Aim and objective: To compare the effectiveness of three irrigation systems, namely, Endovac system, Max I probe, and Navitip FX, in reduction of Enterococcus faecalis population from the root canal using agar diffusion method.

Materials and methods: Fifty-five extracted intact human permanent maxillary anterior teeth were selected for this study. In group I, root canals were irrigated using brush covered 30-gauge Navitip FX. Ultradent in group II root canals was irrigated using brush covered 30-gauge Max-I-Probe Dentsply. In group III, root canals were irrigated using Endoactivator, Dentsply. In group IV, root canal was irrigated by using the Endovac system Sybronendo. The steps followed in the study include preparation of specimen, contamination of the samples followed by conduction of testing procedures with implementation of appropriate irrigation protocols, and sampling procedures.

Results: Data were subjected to statistical analysis to interpret the significant differences among various irrigation systems. One-way analysis of variance, Post hoc Tukey tests were used for statistical analysis in the present study. Among the experimental groups, group IV showed statistically significant difference in reduction of E. faecalis. There were no statistical differences between them in reduction of E. faecalis in group I and group II compared and represented in Tables 1 and 2.

Conclusion: All four irrigation delivery systems have been found to be effective in the reduction of E. faecalis. Endovac showed comparable efficacy in reduction of colony-forming units to that of other delivery systems used in the study. The result has to be validated with in vivo studies and clinical trials of larger sample size.

Clinical significance: Selection of appropriate irrigation system capable of disinfection of canal complexities in apical third with less adverse effects is essential for good clinical success of endodontic treatment.

Keywords: Dynamic irrigation needle irrigation, E. faecalis endoactivator, Endovac.

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The main advantage of Maxi I probe is that it has side vented needle delivering the irrigant, laterally aiding in penetration into the canal aberrations. The main disadvantage of Navitip FX is that it delivers the irrigant short of apex.

Machine-assisted agitation devices such as Endoactivator System (EA) uses sonic energy for activation of irrigant and has been found to have canal free from debris. The compact design enhances the effective delivery of irrigant into the canal complexities without causing any alterations to the dentin substrate.

The Endovac system works on the negative pressure principle to suck out debris and aids in cleaning the prepared canal with less potential of irrigant leakage. The major disadvantages of Endovac system is related to technique sensitivity, difficulty in sterilization of device, and cost.

The study was designed in such a way to compare the different concepts, such as positive pressure vs negative pressure and irrigant activation concepts and its ability to assess the efficacy in reduction of E. faecalis count.

The aim of this in vitro study was to compare the effectiveness of three irrigation systems, namely, Endovac system, Max I probe, and Navitip FX in reduction of E. faecalis population.

Materials and Methods

Sixty permanent maxillary incisors extracted for prosthodontic purposes were selected for this study. Teeth were debrided with ultrasonic scaler tips. Access cavity preparation was done with no. 2 round burs.

Root canal procedures were done in department of conservative dentistry and endodontics by the primary investigator, and colony-forming units counts were done in the microbiological laboratory by the microbiologist after blinding the materials used for the study.

Patency was established with 10 size K-file. Working length was standardized to 20 mm. The apical enlargement was done till 25 size, and the apical foramen was sealed with Type II GIC. The teeth were mounted in blocks made of self-cure resin. The samples were sterilized in autoclave for 20 minutes at 121°C.

Contamination of the Specimen

ATCC 29212 was used in the study and grown in trypticase soy broth for 24 hours. A ratio of 1:5 was employed for preparation of suspension of E. faecalis. The inoculation of the sample was done using sterile 1-mL syringe and carried to the entire root canal system with help of sterile K-type file. A rectangular surgical tray was used for placement of blocks and incubated at 37°C for 7 days in 100% humidity.

Testing Procedures

After 7 days of experimental contamination, the study was designed in such a way and segregated into four experimental groups of 15 based on the irrigation technique employed.

