Evaluation of apical extrusion and cone-beam computed tomography assessment of irrigant penetration in oval-shaped canals, using XP Endo Finisher and EndoActivator

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Abstract

Background: Thorough cleaning of the pulp space is a challenging task. The mechanical instrumentation alone is usually not sufficient to completely debride the canals, and therefore, it requires the chemical action of irrigants also to disinfect the difficult to reach areas.

Aim: The purpose of this study was to determine apical extrusion and assess irrigant penetration through cone-beam computed tomography (CBCT) for EndoActivator (EA) and XP Endo Finisher (XP).

Materials and Methods: Sixty single-rooted mandibular premolars with oval-shaped canals were equally divided into three groups after instrumentation, based on the final irrigation: Group-1 syringe needle (30G Max-I-probe), Group-2 EA, and Group-3 XP. After the final irrigation, the weight of the extruded sodium hypochlorite was calculated. The prepared canals were then irrigated with a radiopaque contrast medium, which was activated according to the group of the sample (Group-1, 2, or 3). The volume of irrigant filled in the canal, especially in the apical third was determined through special tools in CBCT imaging.

Statistics: One-way ANOVA test was used to compare the different groups.

Results and Conclusion: Significantly more apical extrusion was seen in XP ($P < 0.001$). Both XP and EA have shown complete penetration of irrigant in the canal (100%).

Keywords: Apical extrusion; cone-beam computed tomography; EndoActivator; irrigant penetration; XP Endo Finisher

INTRODUCTION

The mechanochemical cleaning of the pulp chamber and canal space contributes greatly to the success of root canal therapy. Not only the shaping of the canal but irrigation also plays a prime role in eliminating any remaining pulp tissues and debris. Sodium hypochlorite (NaOCl) is the most frequently used irrigant in endodontic therapy, but its periapical extrusion can cause adverse effects such as severe pain, edema, profuse hemorrhage, and ecchymosis. Hence, it is essential to achieve a balance between safety and effectiveness in this area.

The conventional needle (CN) irrigation is the most commonly used technique because of its easy availability. However, its cleaning efficacy greatly relies upon the depth to which the needle is placed in the canal, affecting the canal debridement. Thus, newer irrigation techniques have been introduced in recent times.
EndoActivator (EA) (Advanced Endodontics, Santa Barbara, CA, USA) provides sonic agitation to irrigants. It is especially useful in canal irregularities such as isthmi, lateral canals, and fins.[3] The system comprises of a battery-driven handpiece and polymer tips, which are available in three different sizes.

XP Endo Finisher (XP) (FKG Dentaire, La Chaux-de-Fonds, Switzerland) is a recently introduced #25 nontapered NiTi file for irrigant activation. It is made up of a unique NiTi MaxWire alloy which assumes a different shape at a higher temperature, i.e., a spoon shape at body temperature. This results in continuous agitation of the irrigant along with scrubbing of the canal walls.[4]

This study was done to evaluate apical extrusion and cone-beam computed tomography (CBCT) assessment of irrigant penetration for contemporary irrigation systems such as EA and XP, in oval-shaped canals.

MATERIALS AND METHODS

The study was conducted in the Department of Conservative Dentistry and Endodontics, Maulana Azad Institute of Dental Sciences, New Delhi, India. Sixty human extracted mandibular premolars were included (extracted for reasons unrelated to the study), based on the following criteria: single rooted teeth with fully formed root; and a single (oval-shaped) canal with a long:short diameter ratio of ≥2. The samples were then inspected under a stereomicroscope for the absence of cracks, fractures, or any other structural or resorptive defects.

Standard endodontic access cavities were prepared, following which a #10 K-file (Dentsply Maillefer, Switzerland) was introduced into the canal until it was visible at the apical foramen. The working length (WL) was established 1 mm short of this length. To standardize the apical size of canals, all samples with initial binding at #15 K-file were included. A glide path was created using ProGlider file (Dentsply Maillefer, Ballaigues, Switzerland). Canals were then prepared with ProTaper Next (PTN) (Dentsply Maillefer, Ballaigues, Switzerland), till X3 (#30.07) up to the WL. Patency was confirmed with a #10 K-file. The specimens were irrigated with 4 ml of 2.5% NaOCl following each instrument, using a syringe and 30-G side vented needle (Max I Probe, Dentsply International, York, PA, USA), warmed to 37°C.

Before the final irrigation, each sample was mounted through a hole in the rubber matting lid of a collection vial. Each vial was weighed using a digital weighing balance (Sartorius, Germany) to the fourth decimal (10⁻⁴ g), to determine the pretest weight. A 20-gauge needle (for atmospheric pressure equalization) was inserted next to the prepared tooth.[7] A 3-way safety valve was screwed to the needle, through Luer lock; the other end of which was connected to a syringe used to generate a dynamic backpressure in a range of 5.8 ± 0.2 mmHg in the glass chamber.[8] The third end of the valve was connected to a digital manometer, which measured the pressure inside the chamber [Figure 1].

