An *in vitro* radiological evaluation of irrigant penetration in the root canals using three different irrigation systems: Waterpik WP-100 device, passive irrigation, and manual dynamic irrigation systems

Suragani Hemalatha, Archana Srinivasan¹, A. Sirekha¹, Lekha Santhosh¹, C. Champa¹, Ashwija Shetty¹

Departments of Conservative Dentistry and Endodontics and ¹Conservative and Endodontics, The Oxford Dental College, Bengaluru, Karnataka, India

**Abstract**

**Background:** Instrumentation and irrigation of the root canal facilitating effective debridement is considered the most important single factor in the prevention and treatment of endodontic diseases.

**Aim:** The aim of the study was to evaluate the depth of penetration of the irrigant depending on the final activation using Waterpik device modified with NaviTip needle, passive irrigation, and manual dynamic activation using the radiopaque solution in conjunction with digital dental radiography.

**Materials and Methods:** Ninety freshly extracted single-rooted mandibular premolars based on the inclusion and exclusion criteria were used for this study. Access cavity preparation was done for all the samples, and the working length of each sample was determined using a size 10-k file. The radiopaque solution (Urografin) was delivered into (Groups A, B, and C) prepared canal of samples at the rate of 1 ml in 30 s with up-and-down motion.

**Results:** The test results showed that Waterpik WP-100 group showed significantly high infiltration index values as compared to passive irrigation and manual irrigation group at $P < 0.002$ and $P = 0.007$, respectively.

**Conclusion:** Sonic irrigation using a Waterpik device modified with a NaviTip needle permits better infiltration of the irrigant.

**Keywords:** Irrigation techniques; manual dynamic irrigation; passive irrigation; radiopaque dye; sonic irrigation

**INTRODUCTION**

The goal of root canal therapy is to remove infected and necrotic pulp tissues, shape the root canal system and provide adequate sealing using obturation materials. Instrumentation alone cannot achieve total elimination of bacteria and debris in canals, and hence, an effective irrigant delivery to the working length is required.[¹]

Root canal irrigation systems can be divided into two broad categories: manual and machine-assisted irrigation techniques. Manual irrigation techniques include passive irrigation which is commonly performed with a syringe and an endodontic needle; it allows control of the depth of needle penetration in the canal and the volume of irrigant flushed through the canal, manual dynamic irrigation which is performed with nickel–titanium (Ni-Ti) files.[²,³] Machine **Address for correspondence:**

Dr. Suragani Hemalatha,
Department of Conservative Dentistry and Endodontics, The Oxford Dental College, Bommanahalli, Bengaluru - 560 068, Karnataka, India.
E-mail: hema72576@gmail.com

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assisted irrigation includes Rotary brushes, sonic irrigation, ultrasonic irrigation, pressure alteration devices, Endovac system, Risendo system etc., A study compared the microcomputed tomography scans before and after mechanical instrumentation and found that irrespective of the instrumentation technique, 35% or more of the root canal surfaces remained uninstrumented. Therefore, disinfection of the uninstrumented surfaces significantly depends on the use of irrigants. It had been illustrated that diligent instrumentation with copious irrigation substantially reduced the bacterial concentration. They are different strategies required to maximize root canal disinfection before filling. In this regard, many different irrigation protocols, solutions, and delivery systems have been recently introduced in endodontics, with the promise of optimizing root canal disinfection. The prime focus of the current study will be on three different irrigation systems: Waterpik device system, passive irrigation system, and manual dynamic irrigation system.

Waterpik WP-100 is a powerful oral irrigation activation device with a flow rate of 384 mL/min and water pressure of 10–100 PSI. The Waterpik Power Flosser is used to floss between the teeth. It operates on the same premise as the EndoActivator, using sonic activation (1–6 kHz) to induce hydrodynamic intracanal fluid agitation; in addition, the EndoActivator and Power Flosser system tips are interchangeable. As a result, the efficacy of the commercially available EndoActivator can be compared to Waterpik, which is more economical.

In manual dynamic agitation (MDA), an irrigant is dispensed into a canal through needles/cannulas of various gauges, either passively or with agitation. Moving the needle up-and-down the canal space accomplishes the latter. The most commonly documented approach for removing debris from the root canal is mechanical instrumentation with a master apical file and profuse irrigation with sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA). However, several other methods have also been proposed over the years, for example, using gutta-percha or rotary Ni-Ti instruments, using a patency file, and using various devices for the agitation of an intracanal irrigating solution to increase its efficacy. The simplest and most cost-effective way for overcoming apical vapor and allowing irrigant exchange close to the final working length is MDA with Ni-Ti file. After root canal instrumentation, the file was said to boost the effectiveness of final irrigation.

There is a shortage of literature regarding the efficacy of the three systems; thus, the aim of this study was to evaluate the depth of penetration of the irrigant depending on the final activation using sonic irrigation, passive irrigation, and manual dynamic irrigation using a radiopaque solution in conjunction with digital dental radiography.

