Original Article

Comparative Evaluation of Efficacy of Different Irrigating Needles and Devices in Removal of Debris from Apical Third of Root Canal: An *In-vitro* SEM Study

Abstract

Background: Irrigants were required to eliminate the microbes and debris from the intraradicular space and must have direct contact with the entire root canal wall. Therefore, different irrigation methods have been proposed to deliver the irrigant as close as possible to the remote areas of the root canal. **Aim:** The aim of the present study is to evaluate the cleaning efficacy of single-beveled needle, side-vented needle, endovac, and endo-irrigator plus in the removal of debris from apical third of root canal by Scanning Electron Microscope. **Materials and Methods:** Forty single-rooted freshly extracted human permanent mandibular premolars were collected. Root canals were cleaned and instrumented till X2 (25/06) with rotary Protaper Next at working length 1 mm short of the apex. Teeth were randomly divided into four equal groups: Group 1 (n = 10): Endovac, Group 2 (n = 10): Endo irrigator plus, Group 3 (n = 10): Side-vented needle, and Group 4 (n = 10): Single-beveled needle. Irrigation was done with 5.25% NaOCl, followed by 17% ethylenediaminetetraacetic acid. Samples were sectioned and examined under SEM at apical levels. **Statistical Analysis:** Analysis of variance followed by Tukey's *post hoc* test was performed. **Results:** The level of debris removal efficacy is as follows: Endovac > Endo-irrigator plus > Side-vented needle ~ Single-beveled needle. **Conclusion:** Endovac showed the maximum number of debris removal and has better cleaning efficacy in the apical areas of the root canal, followed by Endo irrigator plus, Side-vented needle and Single-beveled needle.

Keywords: *Endovac, endo-irrigator plus, needle irrigation, residual debris*

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Introduction

The abolition of bacterial load from the root canal system is the main goal of the endodontic treatment.[1] Moreover, the importance of chemo-mechanical debridement of the root canal should not be overlooked. The proper delivery of the irrigant helps to achieve the adequate antimicrobial effect and thus boosting the success of endodontic treatment.[2] The present study is formulated *in-vitro* to compare the cleaning efficacy of two irrigating devices - Endovac and Endo-irrigator plus and two irrigating needles – Side-vented needle and Single beveled needle in the apical third of the root canal.

Materials and Methods

The present *in-vitro* study was carried out in Sardar Patel Post Graduate Institute of Dental and Medical Sciences, Lucknow. Forty freshly extracted human mandibular premolar teeth with single root and straight canal, mature apex and teeth with no developmental anomalies/dilacerations were collected. Teeth with curved roots and any cracks or fracture were excluded. Access cavity was made using Endo access kit (Dentsply, Maillefer, Switzerland U.S.A.) and working length was determined using size 15 K file (Dentsply, Maillefer, Switzerland U.S.A.) by radiographic method. On the basis of the irrigating needles and devices used, all the samples were randomly divided into four groups (3 experimental and 1 control group) having 10 samples each.

- Group 1: The irrigation was done using Endovac (Discus Dental, Culver City, California, USA) device during instrumentation [Figure 1]
- Group 2: Irrigation done using Endo irrigator plus (K-Dent Dental System) device during instrumentation [Figure 2]

Submitted : 30-May-2020
Revised : 25-Jun-2020
Accepted : 16-Jul-2020
Published : 21-Sep-2021

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Access this article online
Website: www.contempclindent.org
DOI: 10.4103/ccd.ccd_468_20
Quick Response Code:

How to cite this article: Srivastava I, Srivastava S, Grover R, Paliwal A. Comparative evaluation of efficacy of different irrigating needles and devices in removal of debris from apical third of root canal: An *In-vitro* SEM study. Contemp Clin Dent 2021;12:222-9.

- Group 3: Conventional irrigation done using Side-vented needle (Dentsply Tulsa Dental Specialties, Tulsa, Oklahoma, USA) during instrumentation [Figure 3]
- Group 4: Irrigation done using Single beveled needle (Ultradent Products, South Jordan, UT, USA) during instrumentation [Figure 4].