Final irrigation protocol

Group 1 - Conventional needle irrigation

A 30-gauge side-vented needle was placed within 2 mm from the WL and moved in a vertical motion to avoid the needle being locked in the canal. To ensure length control, a stopper was placed on the needle at the desired length.[9]

Group 2 - EndoActivator

The irrigation needle was placed at the pulp chamber level and under constant irrigation, a yellow EA tip was placed in the canal 1 mm short of the WL, and irrigant was activated at 10,000 cycles per minute for 1 min.[5,10]

Group 3 - XP Endo Finisher

The XP was inserted to WL; the canal access cavity was filled with the irrigant and the instrument operated in the canal for 60 s using mild 7–8 mm lengthwise vertical strokes. The file was used at a speed of 800 rpm and torque 1 N cm.[10,11]

Measurement of the extruded irrigant

After the test, the glass vial was disconnected from the testing apparatus, and the collection vial was weighed again to obtain the posttest weight (10⁻⁴ g). The mass of the extruded irrigant (NaOCl) was calculated with the following formula:

\[
\text{Posttest weight} - \text{Pretest weight} = \text{Weight of the extruded irrigant (NaOCl)}
\]

\[
\text{Volume of the extruded irrigant (NaOCl)} = \frac{\text{Weight of the extruded irrigant (NaOCl)}}{\text{Density of NaOCl}}
\]

Figure 1: (a) Mounting of the tooth in the rubber matting lid of collection vial; (B) testing apparatus for apical extrusion (A) tooth mounted on collection vial, (B) atmospheric equalization needle (20 G), (C) 3-way safety valve, (D) digital manometer, (E) syringe used to maintain pressure in a glass vial)
To check irrigant penetration using cone-beam computed tomography

The prepared canals were finally irrigated using a known radiopaque contrast medium, Iohexol (Contrapaque 300, JB Chemicals and Pharmaceuticals, Mumbai), commonly used in head imaging. Iohexol has similar physical properties, i.e., viscosity, density, and flow properties as NaOCl. The contrast medium was not activated in Group I; sonically activated using EA in Group II; and activated using XP in Group III, using the same protocol as described earlier.

CBCT scans were performed on Carestream 9300 Premium CBCT scanner (Carestream Health, Inc., Rochester, NY, USA) with ultrahigh-resolution voxel size (90 microns) and field of view of 5 cm × 5 cm, tube current 5 mA, 90 kVp, TFT sensor, scanning time of 28 s, and reconstruction time of <2 min. DICOM datasets from the scans were analyzed on GE advantage windows (GE Healthcare, United States) software version 4.6 for volumetric analysis of samples using patented “Paint on slices” technique in “Segment tool.” For each sample, the total canal volume and the volume of canal filled with irrigant (contrast medium) was measured [Figure 2]. Irrigant penetration(%) was determined using following formula.

\[
\text{Irrigant penetration (\%)} = \frac{\text{Volume of irrigant (radiopaque contrast medium) in canal}}{\text{Total volume of canal}} \times 100
\]

Means ± standard deviations of independent experiments were analyzed by the 1-way analysis of variance test. Post hoc Bonferroni test was used for intergroup comparison in both the criteria. All statistical analyses were performed using the IBM SPSS 20 software (IBM SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at \( P < 0.05 \).

**RESULTS**

The descriptive statistics (means and standard deviations) of the data are given in Tables 1 and 2. There was a significant difference in mean extrusion volume (ml) between CN, EA, and XP \((P < 0.001)\), with the greatest extrusion shown by XP \((0.0184 ± 0.0030 \text{ ml})\). The mean irrigant penetration was also found to be significantly different among the tested groups \((P < 0.01)\). The post hoc Bonferroni test indicated that EA and XP groups were significantly better than CN, whereas there was no difference between EA and XP.

The mean irrigant penetration in the coronal, middle, and apical third of the root canal was also compared among the tested groups. In EA and XP, it was found to be 100% in all the portions of the root canal, whereas, in CN, it was found to be significantly lower in the apical third \((97.37\% ± 0.92\%)\), as compared to the middle third \((99.29\% ± 0.75\%)\) and coronal third \((100\%)\) \((P < 0.01)\).

**DISCUSSION**

The removal of all the pulp tissue, whether inflamed or necrotic, and the elimination of microbes from the endodontic cavity contribute greatly toward the success of root canal treatment. However, the apical region exhibits a great number of complexities, i.e., isthmi, lateral canals, fins, apical delta, etc., leading to a more intricate localization of microbes. Wu et al. demonstrated the inefficiency of rotary instruments in cleaning oval-shaped canals, especially in its apical extensions. Thus, active irrigation plays a prime role in order to clean the area beyond the reach of root canal instruments.