### MATERIALS AND METHODS

The present in vitro comparative study was conducted in the Department of Conservative Dentistry and Endodontics at Oxford Dental College, Bangalore, on 90 freshly extracted single-rooted mandibular premolars with a single canal, which were extracted for periodontal/orthodontic reasons. Tooth with morphological defects, previously restored, crack or fracture lines, previous endodontic treatment, calcified canals, or with immature apices were excluded from the study. After extraction, teeth were preserved in saline before instrumentation. Access cavity preparation was done for all the samples, and the working length of each sample was determined by using a size 10-k file until the tip of the instrument appeared from the apical foramen and adjusted to the length 1 mm short of the working length. Cleaning and shaping was performed with stainless steel K-files up to 20 sizes and Neoendo rotary files up to #30/0.04 taper, then it was irrigated with 3 ml of 3% NaOCl and 3 ml of 17% EDTA. Each sample was numbered, and a layer of varnish was applied to the root to prevent contamination with plaster. Each sample was sunk into the mixture of plaster and sawdust and placed on an individual plinth [Figures 1 and 2].

**Standardization of study groups**

The experimental study consisted of 90 extracted teeth. After the specimen preparation, the 90 samples were divided into three groups of 30 teeth each.

**Group-A Waterpik water device modified with NaviTip needle**

For the pressurized water technique, the Waterpik device was modified by the addition of a 30G single side-vented NaviTip needle adapted to the standard jet tip of the Waterpik irrigation system using cyanoacrylate resin, which binded the jet tip to the needle. Urografin dye was injected and agitated inside the prepared canals at the rate of 1 ml in 30 s with up-and-down motion, 1 mm short of working length. The samples were irrigated with water to remove the contrast solution. A radiograph was taken to measure the infiltration of the contrast solution for all the samples [Figures 3 and 4].

**Group-B passive irrigation/conventional irrigation**

Passive irrigation with Positive pressure was done using a 2.5 cc syringe and 30 G single side vented needle (25 mm length/0.30 mm wide), urografin dye was injected and agitated inside the prepared canals similar to Group A. Finally, the samples were irrigated with water to remove the contrast solution. A radiograph was taken to measure the infiltration of the contrast solution for all the samples [Figure 5].

**Group-C manual dynamic activation with nickel-titanium file**

The canal was irrigated with 3 ml of 3% NaOCl followed by 3 ml of 17% EDTA by using a 2.5 cc syringe and 30 G
Hemalatha, et al.: Radiological evaluation of irrigant penetration

needle (25 mm length/0.30 mm wide), and additional agitation with Ni-Ti files (Dentsply, K-file) into the canal adjusted to 1 mm short of working length. To achieve this effect, the endodontic file was moved vertically and passively within the root canal. The file promoted the irrigant penetration and reduced the presence of air bubbles in the canal space. Urografin dye was injected and agitated inside the prepared canals, similar to Group A. Finally, the samples were irrigated with water to remove the contrast solution. A radiograph was taken to measure the infiltration of the contrast solution for all the samples [Figure 6].

Radiological examination
A fixation system was developed and divided into three parts: the first part to fix the X-ray cone (a), the second to place the sample (b), and the third to fix the radiographic sensor (c). This fixation system had a major role in the study; distance relative to cone/sample and sample/sensor was fixed, thus avoiding potential bias on the calculations related to radiation magnification. The radiographic cone was fixed on two slots, perpendicular to the plane of the sensor and the axis of the sample. Radiopaque solution (Urografin) was delivered, allowing visualization of infiltration. Digital radiography with an intraoral sensor was used in conjunction with dental imaging software to provide immediate results for each technique [Figure 7].

Radiological evaluation
The length of the infiltration of the irrigant was measured by drawing a line connecting the coronary landmark to the limit of the infiltration.

An index of infiltration was calculated; the length of the infiltration of the irrigant was divided by the working length:

\[ \text{Index of infiltration} = \frac{\text{Infiltration length}}{\text{working length}}. \]

The data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows 26.0. (SPSS, Inc., Chicago, Illinois, USA) Confidence intervals were set at 95%, and \( P \leq 0.05 \) was considered statistically significant. Descriptive statistics were applied for infiltration index values in terms of mean and standard deviation for each study group. One-way ANOVA test followed by Tukey’s post hoc test was used to compare the mean infiltration index values between different study groups.

RESULTS
Result shows the comparison of mean infiltration index values between three groups.

