue, microbiota and by-products and organic and inorganic. To achieve this objective, selection of an appropriate irrigant delivered through an effective and safe irrigating system is essential.[2]

Endeavors have consistently been made to develop more effective irrigant delivery systems which can be broadly categorized as manual agitation and machine assisted agitation techniques for the purpose of root canal irrigation. Manual irrigation includes positive pressure irrigation, NaviTip and Max-I-Probe and manual dynamic irrigation. Machine assisted irrigation devices include sonic as well as ultrasonic devices like the EndoActivator, Vibringe, RinsEndo and ProUltra PiezoFlow System.[3]

One such system is the EndoVac irrigation system which was introduced in 2006 and works on the principle of apical negative pressure. It consists of two cannulas, a macro-cannula which is used for gross initial flushing of the coronal part of the root canal and a micro-cannula for irrigation and cleansing of the apical part of the root canal. The cannula generates a negative apical pressure which pulls irrigant from the chamber down the canal to the tip of the cannula, thus ensuring a constant flow of irrigant up to the working length which helps in better debridement of the apical third of the canals. It also avoids air entrapment and is also advantageous in its ability to safely deliver irrigants up to the working length without causing their undue extrusion into the periapex.[4] Its efficacy has been proven in studies done on permanent teeth for obtaining thorough disinfection through debris and smear layer removal when used in a closed system.[5,6] But limited literature is available for its use in primary teeth.

Hence the present study was undertaken to assess the efficacy of the EndoVac irrigating system over the conventional irrigating system by assessing the amount of extruded irrigant from the periapical foramen as well as the penetration depth of the irrigant into the dentinal tubules with the help of dye penetration as a marker in primary molar teeth.

MATERIALS AND METHOD

A total of 25 freshly extracted primary molar teeth which satisfied the inclusion criteria were used in the study. Primary molar teeth with reasonable amount of crown and root structure, with no or minimum amount of root resorption and teeth with full/more than 2/3rd of root length and normal root morphology were included in the study. Teeth with obliterated root canal systems, teeth with resorption extending to approximately more than one third the root length and teeth with abnormal root anatomy were excluded from the study. The entire protocol followed in the present study was based on the methodology followed by Myers and Montgomery.[7] Also, the evaluation of penetration depth of the irrigant into the dentinal tubules was assessed with the help of dye penetration as a marker based on the dye penetration evaluation model of Hauser , Braun and Frentzen .[8]

Teeth were cleaned of debris using ultrasonic scaler and coronal caries were removed using 330 round burs (Mani Inc., Tochigi, Japan) in a conventional slow speed airotor handpiece. Initially, the occlusal edges of all the teeth were flattened to get a consistent reference point for the determination of working length and canal instrumentation. Hence, in the present study, great care was taken not to instrument to the entire canal length or otherwise up to/beyond the apical foramen in an attempt to prevent significant extrusion of debris through the apical foramen. The roof of the pulp chamber was removed, complete access was gained to the pulp chamber and pulp remnants were carefully extirpated with a fine barbed broach (Mani Inc., Tochigi, Japan) with care taken not to push the broach through the apical foramen.

The apices of the roots were examined and evaluated under a Profilometer (Vibrotech Instruments Pvt. Ltd., Chennai, India) which was connected to a computer-aided measurement system to measure the area of the apical foramen. The evaluated roots were grouped purely based on the pore volume of the apical foramen (Table I) and not based on the length and canal diameter of the roots. Area values were recorded in a database and ranked by increasing order to allow equal distribution of apical foramen areas into two groups of 29 roots in each. For identification, the roots were color coded with insulation tapes and numbered accordingly. The teeth were mounted in holes cut through the lids of empty pre-weighed glass bottles (weighed in Sartorius analytic balance). The glass bottles used for collection were clean and dry. Twenty nine roots of 12 teeth (7 two rooted and 5 three rooted teeth) in Group I were irrigated with the EndoVac irrigating system whereas 29 roots of 13 teeth (10 two rooted and 3 three rooted teeth) in Group II were irrigated with manual irrigating syringe. If the same teeth were to be irrigated with both the irrigating systems, the canal which was to be irrigated with one device was kept patent while that one to be irrigated with the other device was blocked using modeling wax.