In the present study, the PTN system was used for canal preparation, as it is known to cause lesser extrusion than other rotary or reciprocating file systems. The final apical size (#30/0.07) was sufficient to freely place the 30-gauge (0.25 mm diameter) needle within the apical 2 mm. The CN tip was placed within 2 mm of WL in all canals since the literature suggests the irrigant release to be 1–1.5 mm beyond its tip.

Table 1: Mean Extrusion volume (ml) of sodium hypochlorite beyond apex (One-way ANOVA; \( P < 0.001 \))

| Group                  | n (No. of samples) | Mean (ml) | Std. Deviation | \( F \) | \( P \)   |
|------------------------|--------------------|-----------|----------------|-------|----------|
| CN (Conventional Needle) | 20                 | 0.0142    | 0.0011         | 60.934| <0.001*  |
| EA (EndoActivator)     | 20                 | 0.0019    | 0.0018         |       |          |
| XP (XP Endo Finisher)  | 20                 | 0.0184    | 0.0030         |       |          |

Table 2: Mean Volume percentage of Irrigant Penetration in Coronal, Middle and Apical 3rd (One way ANOVA; \( P < 0.01 \))

| Group                        | Mean Volume % | Standard Deviation | \( F \) | \( P \)   |
|------------------------------|---------------|-------------------|-------|----------|
| CN (Conventional Needle)     | 79.2797       | <0.01*            |       |          |
| Coronal 3rd                  | 100           | 0                 |       |          |
| Middle 3rd                   | 99.295        | 0.75              |       |          |
| Apical 3rd                   | 97.372        | 0.92              |       |          |
| EA (EndoActivator)           |               |                   |       |          |
| Coronal 3rd                  | 100           | 0                 |       |          |
| Middle 3rd                   | 100           | 0                 |       |          |
| Apical 3rd                   | 100           | 0                 |       |          |
| XP (XP Endo finisher)        |               |                   |       |          |
| Coronal 3rd                  | 100           | 0                 |       |          |
| Middle 3rd                   | 100           | 0                 |       |          |
| Apical 3rd                   | 100           | 0                 |       |          |
The first part of the study concentrated on the calibration of apical extrusion of irrigant. The experimental apparatus was developed to mimic the resistance to extrusion offered by periapical tissue. Since the exact apical pressure that might result in a NaOCl accident is not known, the safety limit in this study was set to not exceed the central venous pressure of 5.88 mmHg, suggested to prevent the occurrence of intravenous accidents.\[8\]

It was seen that EA extruded the least amount of irrigant in comparison to the other two groups. This is in accordance with an in vitro study which has also demonstrated similar results.\[19\] A clinical study comparing postoperative pain after using CN and EA revealed that EA resulted in significantly less pain.\[20\] The increased apical extrusion and postoperative pain using CN have been attributed to the positive pressure generated in the canal space by CN.\[1,7,9\]

XP has shown significantly greater extrusion of NaOCl than other groups. Previous in vitro studies have demonstrated greater extrusion of debris by XP.\[11,21\] An in vivo study comparing postoperative pain after using CN and XP for the final irrigation found that both CN and XP resulted in similar incidence and intensity of pain.\[22\] These findings could be credited to the unique functioning of the XP file, wherein the file assumes a sickle shape in the root canal causing more turbulence and pressure, thereby forcing the debris and irrigant toward the periapical area.

In the second part of the study, the prepared canals filled with contrast medium (iohexol) were subjected to CBCT scans for the evaluation of irrigant penetration. Earlier studies checking irrigant penetration have used two-dimensional (2D) radiographic imaging as an evaluation tool.\[14,12\] However, such 2D images might lead to underestimation of results. Therefore, CBCT imaging was selected as the tool of choice.

CN has shown lesser irrigant penetration in the apical third of the oval-shaped canals [Figure 2]. This is in harmony with the previous studies,\[4,12\] wherein gas bubbles/apical vapor lock led to deficient penetration of irrigant in the apical third.\[23-25\] However, EA and XP have shown significantly better penetration of irrigant (100%) in the apical third of oval-shaped canals. This is related to the sonic agitation provided to irrigant when EA tip is placed inside the root canal.\[5\] The XP file is in continuous motion which allows the bulb and tip of the instrument to expand and contract in the canal. Such motion of file leads to a better irrigant penetration in the canal irregularities.

This study could not calibrate the amount of irrigant reaching the irregularities, and whether it was sufficient to disinfect the canal completely or not. However, previous in vitro studies done by confocal laser scanning microscope\[10,26\] revealed that XP and EA have proven to be significantly better in disinfecting canals and dentinal tubules up to a depth of 50 µm. This evidence further strengthens the results of the present study.

CONCLUSION

Within the constraints of this study, EA appears to be the...
most efficacious and safe method of irrigation, and CN was found to be least efficacious in irrigant penetration in the apical third of the root canal. However, XP has shown equivalent efficacy to EA in terms of irrigant penetration but has caused more apical extrusion. Further clinical research is required in this direction, before extrapolating the results to the clinical scenario.

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**Conflicts of interest**
There are no conflicts of interest.

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