Instrumentation in all of the experimental and control groups were ini`ates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland) for coronal enlargement. Then biomechanical preparation was carried out using the crown down technique. All the samples in each group were instrumented using rotary file system Pro Taper Next to an apical size of 25/06 (X2) (Dentsply Maillefer, Ballaigues, Switzerland) as per the manufacturer's instructions. After each instrumentation, irrigation was done with 5.25% NaOCl (Clorox Co., 10th Ramadan, Egypt) using different irrigating devices and needles. For final irrigation, 17% ethylenediaminetetraacetic acid (EDTA) (Canalarge, Ammdent, India) followed by sterile water was used. No clearing technique was used to check the leakage from the root canals.

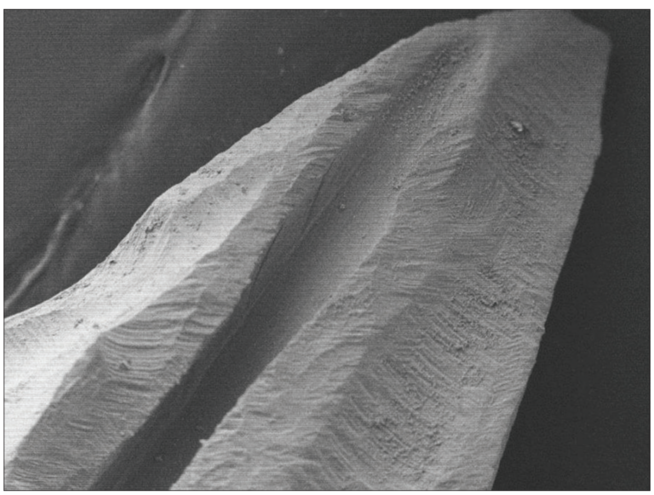


Figure 1: SEM photograph of apical third of root canal irrigated with Endovac

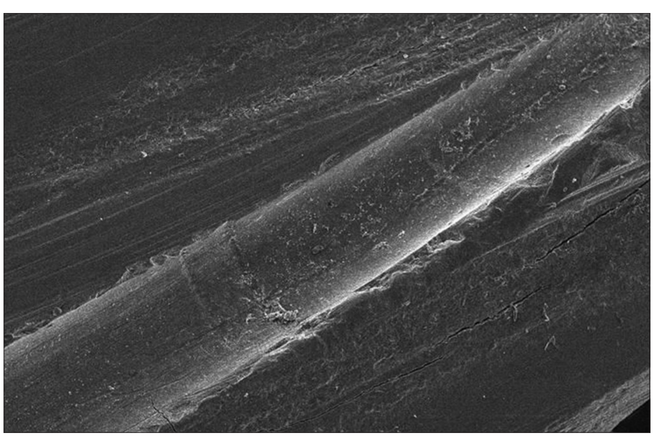


Figure 3: SEM photograph of apical third of root canal irrigated with Side vented needle

After completion of the biomechanical preparation in each group, horizontal sectioning was done at 3 mm level from the apex, followed by vertical splitting of separated segment into 2 equal halves using chisel and mallet. Chisel and mallet was used for splitting as it prevents the accumulation of debris within the canal when compared with carborandum disc for sectioning. The half of each sectioned part was randomly collected from each separated segment and was observed under scanning electron microscope (SEM) with a magnification of 100x. The digital images obtained from the Scanning electron microscope were subjected to the morphometric analysis of photomicrograph. The images were imported using Corel Draw Version 21.0. The no. of debris (N) were counted in the entire photomicrograph.

The following universal formula was used to calculate the no. of debris specimen per unit area =

$$\left(\text{No. } / \text{mm}^2\right) = \frac{N \times 10^6}{(w/[S/V] \times [H/S/V])}$$

Where,

N = no. of debris, *W* = marked area, *H* = marked area height,

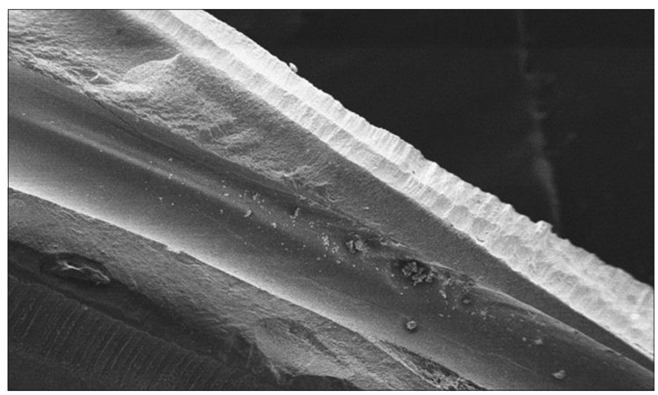


Figure 2: SEM photograph of apical third of root canal irrigated with Endoirrigator plus

