ABSTRACT

Introduction: The aim of this study was to evaluate and compare root canal debridement with three different irrigation systems, i.e., syringe, sonic, and ultrasonic.

Materials and Methods: Forty-five maxillary anterior teeth were decoronated and prepared biomechanically using Protaper rotary files till size F4. Irrigation was done with 1 ml of 4% sodium hypochlorite solution after each file use. The samples were divided into three groups on the basis of final irrigation protocol - Group 1 = Syringe irrigation, Group 2 = Passive sonic irrigation, and Group 3 = Passive ultrasonic irrigation. The samples were then sectioned and observed under the scanning electron microscope (SEM) at coronal, middle and apical thirds of root canal. The SEM was evaluated and scored for residual debris and smear layer.

Results: Intragroup comparison showed that smear layer and debris removal at coronal third was significantly better when compared to apical third. Intergroup comparison showed that all the systems performed equally well in the coronal third. At apical one-third, passive ultrasonic performed significantly better than both sonic and syringe irrigation.

Conclusion: Root canal cleanliness achieved by ultrasonic, especially in the apical third is significantly better than sonic and syringe irrigation.

Keywords: Agitation, residual debris, scanning electron microscope, smear layer, sonic irrigation, ultrasonic irrigation

INTRODUCTION

The goal of endodontic therapy is the removal of all vital or necrotic tissue, micro-organisms, and microbial by-products from the root canal system. To achieve this, chemo-mechanical root canal preparation is done which consists of canal enlargement and debridement by thorough irrigation with bactericidal irrigants, but the intricate nature of root canal anatomy such as isthmuses, fins, webs, and other irregularities within the root canal often harbor tissues, microbes, and debris following instrumentation which complicates the complete debridement of all areas of the root canal.

Conventionally, irrigation has been done with the help of syringe, but it has proven to be ineffective in the apical part of the root canal as flushing action created by syringe irrigation is relatively weak and is dependent on the depth of placement and the diameter of the needle. This led to the introduction of newer irrigation systems, in which irrigant was activated sonically or ultrasonically leading to cleaner areas when compared to conventional syringes.
The use of sonic instruments in endodontics was first reported by Tronstad in 1985. The sonic system operates at a frequency of 1–6 kHz and produces small shear stresses. The endoactivator is a recently introduced sonically driven canal irrigation system. The system has three different sizes of tips that are easily attached to handpiece that creates the sonic vibrations. Endoactivator facilitates the penetration and renewal of the irrigant in the canal with no increase in the risk of irrigant extrusion through the apex. The possible advantage of attaching nylon tips is to make the device more flexible and less prone for breakage when compared to ultrasonic files.

The concept of using ultrasonics in endodontics was first introduced by Richman in 1957. The term endosonics was coined by Martin and Cunningham and was defined as the ultrasonic and synergistic system of root canal instrumentation and disinfection.

Both sonic and ultrasonic activation converts electric energy into waves with certain frequencies. This energy produces a rapid movement of fluid in a circular motion around the vibrating instrument. This rapid movement is called acoustic streaming and occurs inside the canal when activating irrigant. Ultrasonic irrigation operates at a much higher frequency (25–30 KHz), resulting in multinodal formation along the length of instrument, whereas sonic activation uses a lower frequency resulting in uninodeal formation which prevents the type of acoustic streaming seen in ultrasonic irrigation. A second contrast between sonic and ultrasonic activation is ultrasonically activating an instrument can result in cavitation of the irrigant, whereas sonic cannot cause cavitation due to its lower energy.

The purpose of this study was to evaluate the efficacy of syringe irrigation, passive ultrasonic, and passive sonic irrigation in terms of debris and smear layer removal at apical, middle, and coronal thirds of the root canal using scanning electron microscope (SEM).

**MATERIALS AND METHODS**

Forty-five freshly extracted, intact, single canal maxillary anterior human teeth were selected. They were cleaned of organic debris by ultrasonic scaler. Thereafter, disinfection was carried out with 2% thymol solution. To obtain a standardized root length of 12 mm, the selected teeth were decoronated by using water-cooled double-sided diamond disc. In decoronated samples, working length was determined by inserting the # 10 K file into the root canal until the tip of the file was just visible at the apical foramen, and the file was withdrawn 1 mm.

Each canal was shaped by crown down technique using the Protaper rotary system with X Smart; Endodontic Torque Control Motor (Dentsply, MalliferBallagiucc, Switzerland). Instrumentation was done by sequential use of files in the order S1–S2 followed by apical preparation till pro taper size F4. After each file use, irrigation was done with 1 ml of 4% sodium hypochlorite solution.