Figure 1: Samples with plinth base
Figure 2: A single sample with plinth base
Figure 3: Customized Waterpik with sided vented NaviTip irrigation needle

The test results demonstrate that the mean infiltration index values for Waterpik WP-100 group was 0.9692 ± 0.0342, for the passive irrigation group was 0.7598 ± 0.0601, and for the manual irrigation group was 0.9250 ± 0.0659. This mean difference in the infiltration index values between three groups was statistically significant at \( P = 0.001 \) [Table 1]. The multiple comparisons of mean differences in infiltration
index values was done between three groups. The test results showed that Waterpik WP-100 group showed significantly highest infiltration index values as compared to passive irrigation and manual irrigation group at $P < 0.002$ and $P = 0.007$, respectively. This was followed by the manual irrigation group showing significantly higher mean infiltration index values as compared to passive irrigation group at $P < 0.001$. This infers that Waterpik WP-100 group showed significantly the highest mean infiltration index values, followed by the manual irrigation group and least with the passive irrigation group [Table 2].

**DISCUSSION**

Traditional irrigation during root canal treatment with a syringe and needle is associated with only limited penetration beyond the main canal into dentinal tubules. To increase the efficacy of irrigants, several devices and irrigation techniques have been established to facilitate the root canal debridement.\[11\]

The three techniques have been the subject of this experiment and were each evaluated by X-ray acquisitions. The first technique was Waterpik device modified by the addition of a NaviTip (single side-vented needle 30 G) that does not allow direct ejection of the solution in an apical direction, unlike open-ended needles. Increased volume significantly improved solution penetration. One of the advantages of syringe irrigation is that it allows comparatively easy control of the depth of needle penetration within the canal and the volume of...
irrigant that is flushed through the canal.[12,13] The second technique was passive irrigation using a 2.5 cc syringe and NaviTip (single side-vented needle 30 G); the final technique was using a 2.5 cc syringe and NaviTip (single side-vented needle 30 G) and additional agitation with Ni-Ti files (Dentsply, K-file) into the canal adjusted to 1 mm short of working length.

In the present study, Table 1 illustrates the comparison of mean infiltration index values between three groups. The test results demonstrate that the mean infiltration index values for sonic irrigation with Waterpik WP-100 (Group A) (Waterpik, Inc., Fort Collins, Colorado, USA) showed significantly the highest infiltration index values, followed by the manual dynamic activation group and least with passive irrigation group at $P < 0.002$ and $P = 0.007$, respectively.

The better performance by the sonic irrigation (Waterpik device) group can be attributed to water pressure which is 7 kgf/cm$^2$ and frequency of 3–10 kHz, 1800 pulsations per minute, and produced vacuum inside the canal, which lead to better cleaning efficiency. Furthermore, the oscillating patterns of the sonic devices are different compared with ultrasonically driven instruments. A minimum oscillation of the amplitude might be considered a node, whereas a maximum oscillation of the amplitude represents an antinode. They have one node near the attachment of the file and one antinode at the tip of the file.[14] When the movement of the sonic file is constrained, the sideway oscillation disappears. This results in a pure longitudinal file oscillation. This mode of vibration has been shown to be particularly efficient for root canal debridement because it is largely unaffected by loading and exhibits large displacement amplitudes.[14] This is in accordance with a study done by Shalan et al.[15] and also with another study done by Shenoy et al.[9] which concluded that the pressurized water irrigation technique could be used as an intracanal irrigation technique with good results.

In the present study, Table 2 illustrates the multiple comparisons of mean differences in infiltration index values between three groups. The test results showed that Waterpik WP-100 group showed significantly highest infiltration index values as compared to passive irrigation and MDA group at $P < 0.002$ and $P = 0.007$, respectively. This was followed by MDA group showing significantly higher mean infiltration index values as compared to passive irrigation group at $P < 0.001$. This infers that Waterpik WP-100 group showed significantly highest mean infiltration index values, followed by the MDA group and least with the passive irrigation group.

MDA was shown to perform better than passive irrigation which could be due to air entrapment that follows removal of the gutta-percha, and conventional positive pressure irrigation may result in retention of the debris along the apical part of the canal walls. The results are in line with a study done by Susila and Minu[16] and Khaord et al.[17] who suggested that manual dynamic irrigation devices are beneficial in reducing postoperative pain and improving canal and isthmus cleanliness during endodontics.

Hence, the null hypothesis, stating that there is no difference in the depth of penetration of the irrigant depending on the final activation between the three irrigation activation systems, was rejected.

When the limitations of this research were considered, it showed that it does not exactly stimulate the clinical conditions of root canal treatment. Therefore, more research is required in the future on advanced irrigation techniques in vivo to determine the penetration depth of the irrigant. Despite the promising results, there are other limitations in this study. The root canals that were used in this study were large and straight. Whether similar results could be observed in narrow or curved canals is unknown and could be recommended for further investigation using different methods.

**CONCLUSION**

Sonic irrigation using a Waterpik device modified with NaviTip needle permits better infiltration of the irrigant with a significant difference compared to passive irrigation and manual dynamic irrigation. Considering the complexity of the canal system, full potentiality of the irrigant is required. Utilizing a manual or mechanical activation allows infiltration and better efficiency.

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Conflicts of interest
There are no conflicts of interest.

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