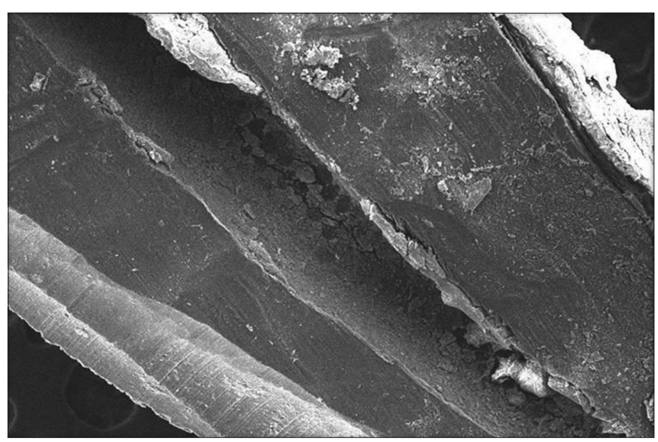


Figure 4: SEM photograph of apical third of root canal irrigated with Single beveled needle

S = scale width, V = scale value

Statistical analysis was done using analysis of variance (ANOVA) and Turkey *post hoc* test.

Statistical Analysis and Results

Only 10 specimens were allocated to each group and a high variability in the number of debris per square mm was observed. Kolmogorov–Smirnov test was applied to test the symmetry of data.

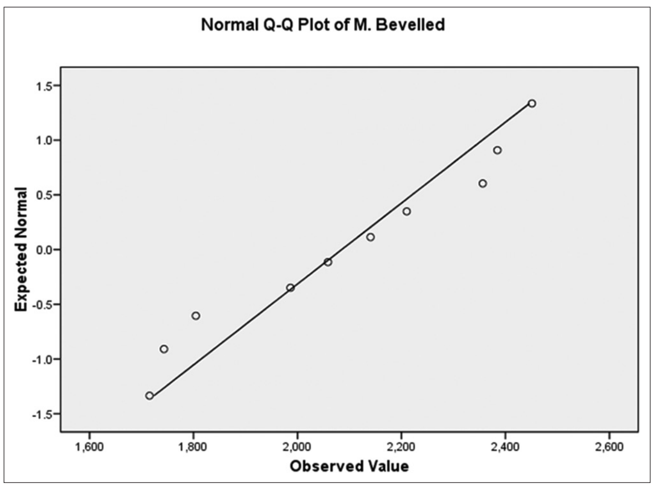
On the basis of descriptive statistics and normality assessment, all the four groups were found to have normal distributions (P > 0.05) [Table 1]; hence, a parametric evaluation plan was adopted. ANOVA followed by Tukey's *post hoc* test was used for the purpose of comparison of data [Tables 2 and 3].

On intergroup comparison, highly significant statistical differences were found between Group I and Group IV (1507.25 ± 130.92/mm^2), Group 1 and Group 3 (1306.26 ± 130.92/mm^2), Group 1 and Group 2 (864.02 ± 130.92/mm^2) and followed by Group 2 and Group 4 (643.23 ± 130.9/mm^2).

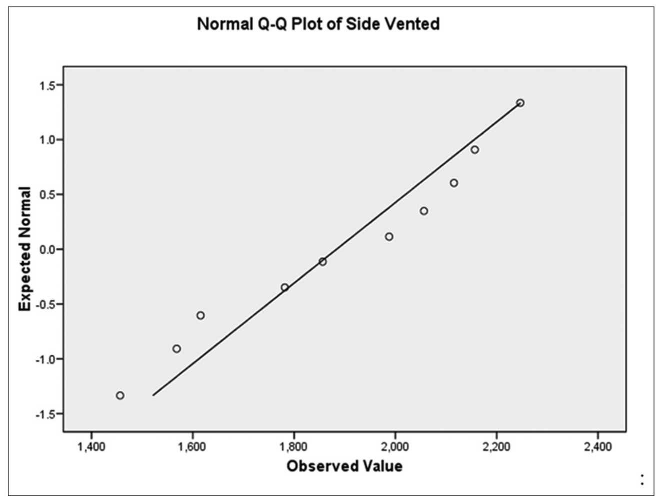
Significant differences were seen between Group 2 and Group 3 (442.24 ± 130.92/mm^2). While no significant differences were found between Group 3 and Group 4 (200.99 ± 130.92/mm^2). The differences between all the groups, except Group 3 and Group 4, were found to be statistically significant.