Samples were randomly divided into three groups of 15 samples each (n = 15) on the basis of final irrigation protocols.

- **Group 1 = Syringe irrigation**
- **Group 2 = Passive sonic irrigation using endoactivator**
- **Group 3 = Passive ultrasonic irrigation.**

The samples in each group were prepared as follows.

**Group 1 – Syringe irrigation**

After final preparation with F4 pro taper, irrigation was done with 1 ml of 17% ethylenediamine tetra-acetic acid (EDTA) for 60 s by 30G side ported needle (Max I Probe; Dentsply International, PA) which was placed 2 mm short of working length. Final irrigation was done with 3 ml of 4% sodium hypochlorite solution.

**Group 2 – Passive sonic irrigation using endoactivator**

The canal was filled with 1 ml of 17% EDTA and the endoactivator tip (Dentsply, Tulsa Dental Specialities, Tulsa) corresponding to # 20 ISO size was inserted 2 mm short of working length and centered in the canal to minimize contact with canal wall. The tip was further activated for 60 s and finally rinsing was done with 3 ml of 4% NaOCl.

**Group 3 – Passive ultrasonic irrigation**

The canal was filled with 1 ml of 17% EDTA, a passive stainless steel ultrasonic file corresponding to # 20 ISO size (Irrisafe, SatelecAceton, Merignac, France) was kept 2 mm short of working length and was ultrasonically activated by Piezoelectric Ultrasonic unit (DTE). Final rinsing was done with 3 ml of 4% NaOCl.

**Root sectioning and scanning electron microscope imaging**

The root canals were dried with paper points, and the root orifices were closed with cotton pellets followed by cavity to prevent the entry of the debris during sectioning. Shallow longitudinal grooves were made on buccal and lingual surfaces of roots. The roots were then split longitudinally using a surgical chisel and mallet, resulting in mesial and distal halves of each canal.

Both the mesial and distal halves were mounted on aluminum stubs, sputter-coated (SDC 050 Sputter Coater, Bal-tec S/A, Tokyo, Japan) with gold-palladium and examined under SEM.
with SEM (JSM-T 330 A, JEOL, Tokyo, Japan). To assess approximately the same area of each sample, two defined reference points were measured and marked on each half of root at a level of 4 mm and 8 mm from the apex with a scalpel blade before microscopy.

Representative sections of each third of the canal were screened and SEM images were recorded at low magnification (×500) for debris [Figure 1] and at higher magnification (×3000) for smear layer evaluation [Figure 2] at the apical, middle, and coronal region of each canal according to the scale developed by Hülsmann et al.

Debris
Debris is defined as dentine chips, pulp remnants, and particles loosely attached on the root canal wall.

- Score 1 – clean root canal wall, only a few small debris particles
- Score 2 – few small agglomeration of debris
- Score 3 – many agglomerations of debris covering <50% of the root canal wall
- Score 4 – more than 50% of root canal wall covered by debris
- Score 5 – complete or nearly complete root canal wall covered by debris.

Smear layer
Smear layer is defined as a surface film of debris retained on the dentin or other surfaces after instrumentation with either rotary instruments or endodontic file, consisting of dentine particles, remnants of the vital or necrotic pulp tissue, bacterial components and retained irrigant.

- Score 1 – no smear layer, open dentinal tubules
- Score 2 – small amount of smear layer covering the root canal wall, only a few dentinal tubuli open
- Score 3 – homogeneous smear layer covering the root canal wall, only a few dentinal tubuli open
- Score 4 – complete root canal wall covered by a homogeneous smear layer, no open dentinal tubuli
- Score 5 – heavy, nonhomogeneous smear layer covering the complete root canal wall.

The scoring procedure was performed by two different evaluators who were not identical to the operator. The photomicrographs of samples were coded and randomly distributed to the two evaluators who according to the scoring criteria independently rated the samples at a difference of 5 days to determine the interevaluator and intraevaluator agreement and reproducibility. The results were then statistically analyzed using the ANOVA and unpaired t-test.