In EndoVac group**,** the canals were irrigated with the EndoVac (Kerr Corp., Orange, CA., U.S.A.) system following the recommended protocol.[2] The root canals were prepared to a size 35 using .02 taper K-files (DENTSPLY India Pvt. Ltd., Bangalore, India) using balanced force and crown down pressure less technique which has been proven to extrude the least negligible amount of debris through the apical foramen.[9] Chemomechanical preparation of the canals with simultaneous macro and micro-irrigation of the root canal was done with 5.25% sodium hypochlorite solution (Neelkanth HealthCare Pvt. Ltd., Jodhpur, India) mixed with a dye marker (five grams acid fuchsin crystals (CHENCHEMS Laboratories, Chennai, India) dissolved in 100ml of sodium hypochlorite) after each file used.[6] Macro-irrigation of each canal with 5.25% sodium hypochlorite was accomplished over 30 seconds period using the EndoVac evacuation/delivery tip while the macro-cannula (Figure 1) was constantly moved up and down in the canal from a point where it started to bind to a point just below the orifice. The canal space was then left undisturbed, full of irrigant for sixty seconds. Micro-irrigation was accomplished by using a micro-cannula (Figure 2). During micro irrigation, the pulp chamber had maintained full irrigant with the micro-cannula placed at working length for thirty seconds. After thirty seconds of irrigation, the micro-cannula was withdrawn from the canal in the presence of sufficient irrigant in the pulp chamber to ensure that the canal remained totally filled with irrigant and no air was drawn into the canal space. The canal filled with irrigant was left undisturbed for thirty seconds.

In manual irrigation group, the canals were irrigated short of the binding point with 2ml flush of 5.25% sodium hypochlorite using DISPO VAN single use syringe containing 25mm needle of diameter 0.50mm following every instrumentation so that the canals were left filled with the irrigant between each instrumentation. A small (1-2mm), constant apical-coronal movement of the needle was maintained during expression of irrigant. The irrigant was then left undisturbed in the canal for sixty seconds. The rate of irrigant flow was standardized to 1ml over a period of thirty seconds. The total volume of irrigant used was 10ml for both the groups.

Figure 1: EndoVac Irrigation With Macro-cannula

Figure 2: EndovVac irrigation with micro-cannula

Extruded material was collected into glass bottles which were pre-weighed using Sartorius analytic balance. Literature has shown some amount of debris collection during instrumentation to or beyond the foramen.[10] Therefore, In the present study, the amount of extruded debris was kept significantly lower as the canals were instrumented only up to the apical foramen (and not beyond this point). The weight of extruded irrigant was calculated by subtracting the weight of the glass bottle before irrigation from the weight of the glass bottle after irrigation.

The irrigated teeth were removed from the glass bottles and mounted in self-cure acrylic blocks (3×1cms) and transverse sections were made using a hard tissue microtome at 2, 4 and 6mm from the apex of the canals for both the EndoVac group and manual irrigation group. The transverse cut sections were then examined on a stereomicroscope (Scientico®, Mumbai, India) which was calibrated with an ocular micrometer at 10X magnification to measure and record total dentine thickness and maximum linear dye penetration into dentine in the buccal, lingual, mesial and distal directions.

The two measurements (total dentine thickness and maximum linear dye penetration) were used to determine the percentage of depth of irrigant penetration into the dentinal tubules towards each direction for each section. The values obtained for the four directions on each section were then averaged.

Percentage of irrigant penetration into the dentinal tubules was calculated using the formula:

(Depth of dye penetration/Total dentine thickness) × 100.

Data were statistically analyzed to compare the amount of extruded irrigant and the depth of penetration of irrigant into dentinal tubules using the Student 't' test. The statistical significance was set at $P<0.05$ and the analysis was performed using SPSS version 16.0 software.

Table 1: Sample distribution according to the area of apical foramen (mm)

S. No	ENDOVAC SYSTEM	MANUAL IRRIGATION
1	0.4381	0.4711
2	0.5832	0.7818
3	0.8191	0.8375
4	0.9630	0.9751
5	1.0800	1.0837
6	1.0878	1.0959
7	1.1080	1.1621
8	1.3105	1.3218
9	1.3391	1.3437
10	1.4683	1.4765
11	1.6481	1.7226
12	1.8925	1.9133
13	2.0139	2.0901
14	2.2397	2.2471
15	2.2546	2.2727
16	2.5417	2.5605
17	2.8090	2.8301
18	2.8781	2.8992
19	3.0484	3.0926
20	3.4487	3.4674
21	3.4849	3.5227
22	3.7085	3.7206
23	3.9331	3.9564
24	4.0278	4.0911
25	4.1967	4.3218
26	4.3647	4.4309
27	4.4332	4.4474
28	4.5829	4.633
29	4.7741	4.7984
TOTAL	72.4777	73.5107
RANGE	0.4381 – 4.7741	0.4711 – 4.7984
MEAN±S.D	2.4992 ± 1.3655	2.5349 ± 1.3642

P value = 0.924

RESULTS

There was no significant difference in the apical foramen areas between the two groups and the samples were equally distributed with regard to the apical foramen area (P=0.924 Table 1).