Hence, the level of debris removal efficacy is as follows:

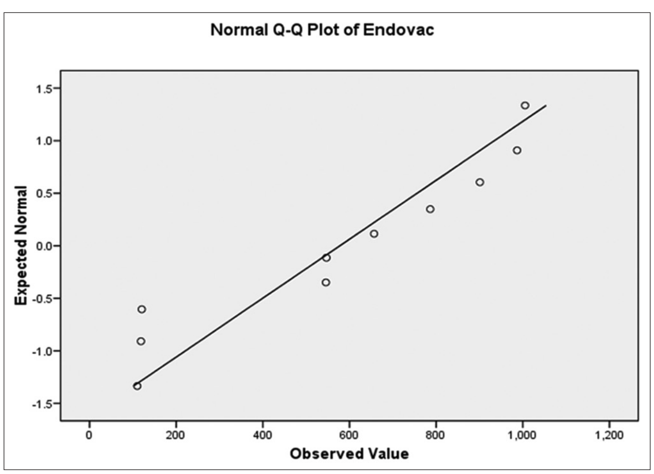
Group 1 > Group 2 > Group 3 ~ Group 4



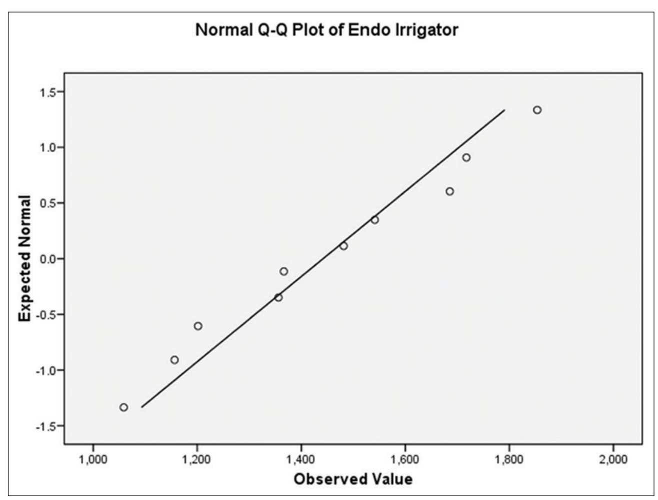
Graph 1: In Group 4 (Single beveled needle), minimum number of debris was 1715.30/mm^2 while maximum was 2451/mm^2, median was 2099.55/mm^2. Mean number of debris in Group 4 was 2085.04 ± 270.52/mm^2. Data was found to be symmetric by Kolmogrov–Smirnov test (K = 0.150; P = 0.200)



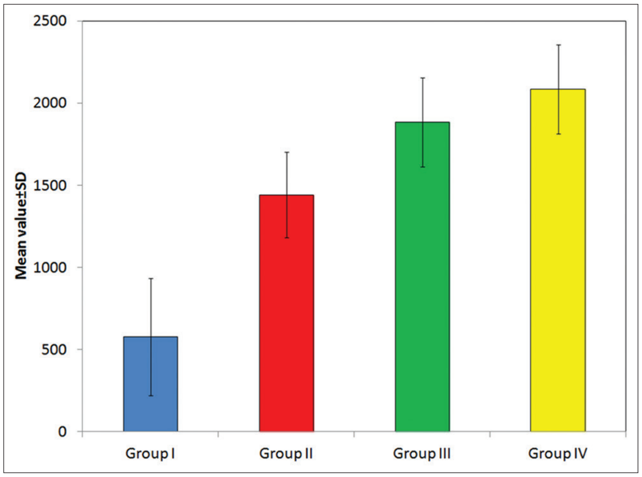
Graph 2: In Group 3 (Side vented needle), minimum number of debris was 1456.40/mm^2 while maximum was 2246.50/mm^2, median was 1922.00/mm^2. Mean number of debris in Group 3 was 1884.05 ± 272.03/mm^2. Data was found to be symmetric by Kolmogrov–Smirnov test (K = 0.148; P = 0.200)