Criteria for grouping the samples along with the irrigation techniques employed are as follows:

- In Group I, samples were irrigated by using brush covered 30-gauge NaviTipFX. Ultradent
- In Group II, samples were irrigated by using brush covered 30-gauge Max-I-Probe Dentsply
- In Group III, samples were activated using Endoactivator irrigation system Sybrnonendo
- In Group IV, samples were irrigated by using the Endovac system Dentsply

All the experimental groups were irrigated with 3% NaOCl (sodium hypochlorite) and 17% EDTA.

Irrigation Protocols

In group I, the irrigation was done with 2 mL of NaOCl using a 30-gauge NaviTipFX at the end of each instrumentation. In group II, the irrigation was done with 2 mL of NaOCl using a 30-gauge Max-i-probe.

The position of the needle was ensured to be 2 mm short of apex and moved in up and down motion to prevent the extrusion of the solution. After the usage of F4 Instrument, irrigation was done with 3% NaOCl for 30 seconds followed by 17% EDTA for 30 seconds, and again with 3% NaOCl for 30 seconds.

In group III, the irrigation protocols were similar to that of groups I and II, and the tip size was kept as 35 with 4% of taper for irrigant activation.

The activation was done for 30 seconds with 2 mm short of apex. The cleanliness of the canal was ensured with irrigation of saline solution followed by drying with paper points. The activation of irrigant was repeated.

In group IV, the canal was loaded with irrigant throughout the procedure.

Macro-irrigation cycle: The irrigant delivery was done with master delivery tip at the end of instrumentation. The macro-irrigation was done using 3% NaOCl for 30-second period. The coronal third of the canal was irrigated with master delivery tip. The macro-cannula was taken in and out and kept 4 mm short of apex.

Micro irrigation cycle: Three cycles of micro irrigation was carried with microcannula placed at WL for 6 seconds. This was followed by sequence of irrigation with placement of microcannula at 2 mm from the WL for 6 seconds and reverted back to WL for 6 seconds.

The in and out motion was done for 30 seconds with 18 seconds of active irrigation at working length. Care was ensured to avoid entrapment into the canal system during the handling of microcannula in presence of irrigant. The irrigants employed in first cycle was 3% NaOCl as the irrigant, the second cycle employed 17% EDTA, and the third cycle was completed again with 3% NaOCl once again. Excess irrigant was removed periodically.

Sampling Procedures

The sampling was done with meticulous care by rinsing the canal space with 1 mL of 10% sodium thiosulfate to negate the effects of NaOCl and then with saline. This was followed by evacuation of canal contents with a 1-mL plastic syringe and transferred into tubes containing 1 mL of sterile saline. The corresponding size paper points was placed at the WL to soak the canal contents and transferred to the tube containing saline. This was followed by agitation in vortex with 10-fold serial dilutions in saline. Afterward, aliquots of 0.1 mL were plated onto brain heart infusion agar plate and incubated at 37°C for 48 hours. The colony-forming units (CFUs) were numbered after analyzing the dilution factors.

Results

The data were subjected to various statistical significance to interpret the significant differences among various irrigation systems.
The primary etiology of apical periodontitis arises due to localization of microbial agent in the apical portion of the root canal system. The management of irreversible pulpits aims to prevent the progression of infection into periapical region. Secondary apical periodontitis arises due to the exacerbating of residual bacterial load. The predominant bacteria from the secondary infection include Lactobacilli, Staphylococci, Enterococcus faecalis, and Propionibacterium.8

Enterococcus faecalis is a facultative gram-positive anaerobe with a prevalence of 22–77%. It has a potential to modulate the internal pH by an efficient proton pump. It has the capacity to travel deep to the dentinal tubules and get lodged into the canal irregularities. The organism exhibits resistance pH variations and can last in the challenging and tough environment.9

The anatomical complexity necessitates employment of special mechanical aids to ensure thorough debridement. The mechanical instrumentation removes the necrotic and vital organic tissue and ensures the fulfillment of mechanical objectives.10 In this present study, the apical size was prepared with #40 ProTaper which has taper of 0.09, and this enlargement helps in placement of microcannula at the working length.