The EndoVac group showed significantly less amount of extrusion when compared with the manual irrigating syringe (P=0.002* Table 2).

Significantly better depth of penetration into the dentinal tubules was seen at the six mm level compared to the four mm level (P=0.000)* and the four mm sections showed better penetration compared to the two mm level (P=0.000)* in both the groups i.e, the depth of irrigant penetration into the dentinal tubules decreased progressively as the irrigant progressed towards the apex. The EndoVac irrigation system resulted in a significantly greater percentage of irrigant penetration into dentin at all the three levels (two mm, four mm and six mm) when compared to manual irrigation system (P=0.000* Table 3).

Table 2: Weight of extruded irrigant with the EndoVac and manual irrigating system (g)

S.NO	ENDOVAC	MANUAL IRRIGATION
1	0.3	0.9
2	0.3	0.7
3	1.5	4.8
4	1.8	1.6
5	2.2	3.8
6	2.1	4.9
7	2.2	2.4
8	0.1	0.3
9	2.1	3.2
10	2.2	4.4
11	0	0.1
12	3.2	3.3
13	3.6	3.6
14	0.2	0.2
15	0.4	0.1
16	0.7	3.2
17	0.6	0.7
18	0	3
19	0.1	2.3
20	0.8	1.5
21	0.2	1.5
22	0.1	0.4
23	2.1	3.8
24	0.8	3.2
25	2.2	0.7
26	0.7	1.5
27	0.2	4.4
28	1.5	3
29	2.1	3.2
TOTAL	34.3	66.7
RANGE	0 .00 – 3.60	0.10 – 4.90
MEAN±S.D	1.18 ± 1.04	2.3 ± 1.55

P value = 0.002*

DISCUSSION

In the present study, apical extrusion of irrigant and the depth of penetration of the irrigant into the dentinal tubules using EndoVac irrigating system were compared with the manual irrigating system in primary molar teeth.

Apical extrusion has been assessed in various studies using different techniques like the photographic technique[11,12], dry weight technique[13] and qualitative assessment.[14] This method was adapted as it was easy to use and convenient without any material loss due to immediate direct weighing of the extruded material with a Sartorius analytic balance.

Various methods such as amount of smear layer removal[15], microbiological assessment, antimicrobial efficacy[16,17], debris removal effect[18] and radiographic technique using contrast media[19] were used to assess the cleaning efficacy of irrigants and irrigating devices. In the present study, dye penetration was used as a marker for penetration of sodium hypochlorite which indicates the amount of cleaning of the canal. But it has not been established beyond doubt that the penetration depth of the dye matched the penetration depth of sodium hypochlorite. It has been reported that the surface tension of sodium hypochlorite limits its ability to spread within the canal.[20] Adding acid fuchsin to sodium hypochlorite might have had an effect on its surface tension, which should be investigated in future studies. Because of the small molecular size of sodium hypochlorite, it might be possible that the penetration depth of sodium hypochlorite was deeper than that of the dye itself. Thus, the advanced front of the irrigant was only detectable indirectly. Therefore, no absolute results were considered, instead a standardized intra-experimental comparison between the experimental group and the comparative group was established.[20] In the present study, depth of penetration of the irrigant into the dentinal tubules was analyzed by transverse cut sections using a hard tissue microtome and examined under a stereomicroscope calibrated with an ocular micrometer.

The present study results showed that irrigant was extruded apically with both the conventional syringe and EndoVac systems. The possible reason could be due to certain anatomical differences in the canal anatomy of primary molar teeth in its apical parts such as the thinner root dentine and flaring of roots as they approach the apex. In contrast to the present study findings, a study done by Desai[2] showed that there was no irrigant extrusion with the EndoVac irrigating system. However the present study shows significantly greater amount of extrusion with the conventional (manual) irrigating technique when compared to the EndoVac group (P=0.002)*. This was in accordance with the studies done by William *et al* [13] and Mitchell *et al* [11,12]

In the present study, the tip of the needle was placed at the working length whereas in other studies, the amount of extrusion was assessed by placing the needle tip at various levels from the apex. The needle design, apical preparation size, method of activation and delivery of sodium hypochlorite into the apical one third of the canal play an important role in the amount of extrusion into the apical tissues.[11] Other influencing factors like canal length, canal morphology and degree of canal curvature should be analyzed in further studies.[13]

In the present study, greater depth of penetration of the irrigant into dentine at all the three levels was recorded with the EndoVac system and compared with the manual irrigating device. However

Table 3: Percentage of penetration depth of the irrigant into dentin.