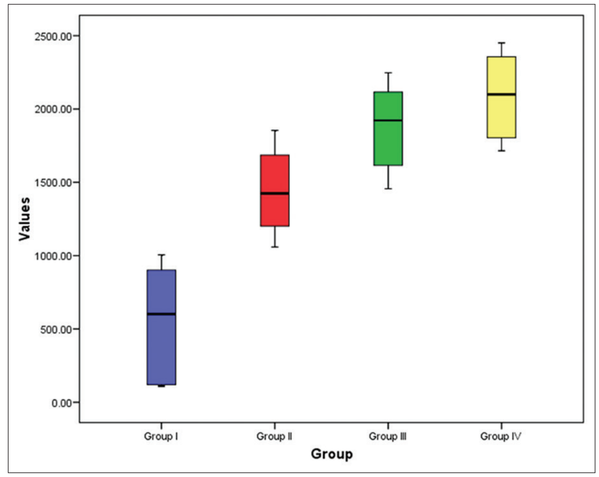
Graph 3: In Group 1 (Endovac), minimum number of debris was 110.10/mm^2 while maximum was 1005.30/mm^2, median was 601.75/mm^2. Mean number of debris in Group 1 was 577.79 ± 356.69/mm^2. Data was found to be symmetric by Kolmogrov–Smirnov test (K = 0.200; P = 0.200)



Graph 4: In Group 2 (Endo irrigator plus), minimum number of debris was 1058.60/mm^2 while maximum was 1853.60/mm^2, median was 1423.95/mm^2. Mean number of debris in Group 2 was 1441.81 ± 261.50/mm^2. Data was found to be symmetric by Kolmogrov–Smirnov test (K = 0.124; P = 0.200)



Graph 5: Mean debris was found to be minimum in Group 1 (577.79 ± 356.69/mm^2) followed by that of Group 2 (1441.81 ± 261.50/mm^2) followed by that of Group 3 (1884.05 ± 272.03/mm2) and maximum in Group 4 (2085.04 ± 270.52/mm^2)



Graph 6: Box plot showed statistically significant intergroup differnces (*P* < 0.001). Values of Group 4 and Group 3 were of higher order while that of Group 1 was of lower order and of Group 2 was of middle order

Endovac > Endo-irrigator plus > Side-vented needle ~ Single beveled needle

Discussion

The success of endodontic treatment depends on the complete eradication of pulpal remnants, dentinal shavings, and microbes from the root canal space.[3] It is impossible to eliminate these microbes completely with mechanical instrumentation alone. Therefore, irrigating agents were required to eliminate the microbes and debris from the intra-radicular space.[4] Thus, debridement and disinfection of the root canal are crucial for the long-term success of endodontic treatment. Hence, mechanical instrumentation along with chemical irrigation geared toward the disinfection of root canal, resulting in the success of endodontic treatment.[5]

The irrigation usually reduced to a needle on the tray has to be systematically evaluated in order to become an endodontic entity having a precise chronology and codification.[6] The endodontic triad consisting of biomechanical preparation, microbial control, and complete obturation of the canal space is the hallmark of endodontic therapy.[7] The intricacies in the apical third of the root canal, such as narrow isthmus, apical deltas, fins, canal ramifications, can obstruct the entire debridement by mechanical instrumentation alone, even though mechanical instrumentation is the prime factor in the debridement of the root canal.[8] Secondly, after biomechanical preparation, a film of debris composed of organic and inorganic matter is created on walls of root canals, obliterating the dentinal tubule entrances and root canal ramifications reported as smear layer. Persistence or removal of the smear layer is still debatable.[9,10]

Kungwani *et al*. in 2014 and Kumar *et al*. in 2015 proposed that the irrigants must be in direct contact with the entire canal wall surfaces for efficient action mainly in the complexities of the root canals.[11,12] Therefore, chemical debridement through the use of irrigant is a necessary adjunct to mechanical instrumentation to remove organic and inorganic debris created during instrumentation and also reduce the microbial load in the canal system.[13]