Brunson et al. showed that apical enlargement size was directly proportional to volume of irrigant delivered. The majority of infection control mechanism depends on the irrigation techniques and devices to contribute to the reduction in microbial agents.11

The irrigants used for removal of these materials must address both these organic and inorganic components, and the presence of biofilms in the uninstrumented canal can cause treatment failure.12

The removal of the inorganic component in the root canal is of primary importance because it allows penetration of the antimicrobial irrigants to areas of the dentin that may harbor bacteria.13

Sodium hypochlorite when used alone as an endodontic irrigant lacks action on the inorganic component and the dentinal debris which is formed during instrumentation.14

Ethylenediamine tetra-acetic acid (17% EDTA) acts predominantly on the inorganic portion of the root canal system. It also reduces the hydrophobicity and surface free energy of root dentin thereby reducing the adherence of E. faecalis to dentin.15

In the present study, regime of 3% sodium hypochlorite and 17% EDTA was used as final irrigation. In positive pressure technique, irrigant is expelled with pressure from the irrigation system.

Conventional syringe irrigation involves above principle to dispense the irrigant through needle of various sizes passively or with agitation. Mechanical flushing action is relatively weak to displace the debris and bacteria from the inaccessible areas and irregularities, thereby making thorough canal debridement difficult.16

The replenishment and exchange of irrigant in the apical third and the effectiveness of chemical debridement are dependent on the depth of penetration.17

They are less effective in cleaning the apical areas compared to the coronal areas of root canal systems. The close proximity of the needle tip to the apical tissue has a greater chance of apical extrusion of the irrigant.18

It is essential to develop delivery systems that improve the irrigant penetration to the inaccessible areas to ensure complete disinfection of the canal system with minimal in periapical tissues.19

Recently, NaviTip FX irrigation system has been into the market. The special design feature with brush helps to reach up to the apex and scrub the canal wall while concomitantly delivering the irrigant effectively to apex.20

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**Table 1:** The mean colony-forming units (CFUs)/mL of the irrigants

| Group        | Mean   | SD    | p value |
|--------------|--------|-------|---------|
| Endovac      | 12.00  | 7.746 | 0.000   |
| Endoactivator| 156.00 | 34.056|         |
| Max-i-probe  | 210.00 | 53.852|         |
| Navitip Fx   | 425.00 | 32.770|         |

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**Table 2:** Tukey HSD for specific intergroup comparison

| Group       | p value |
|-------------|---------|
| Endovac     |         |
| Navitip FX  | 0.000   |
| Max-i-probe | 0.000   |
| Endoactivator| 0.329  |
| Navitip Fx  |         |
| Max-i-probe | 0.000   |
| Endoactivator| 0.000  |

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One-way analysis of variance (ANOVA) was used to interpret the overall variance among the groups. It was not possible to identify the difference between the various groups with the help of the p values obtained from ANOVA.

To make a comparison of variance within the group, post hoc Tukey was employed. In our study, one-way ANOVA followed by Tukey HSD test showed statistically significant difference among experimental groups related to E. faecalis reduction in each group. Mean E. faecalis count was highest with mean of 425 × 106 colony-forming units (CFUs)/mL in Navitip Fx group.

Mean rank score for E. faecalis count was 210 × 106 colony-forming units (CFUs)/mL in Max-i-Probe group.

Mean rank score for E. faecalis reduction was lowest with mean 12 × 106 colony-forming units (CFUs)/mL in Endovac group.

Among the experimental groups, group IV showed statistically significant difference in reduction of E. faecalis. There were no statistical differences between them in reduction of E. faecalis in group I and group II compared, and the values are represented in Table 2.