	ENDOVAC SYSTEM			MANUAL IRRIGATION		
S.NO	6mm	4mm	2mm	6mm	4mm	2mm
1	40.47	23.3	0	3.92	0	0
2	47.727	25	8.84	6	5.26	0
3	21.27	16.67	0	27.7	36.36	6.97
4	45	37.5	32	51.02	9.67	8.33
5	46.1538	30.30	20.0869	32.43	1.47	0
6	38.1352	32	0	20	11.11	0
7	45.9459	30.30	21.73	0	0	0
8	28.57	27.58	16.66	11.9	3.03	3.33
9	10.81	10.71	5.26	8.16	2.5	0
10	96.66	51.85	22.72	50.8	31.03	31.81
11	82.35	65.51	28.57	51.8	30.77	5.55
12	36.66	22.22	18.60	14.70	11.11	8.33
13	56.25	31.25	9.75	30.77	20	0
14	38.09	28.57	20	30	22.22	14.29
15	64.10	32	15	26.67	18.18	10
16	46.54	43.13	22.72	30	18.75	9.38
17	63.82	15.78	11.76	50.2	9.30	7.5
18	56.09	54.83	12	50.6	18.60	0
19	63.33	37.5	12.5	28.12	18.75	7.14
20	26.67	25.92	17.24	21	0	0
21	55.55	30.6	18.75	51.9	21.95	8.33
22	61.09	45.2	34.28	25.49	20	19.44
23	55.55	44.44	11.11	30.36	14.58	0
24	58.82	37.5	28.57	50.5	22.5	7.5
25	57.14	33.33	16.67	22	14.63	5.56
26	64.18	33.30	12.5	50.9	21.43	0
27	50	25	17.857	50	15	0
28	53.84	25	12.5	30.77	17.5	5.56
29	35.71	16.67	7.5	26.09	11.90	3.13
RANGE	10.81–96.66	10.71–65.51	0–34.28	0–51.9	0–36.36	0–31.81
MEAN±S.D	49.90±17.52	32.17±12.20	15.70±8.91	30.48±16.27	14.74±9.67	5.59±7.09

P value = 0.000*

the findings of Neilsen *et al* [4], Siu *et al* [18], Munoz *et al* [19] and Saini M *et al* [20] suggested that the penetration of irrigant with EndoVac was better at 1mm and no difference was noted at 3mm level from apex when compared to the conventional irrigating device. In our study, both the irrigating systems showed better depth of penetration at 6mm from the apex compared to the level of four mm and two mm from the apex. Similar findings were seen in a study done by Hauser *et al* [8] who used RinsEndo system and compared it with the conventional system.

In the present study, dye penetration was not analyzed separately for the buccal, lingual, mesial and distal directions rather an average value was taken after assessing the dye penetration in all the above mentioned directions. Further investigations are warranted on some important parameters such as canal length, diameter and also on the dye penetration separately in all directions during evaluation of root canal irrigation since there is only limited literature available on techniques that consistently remove all debris from canals and isthmuses using an effective irrigating device that minimizes apical extrusion along with better irrigant penetration deep into the dentinal tubules in primary molar teeth.[6]

In spite of the complex root canal anatomy of the primary molar teeth in its apical parts, the EndoVac irrigating system has achieved effective cleaning and disinfection of the root canal, especially in its apical third where the most debris is found which has been proven in studies done by Schoeffel .[21,22] Usually the effectiveness of EndoVac system at all the levels might be attributed to its apical negative pressure which pulls the irrigant down the canal walls towards the apex creating a rapid turbulent current force towards the terminus of the micro-cannula. This mechanism helps it to overcome the vapor lock effect, thus enabling effective irrigation.[20]

Certain anatomical differences in the primary teeth root and dentine holds the difficulty in evaluating the depth of penetration of the irrigant into dentine at all the three levels especially in primary molar teeth compared to permanent teeth. The present study could be the pioneer in showing significantly better depth of penetration of the irrigant into dentine at all the three levels irrigated using the EndoVac system compared with the manual irrigating device in primary molars.

However, there is a controversy regarding its superior efficacy over other conventional irrigation methods, especially in the canal apical third in curved root canals of primary molar teeth. Hence, Future studies must aim at targeting the evaluation of various limitations of EndoVac irrigating system when used in curved root canals of primary molar teeth.