RESULTS
The mean residual debris and smear layer scores in different groups are mentioned in Table 1. Intragroup comparison showed that smear layer and debris removal at coronal third

Figure 1: Residual debris at coronal, middle, and apical level of root canal in ultrasonic (a–c), sonic (d–f) and syringe (g–i) groups as observed in scanning electron microscope at ×500
was significantly better than the middle third followed by apical third [Table 2]. Intergroup comparison showed that all irrigation systems were efficient in removing smear layer and debris at coronal third (\(P > 0.05\)). At the middle one third, agitation of irrigating solutions by sonic and ultrasonic yielded significantly more removal of smear layer than syringe, whereas no significant difference in debris removal was observed between sonic and syringe group. When irrigant was agitated with ultrasonics, significantly more debris and smear layer were removed from the apical third as compared to syringe and sonic irrigation group (\(P < 0.05\)) [Table 3].

**DISCUSSION**

Any material left between the canal wall and the root canal filling may prevent intimate adaptation between the two and may provide a space for bacterial leakage and bacterial proliferation. In this respect, a 5-µm thick smear layer represents a potential gap between the root canal filling and root canal wall that may be capable of accommodating approximately five layers of bacteria and hence, its removal is of great clinical significance.\(^8\)

In the present study, instrumentation was done by greater taper instruments as it has been postulated that irrigation would be more effective in removing debris from root canals prepared with greater tapers. Final irrigation with chemicals such as EDTA and NaOCl is recommended to remove the inorganic and organic component of smear layer as the combination of multiple irrigants is an effective means of microbial reduction after mechanical shaping and cleaning.\(^4,9\)

The needle chosen for irrigation in the study was a 30G close-ended, side-vented needle, which is in accordance with
the studies done earlier to reach the maximum distance up to the apical foramen (within 2–3 mm). Side vented needles have proved better efficacy, improved hydrodynamic activation of irrigant and also less periapical extrusion as compared to needle with distal opening.\(^5\)

Various studies have shown that 30 s to 1 min of agitation of irrigant is sufficient to produce clean canals.\(^2,10,11\) In this study, 1 min time period for agitation was chosen as shorter passive irrigation time makes it easier to maintain the file in the center of the canal, thus preventing it from touching the canal walls. In addition, Ruddle also recommended 1 min time period for agitation when using endoactivator;\(^10\)

In this ex vivo study, cleanliness was measured as residual smear layer and the amount of residual debris. Hence, sections were examined under SEM under ×500 for debris scoring as it offered a wider view and for smear layer scoring was done at ×3000 as this magnification gave a detailed and precise informative image of the dentine surface for the analysis of smear layer;\(^12,13\)

Results showed that none of the groups completely eliminated the smear layer which was in accordance with the previously conducted study.\(^14\) Intergroup comparison showed that there was no significant \(P > 0.05\) difference in debris removal in the coronal one-third of root canals. The reason may be that coronal flaring allowed for better flushing action of the irrigating solutions and easier accessibility to irrigant.

However, when smear layer removal was compared individually between groups, ultrasonic and sonic resulted in more smear layer removal at coronal level, which was in accordance with the previous studies by Kuah HG et al. and Huffaker SK et al., who showed significantly better smear layer removal with agitation than without agitation.\(^15,16\)

At the middle one third, ultrasonic system performed significantly better than syringe and sonic for removal of debris. A pumping action synergistically combined with mechanical agitation explains the better results achieved with endoactivator system and ultrasonic as compared to syringe irrigation.\(^16\)

The reason for equivalent action of syringe for debris removal but inferior results for smear layer removal in coronal and

### Table 2: Intragroup comparison among different levels for syringe, sonic, and ultrasonic groups using ANOVA and unpaired \(t\)-test

| Serial number | Pairs of group | Probability of unpaired \(t\)-test | \(P\) (significance) |
|---------------|----------------|----------------------------------|---------------------|
| Syringe group | Coronal versus middle | 0.06 | >0.05 (NS) |
|               | Middle versus apical  | 0.47 | >0.05 (NS) |
|               | Apical versus coronal | 0.008 | <0.05 (S) |

| Sonic group   | Coronal versus middle | 0.30 | >0.05 (NS) |
|               | Middle versus apical  | 0.426 | >0.05 (NS) |
|               | Apical versus coronal | 0.075 | >0.05 (NS) |

| Ultrasonic    | Coronal versus middle | 0.16 | >0.05 (NS) |
|               | Middle versus apical  | 0.61 | >0.05 (NS) |
|               | Apical versus coronal | 0.08 | >0.05 (NS) |

| Remaining smear layer-syringe | Coronal versus middle | 0.199 | >0.05 (NS) |
|                              | Middle versus apical  | 0.108 | >0.05 (NS) |
|                              | Apical versus coronal | 3.9×10\(^{-3}\) | <0.05 (S) |

| Sonic | Coronal versus middle | 0.247 | >0.05 (NS) |
|       | Middle versus apical  | 0.008 | <0.05 (S) |
|       | Apical versus coronal | 1.2×10\(^{-3}\) | <0.05 (S) |

| Ultrasonic | Coronal versus middle | 0.56 | >0.05 (NS) |
|           | Middle versus apical  | 0.049 | <0.05 (S) |
|           | Apical versus coronal | 0.014 | <0.05 (S) |