Gulabivala *et al*. 2005 pronounced a variety of chemical agents to be used during instrumentation for the better treatment outcome.[14] 17% EDTA has been found to be most effective in the removal of the smear layer. It has a chelating effect and eliminates calcium ions from the inorganic component of dentin by forming soluble calcium chelates. It is used to remove the smear layer created during root canal preparation, which results in detachment of biofilms adhering to root canal walls.[15] The combination of EDTA and 5.25% sodium hypochlorite (Dakin's solution, NaOCl) solution has proved to be effective in removing the smear layer and debridement of the root canal.[16,17] NaOCl is still considered as "gold standard irrigant" because of its microbiocidal and organic tissue dissolving ability. It has a germicidal potential, solvent action on exudate and predentin and shows far greater tissue dissolving effect on necrotic than on vital tissues.[6] However, few authors documented that the use of a high volume final flush with 17% EDTA, followed by 5.25% NaOCl effectively removes the smear layer.[18]

Therefore, various irrigation methods have been used to deliver the irrigant solution as close as possible to the intricate areas of the root canal. They include conventional needle irrigation (single-beveled and side-vented needle), Max I probe, Navi tip, irrigation devices such as Endoactivator, Endovac based on apical negative pressure technology, Endo-irrigator plus based on positive and negative pressure, Passive ultrasonic irrigation and sonic devices.

Since there is very little documentation regarding the effectiveness of newer irrigation delivery methods. Therefore, the present study was formulated *in-vitro*

Table 1: Comparison of mean values in different groups

Group	*n*	Mean	SD	SE	95% CI for mean		Minimum	Maximum
					Lower	Upper		
Group 1	10	577.79	356.69	112.79	322.63	832.95	110.10	1005.30
Group 2	10	1441.81	261.50	82.69	1254.74	1628.88	1058.60	1853.60
Group 3	10	1884.05	272.03	86.02	1689.45	2078.65	1456.40	2246.50
Group 4	10	2085.04	270.52	85.55	1891.52	2278.56	1715.30	2451.00
Total	40	1497.17	650.86	102.91	1289.02	1705.33	110.10	2451.00

SD: Standard deviation, SE: Standard error, CI: Confidence interval

Table 2: Analysis of variance for intergroup differences

Source	Sum of squares	Df	Mean square	*F*	Significant
Between groups	13435915.85	3	4478638.62	52.261	<0.001
Within groups	3085096.13	36	85697.12		
Total	16521011.98	39			

Df: Degrees of freedom

Table 3: Between group comparisons (turkey honest significant difference test)

Comparison	Mean difference	SE	*P*
Group 1 versus Group 2	−864.02	130.92	<0.001
Group 1 versus Group 3	−1306.26	130.92	<0.001
Group 1 versus Group 4	−1507.25	130.92	<0.001
Group 2 versus Group 3	−442.24	130.92	0.009
Group 2 versus Group 4	−643.23	130.92	<0.001
Group 3 versus Group 4	−200.99	130.92	0.428

SE: Standard error

to compare the cleaning efficacy of two irrigating devices-Endovac and Endo-irrigator plus and two irrigating needles-Side vented needle and Single beveled needle in the apical third of the root canal.

Mandibular premolars were extracted for orthodontic/periodontal purposes were selected for experimentation in the present study due to the highest percentage of variations in canal morphology. Hence, they offer better scope for assessing the effectiveness of irrigating devices even in the most intricate areas of the root canal. Gade *et al*. in 2013; Abraham *et al*. in 2015 also used mandibular premolars to evaluate the amount of debris removal from root canal wall by using Endovac and conventional needle irrigation.[12,19]

The biomechanical preparation was carried out using the crown down technique in the present study. Pereira *et al*. in 2012 inferred that the crown down technique minimizes debris extrusion, has better access and control over apical enlarging instruments with better penetration of irrigants in larger volumes.[20] Several studies have been documented in which, crown down technique showed better results than step-back technique.[21] Protaper next (PTN) rotary files were used in cleaning and shaping the root canal along with chemical debridement. It is based on M wire technology, which improves the resistance to cyclic fatigue, has progressive tapers on a single file. Vamshi Krishna *et al*., in 2016, Capar *et al*. in 2014, correlating with the present study, stated that Pro taper next has a better cleaning efficacy when compared with other rotary files.[22,23] It is well documented in literature that the biomechanical preparation should be done till X2 (25/06) with PTN file system to prevent more enlargement of the apical region.[23,24] Capar *et al*. in 2014 conducted a study using PTN files for biomechanical preparation and showed that the canals should be prepared till X2 to avoid the enlargement of the apical foramen which leads to less extrusion of debris out of the canal.[23]