**DISCUSSION**

The primary etiology of apical periodontitis arises due to localization of microbial agent in the apical portion of the root canal system. The management of irreversible pulpits aims to prevent the progression of infection into periapical region.7

The anatomical complexity necessitates employment of special mechanical aids to ensure thorough debridement. The mechanical instrumentation removes the necrotic and vital organic tissue and ensures the fulfillment of mechanical objectives. In this present study, the apical size was prepared with #40 ProTaper which has taper of 0.09, and this enlargement helps in placement of microcannula at the working length.

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Recently, NaviTip FX irrigation system has been into the market. The special design feature with brush helps to reach up to the apex and scrub the canal wall while concomitantly delivering the irrigant effectively to apex.20
Max-I-Probe is an irrigation system with side vented and close-ended needle that delivers the irrigant laterally. The above design improves the availability of irrigant and reduces the apical leakage of the irrigant. Vinoth Kumar et al. showed that Max-I-probe was effective in displacing the bacteria from the root canal.21

Boutsioukis et al. had a valuable observation and concluded that the exchange of irrigant happens only 1 to 1.5 mm past a side-ventilated needle, and the irrigant beyond that point remains stagnant in his computational fluid dynamic model.22

The Endoactivator system aids in penetration of an irrigant to inaccessible areas of the root canal system and helps in dislodgement of bacteria. The high-frequency sonic energy causes activation of irritant and aids in dislodgment of microbes in an efficient manner. Previous studies have shown that more than 50% of the dentinal tubules remain open and patent. Its ability to create sonic waves in the root canal aids in the removal and reduction of bacteria along with the necrotic tissue debris.

Endovac is an irrigation system that works on the negative-pressure principle and has (1) Macrocannula of 0.55 mm in diameter/0.02 taper (2) Microcannula with diameter of 0.32 mm. Desai et al. compared the safety of different irrigation systems and concluded that Endovac is safe to work at working length.23

Heilbronn et al. observed that volume requirements are unique to the delivery system.24 In the present study, the Endovac [group IV] showed few numbers of bacterial colonies [with a mean of 12 × 10^6 CFUs/mL] and resulted in significant reduction of bacterial load than the other irrigation system.

Group I (Navitip FX) showed comparable reduction in the bacterial load [with a mean of 425 × 10^6 CFUs/mL] which might be attributed to the scrubbing action of irrigation system. Similar results was reported by Al-Hadlaq et al. and Zemner et al. who proved that brush-covered irrigation needle was more effective in

In Group II (Max-I-probe), there was significant reduction in bacteria load with a mean of 210 × 10^6 CFUs/mL. The probable reason may be attributed to its design, closed-ended, side-vented channel, which tends to deliver the irrigant laterally.

This unique design creates a turbulence that removed considerable number of bacteria on comparison with the needle irrigation.25 Similar results were reported by Vinothkumar et al. who concluded that side vented was clinically effective than other irrigation devices.26

Group III Endoactivator group showed with a mean of 156 × 10^6 CFUs/mL. It was found that all four irrigation delivery systems have been found to be effective in the reduction of E. faecalis. Endovac showed comparable efficacy in reduction of colony-forming units to that of other delivery systems used in the study. The results have to be validated with in vivo studies and clinical trials of larger sample size.

**Limitations of the Study**

Usage of Endovac system in thin and curved roots in vivo needs to be warranted. Clinical trials investigating the effects in mixed bacterial community are required to determine the efficacy of disinfection protocols of teeth with apical periodontitis. Additionally, further investigations are also necessary test in vivo situation involving more number of clinical parameters.

**Conclusion**

It was found that all four irrigation delivery systems have been found to be effective in the reduction of E. faecalis. Endovac showed comparable efficacy in reduction of colony-forming units to that of other delivery systems used in the study. The results have to be validated with in vivo studies and clinical trials of larger sample size.

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