CONCLUSION

From this *in vitro* study, it can be concluded that the EndoVac irrigation system showed significantly less amount of irrigant extrusion compared to the manual irrigation system in primary molar teeth. EndoVac irrigation system demonstrated better depth of irrigant penetration into the dentinal tubules at all the three levels compared to the manual irrigation system while both the irrigating systems showed significantly greater penetration depth of the irrigant into the dentinal tubules at the cervical third compared to the middle and apical third of the roots.

REFERENCES

1. Goerig A.C., Camp J.H. Root canal treatment in primary teeth: a review. Pediatr Dent 5(1): 33-7, 1983.
2. Desai P., Himel V. Comparative safety of various intracanal irrigation systems. J Endod 35(4): 545-9, 2009.
3. Gu L.S., Kim J.R., Ling J., Choi K.K, Pashley D.H., Tay F.R. Review of contemporary irrigation agitation techniques and devices. J Endod 35(6): 791-04, 2009.
4. Nielsen B.A., Craig Baumgartner J. Comparison of the EndoVac system to needle irrigation of root canals. J Endod 33(5): 611-5, 2007.
5. Miller T.A., Baumgartner J.C. Comparison of the antimicrobial efficacy of irrigation using the EndoVac to endodontic needle delivery. J Endod 36(3): 509-11, 2010.
6. Susin L., Liu Y., Yoon J.C., Parente J.M., Loushine R.J., Ricucci D. Canal and Isthmus debridement efficacies of two different irrigant agitation techniques in a closed system. Int Endod J 43: 1077-90, 2010.
7. Myers G.L., Montgomery S. A comparison of weights of debris extruded apically by conventional filing and canal master techniques. J Endod 17(6): 275-9, 1991.
8. Hauser V., Braun A., Frentzen M. Penetration depth of a dye marker into dentine using a novel hydrodynamic system (RinsEndo®). Int Endod J 40: 644-52, 2007.
9. Al-Omari M.A.O., Dummer P.M.H. Canal blockage and debris extrusion with eight preparation techniques. J Endod 21: 154-8, 1955.
10. Martin H., Cunningham W.T. The effect of endosonic and hand manipulation on the amount of root canal material extruded. Oral Surg 53: 611-3, 1982.
11. Mitchell R.P., Yang S.E., Baumgartner J.C. Comparison of apical extrusion of NaOCl using the EndoVac or needle irrigation of root canals. J Endod 36(2): 338-41, 2010.
12. Mitchell R.P., Baumgartner J.C., Sedgley C.M. Apical extrusion of Sodium hypochlorite using different root canal irrigation systems. J Endod 37(12): 1677-81, 2011.
13. Williams C.E., Reid JS, Sharkey SW, Saunders WP. *In vitro* measurement of apically extruded irrigant in primary molars. Int Endod J 28: 221-5, 1995.
14. Fukomoto Y., Kikuchi I., Yoshioka T., Kobayashi C., Suda H. An *ex vivo* evaluation of a new root canal irrigation technique with intracanal aspiration. Int Endod J 39: 93-9, 2006.
15. Peters L.B., Wesselink P.R., Buijs J.F., van Winkelhoff AJ. Viable bacteria in root dentinal tubules of teeth with apical periodontitis. J Endod 27(2): 76-81, 2001.
16. Hockett J.L., Dommisch J.K., Johnson J.D., Cohenca N. Antimicrobial efficacy of two irrigation techniques in tapered and non-tapered canal preparations: An *in vitro* study. J Endod 34(11): 1374-7, 2008.
17. Townsend C., Maki J. An *in vitro* comparison of new irrigation and agitation techniques to ultrasonic agitation in removing bacteria from a simulated root canal. J Endod 35(7): 1040-3, 2009.
18. Siu C., Baumgartner J.C. Comparison of the debridement efficacy of the EndoVac irrigation system and conventional needle root canal irrigation *in vivo*. J Endod 36(11): 1782-5, 2010.
19. Munoz H.R., Camacho-Cuadra K. *In vivo* efficacy of three different endodontic irrigation systems for irrigant delivery to working length of mesial canals of mandibular molars. J Endod 38(4): 445-8, 2012.
20. Saini M., Kumari M., Taneja S. Comparative evaluation of the efficacy of three different irrigation devices in removal of debris from root canal at two different levels: An *in vitro* study. J Conserv Dent 16(6): 509-13, 2013.
21. Schoeffel G.J. The EndoVac method of endodontic irrigation: safety first. Dent Today 26(10): 92-4. 96, 2007.
22. Schoeffel G.J. The EndoVac method of endodontic irrigation, part 2-efficacy. Dent Today 27(1): 86-7. 82, 84, 2008.