The results of the previous studies have shown that the mechanical instrumentation, along with needle irrigation does not effectively debride at the apical third of the root canal. To be effective, endodontic irrigants should ideally be delivered as close as possible to the apex. Conventional syringes have been widely used by the clinicians for delivery of irrigant. According to the ISO 9626 standard, needles with gauges of 21, 23, 25, 27, and 30 with an external diameter of 0.8, 0.6, 0.5, 0.4, and 0.3 mm, were used respectively.[25] The flushing action of the single-beveled needle (Group 4) is relatively weak. Since inaccessible canal extensions and irregularities are likely to harbor debris and bacteria; thereby thorough canal debridement becomes difficult in the apical third of root canal with these single beveled needle. Hülsmann and Hahn *et al*. 2000; Zairi and Lambrianidis in 2008 supporting the aforementioned properties stated that the irrigation of the root canal through single-beveled needle includes a risk of extrusion of sodium hypochlorite in the periapical region which could lead to tissue necrosis and induce pain sensation.[26,27] In the present study, results showed that samples of the Group 4 in which 27 gauge single beveled needle was used for irrigation, the amount of debris remaining at the apical third of the root canal ranged from 1715.30/mm^2 to 2451/mm^2 [Graph 1]. To overcome this drawback, side-vented needle has been developed to minimize the risk of irrigant extrusion and tissue damage.[28,29]

In Group 3, side-vented needle of 27 gauge was used with one lateral vent for gentle but for effective irrigation of root canal. It allows the removal of the debris from the canal wall surfaces. It develops lateral hydraulic pressure within the root canal, creating pressure for the removal of the debris from the canal wall surfaces. Moreover, the better effect is due to the turbulence created around the end of the needle, having a closed-end with lateral vent, 2 mm from the tip.[30] In agreement with the present study, a study conducted by Ghivari and Kubasad in 2011 evaluated the effectiveness of different irrigating needles, and results showed that side-vented needle enables better removal of debris in the middle and apical third of root canal when compared with single-beveled needle.[29] In the present study, the no. of debris remaining in the apical third of the canal after irrigation with side-vented needle (Group 3) ranges from 1456.40/mm^2 to 2246.50/mm^2 [Graph 2]. Numerous studies have reported that conventional irrigation methods are effective in cleaning root canals coronally but less effective in the apical third of the root canal.[3,31,32]

Therefore, an effective irrigation delivery system is required, which provides an adequate continuous flow and sufficient volume of irrigating solution in the middle and apical third of the root canal.

In the present study, Endovac (Group 1) based on an apical negative pressure irrigation system, was used. It has the following parts: The Multi-Port adapter (MPA), The Master Delivery Tip, The Macro Cannula, The Micro Cannula. The MPA is autoclavable and re-attached to the high evacuation system for maximum portability between operatories.

The Master delivery suction tip is used during coronal flaring. It delivers the irrigant into the pulp chamber and, at the same time, suctions the irrigant coronally during the instrumentation process and removes the gross debris. It provides a continuous flow of irrigant without the risk of overflow. The benefit of the Master Delivery Tip is, visibility is not blocked, and large volumes of irrigation solution can be delivered with a single tip at the tooth's access. Second, the macro-cannula is used to remove coarse debris and suction the irrigants from the chamber to the coronal and middle segment of the canal together with the Master delivery suction tip. It should be used in short up and down pecking motion for 30 s and used until clear fluid is observed in the tubing. The micro-cannula contains 12 microscopic holes and is capable of evacuating debris from full working length. The fluid is drawn to the apical termination through these holes, creating a vortex-like cleaning of the apical third.[33]

On comparison with the other groups, Endovac system left least no. of debris in the canal than the Endo-irrigator plus, side-vented needle and single-beveled needle. The results of the present study are in accordance with the study carried out by Gade *et al*. in 2013 showed that the Endovac group had significantly less debris at apical third when compared with the conventional needle irrigation group.[19] The amount of debris remaining in the apical third of the root canal after irrigation with Endovac ranges from 110.10/mm^2 to 1005.30/mm^2 [Graph 3].