### Table 3: Intergroup comparison among syringe, sonic, and ultrasonic groups at coronal, middle, and apical levels using the ANOVA and unpaired \(t\)-test

| Pairs of methods       | Probability of unpaired \(t\)-test | \(P\) (significance) |
|------------------------|-----------------------------------|---------------------|
| Syringe versus sonic   | 0.0495                             | >0.05 (S) |
| Sonic versus ultrasonic| 0.426                              | >0.05 (NS) |
| Ultrasonic versus syringe | 0.008                         | <0.05 (S) |

| Middle                 | Syringe versus sonic | 0.06 | >0.05 (NS) |
|                       | Sonic versus ultrasonic | 0.63 | >0.05 (NS) |
|                       | Ultrasonic versus syringe | 0.020 | <0.05 (S) |

| Coronal                | Syringe versus sonic | 0.16 | >0.05 (NS) |
|                       | Sonic versus ultrasonic | 0.61 | >0.05 (NS) |
|                       | Ultrasonic versus syringe | 0.08 | >0.05 (NS) |

| Residual smear layer-apical | Syringe versus sonic | 0.03 | <0.05 (S) |
|                            | Sonic versus ultrasonic | 0.014 | <0.05 (S) |
|                            | Ultrasonic versus syringe | 7.0×10\(^{-4}\) | <0.05 (S) |

| Apical                  | Syringe versus sonic | 0.027 | <0.05 (S) |
|                        | Sonic versus ultrasonic | 0.106 | >0.05 (NS) |
|                        | Ultrasonic versus syringe | 1.6×10\(^{-3}\) | <0.05 (S) |
| Middle                 | Syringe versus sonic | 0.008 | <0.05 (S) |
|                        | Sonic versus ultrasonic | 0.30 | >0.05 (NS) |
|                        | Ultrasonic versus syringe | 3.0×10\(^{-4}\) | <0.05 (S) |

\(S\): Significant; NS: Not significant
middle third may be that the loose debris is easily removed with the flushing action of irrigant, but the smear layer which is bound to tooth requires more action for removal which quite possibly is better with sonic and ultrasonic agitation.

The sonic device endoactivator performed similar to conventional syringe irrigation in the coronal and middle third but removed significantly more debris in the apical part. A possible explanation is that the oscillation amplitude of sonically activated irrigation needle is higher at the tip than at the attached end, resulting in increased fluid velocity.

At apical third, ultrasonic and sonic removed significantly more debris than syringe group however for smear layer, ultrasonic agitation removed more smear layer followed by sonic and syringe group, respectively. This is in accordance with previous studies, which confirm that ultrasonic activation removes significantly more smear layer than the sonic activation.[17‑19]

This is because ultrasonic irrigation operates at a much higher frequency resulting in multinodal formation along the length of instrument, whereas sonic activation uses a lower frequency resulting in uninalodal formation, which prevents the type of acoustic streaming seen in ultrasonic irrigation. A second contrast between sonic and ultrasonic activation is ultrasonically activating an instrument can result in cavitation of the irrigant while sonic cannot due to its lower energy. Furthermore, passive ultrasonic irrigation results in increase in the temperature of the irrigant which will enhance the tissue dissolving capacity of sodium hypochlorite.[18‑21]

Intragroup comparison of sonic and ultrasonic system showed that there was no difference in cleaning efficiency at coronal and middle one third which suggests that both these systems perform equally well in coronal and middle third but ultrasonic results in more smear layer removal in apical one third, this is due to the dampening effect of the sonic tip as it contacts the canal wall in apical third resulting in lower flow velocity and cleaning efficacy, whereas a better current flow and increased irrigant volume in association with ultrasonic.[23]

CONCLUSION

Within the experimental conditions, it can be concluded that activation of irrigating solution yielded cleaner canals although none of the agitation techniques were able to remove the smear layer completely from root canal. The most efficient root canal debridement was seen in the coronal third of root canal where all the irrigating techniques performed equally well. At the middle third, sonic and ultrasonic were better than syringe irrigation whereas at the apical third, ultrasonic yielded significantly better results than sonic and syringe irrigation.

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Conflicts of interest
There are no conflicts of interest.

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