In the present study, irrigation with Endo-irrigator plus (Group 2) has better cleaning efficacy than single-beveled and side-vented needle and lesser than Endovac device. Endo irrigator plus works on the principle of positive and negative pressure and on the ACWIS concept, which refers to activated continuous warm irrigation and evacuation system. It provides irrigation and suction concomitantly, which minimizes the time, allows the irrigation in big volumes, irrigant delivered in the apical region of canal and comes out coronally through the same delivery tip.[34] Functions of activated NaOCl with ACWIS reduces instrument friction during preparation (lubricant), facilitate dentin removal, dissolve inorganic tissue (dentin), dissolved organic matter (dentin collagen, pulp tissue, biofilm). Dr. Bansode *et al*. 2015 stated that it increases the tissue dissolving ability with warm NaOCl.[34] The number of debris left after irrigation with Endo-irrigator plus (Group 2) ranges from 1058.60/mm^2 to 1853.60/mm^2 in the apical third of the root canal [Graph 4].

All the samples in the groups were sectioned horizontally at 3 mm from the apex, followed by a vertical section using chisel and mallet. Chisel and mallet were used for sectioning the samples as it prevents the accumulation of debris within the canal when compared with the carborundum disc. Khalap *et al*., in 2016, conducted a study which is supporting the above-mentioned studies, used diamond disks for making longitudinal grooves on buccal and lingual surfaces of the tooth, and split into two halves with the chisel. They have suggested that chisel and mallet produced lesser debris, which may influence the amount of debris at the sectioned sample in inner dentinal walls.[35]

In the present study, the mean debris was found to be minimum in Group 1 - Endovac (577.79 ± 356.69/mm^2) followed by Group 2-Endo irrigator plus (1441.81 ± 261.50/mm^2) than Group 3-Side-vented needle (1884.05 ± 272.03/mm^2) and maximum in Group 4-Single-beveled needle (2085.04 ± 270.52/mm^2) [Graphs 5 and 6]. Therefore, Endovac (Group 1) has a minimum number of debris left and Single-beveled needle (Group 4) has the maximum amount of debris left in the apical third of the root canal. Hence, Endovac has better cleaning efficacy when compared with other irrigation groups. Statistically, Endovac showed a highly significant difference when compared with single-beveled needle, side-vented needle, and Endo irrigator plus device ($P < 0.001$). Endo irrigator plus (Group 2) showed a statistically significant difference when compared to Endovac device ($P < 0.05$) and highly statistical significant difference when compared with single-beveled needle followed by side-vented needle ($P < 0.001$). Side-vented needle showed not much significant difference when compared with single-beveled needle ($P > 0.05$) and showed highly significant difference when compared with Endo irrigator plus and Endovac irrigation device ($P < 0.001$). Single-beveled needle showed highly significant difference when compared with both Endovac and Endo irrigator plus ($P < 0.001$) and no significant difference when compared with side-vented needle ($P > 0.05$).

Under the confines of the present study and with the agreement of the previous studies, Endovac (Group 1) showed the maximum number of debris removal and hence has better cleaning efficacy even in the apical areas of the root canal when compared with Endo irrigator plus, side-vented needle and single-beveled needle.

Furthermore, studies should emphasize to address the debridement efficacy of various irrigating devices in removing the debris from the intricate areas of the root canal with better irrigant protocol. The combination of irrigants for better cleaning efficacy within the root canal should also be taken into consideration to see their effects on the dentinal walls for the success of long term treatment outcomes. However, more long-term clinical evaluations of these findings are needed in varied clinical conditions with a larger sample size.

Conclusion

The role of irrigants in achieving thorough disinfection of the root canal space cannot be underestimated. Irrigation has a key role in the root canal debridement. Effective irrigant delivery is one of the prerequisited for successful endodontic treatment. As stated by Louis Grossman, "Mechanical instrumentation should be followed by irrigation of the canal to wash out fragments of pulp tissue and dentinal shavings."

With the confines of the present *in-vitro* SEM study, following statement can be concluded by the number of debris per unit area in millimeter square was least in Endovac irrigation group when it is compared with single-beveled needle, side vented needle and Endo-irrrigator plus, especially in the apical third of the root canal. Moreover, Endovac prevent periapical extrusion of irrigant, has no vapor lock effect, provides adequate irrigant volume and has better cleaning efficacy in the remote areas of root canal.

Hence, in the present study, among all the groups, efficacy of debris removal is as follows:

Endovac (Group 1) > Endo irrigator plus (Group 2) > Side-vented needle (Group 3) ~ Single-beveled needle (Group 4).

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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