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Evaluation Of The Apical Extrusion Of Irrigant Using Er:YAG Laser Side Firing Endo Tips At Different Levels From The Apex: An Invitro Study

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Abstract
Background
Effective irrigation is a critical component of root canal treatment to ensure the elimination of debris and bacteria from the root canal system. However, the risk of apical extrusion of irrigants remains a significant concern because it may lead to postoperative complications. The use of laser-activated irrigation, particularly the Er:YAG laser, has emerged as a promising adjunct owing to its ability to enhance irrigant penetration. Side-firing endo tips direct energy laterally, which potentially minimizes apical extrusion. This study aimed to evaluate the apical extrusion of irrigant using Er:YAG laser side-firing endo tips at different levels from the apex.
Methods
Forty-eight single-rooted mandibular premolars were prepared using a Ni-Ti rotary instrument with a diameter of up to F4. Based on the final irrigation/agitation protocols, four experimental groups were created, with each group (n = 12) receiving laser side-firing at 1 to 4 mm from the apex (groups 1 to 4, respectively). The irrigation procedures were carried out for 60 s using a 2.5% NaCl solution and a 17% EDTA solution. The apical extrusion was determined by subtracting the initial weights from the final weight of cube-shaped oasis.
Results
Among the four groups, groups 1 and 2 showed significant apical extrusion after the final Er:YAG laser-assisted irrigation at 1 and 2 mm, while groups 3 and 4 had no significant extrusion of irrigant.
Conclusion
Within the limitations of this study, we conclude that Er:YAG laser-assisted endodontic irrigation using a side-firing endo tip can be done safely at 3 mm from the apex. This method could ensure efficient cleaning and the safety of the patient.
Keywords: *Er:YAG laser, side firing endo tip, apical extrusion, laser assisted irrigation.*

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I. Introduction

Successful root canal treatment requires preparation that completely removes debris and the smear layer from the root canal and subsequently allows three-dimensional obturation. Chemo-mechanical preparation alone is insufficient to provide complete cleaning because of the complex anatomy of the root canal. Thus, an effective irrigation protocol is also required for the successful debridement of root canals (1).

During root canal preparation, instrumentation may inadvertently push irrigants such as sodium hypochlorite (NaOCl), along with necrotic tissue and microbial debris, beyond the apical foramen, potentially triggering inflammation and postoperative complications (2). Sodium hypochlorite serves as the main endodontic irrigant owing to its strong antimicrobial effect and tissue-dissolving ability. However, when it goes beyond the root canal system, it can damage periapical tissues and stem cells (3) in so-called hypochlorite accidents (4). In addition, inter-appointment flare-ups of infections are extremely undesirable for patients; therefore, proper measures need to be employed to reduce apical extrusion of infected debris (5).

Various irrigation techniques and devices have been developed and tested to enhance penetration, dispersal, and activation of irrigants in mechanically untouchable areas. Improved irrigation techniques such as sonic and ultrasonic irrigation and laser-activated irrigation appear to be more effective than classical syringe needle irrigation (6).

Sonic and ultrasonic irrigation exhibits better canal debridement efficacy over needle irrigation. However, it has some drawbacks, including uncontrolled removal of dentin, deformation of root canal morphology, and the risk of debris and irrigant extrusion into the periapical region (7-9). In recent years, erbium-yttrium aluminum garnet (Er:YAG) laser in combination with irrigant has been used as a new modality of endodontic disinfection (10).

Laser-activated irrigation was found to be an effective method for root canal irrigation. It can successfully remove the smear layer on the root canal wall, but a potential disadvantage is the extrusion of irrigant through the apex (11).

Photon-induced photoacoustic streaming (PIPS) is a cutting-edge laser-activated irrigation technique that utilizes low-energy photons and microsecond pulse durations. Because the tip is kept stationary in the coronal aspect of the access preparation, the efficiency of irrigation in the apical third of the root canal is improved (12).

Generating shock waves in the narrow root canals is difficult, however, and an innovative Er:YAG modality “shock wave-enhanced emission photoacoustic streaming” (SWEEPS) has been introduced to address this challenge. SWEEPS works similarly to PIPS, but it has a distinct mechanism of action whereby it sends pulse pairs into the irrigant, which generates primary and secondary shock waves throughout the root canal system. In SWEEPS, the laser tip is placed in the pulp chamber and effectively disinfects the root canal system without any direct contact with the root canal walls (1).

A side-firing spiral endo tip (Lite Touch™) was designed exclusively for cleaning and subsequent disinfection of the root canal during endodontic treatments and retreatments. The shape and volume of root canals prepared with NiTi rotary instruments fits the configuration of the tip. The endo tip is hollow, conical, flexible, and round in cross-section and has spiral slits placed circumferentially along its entire length. The end of the endo tip is closed, which prevents radiation transmission through the apical foramen (10).

The aim of the present study was to evaluate variation in the apical extrusion of irrigant using an Er:YAG side-firing endo tip at different distances from the apex.

II. Materials And Methods

Materials used

Oasis cube of size 3* 3* 3 inches were used to determine the amount of extruded irrigant.

Rubber dam sheets of thickness 0.2 mm (0.008 inches) (GDC Fine Crafted Dental Pvt. Ltd, Hoshiapur, India) were used to cover the oasis cube.

Protaper NiTi rotary files SX, S1, S2, F1, F2, F3, F4 (Dents-ply, Tulsa Dental Specialties, Tulsa, OK, USA) were used for cleaning and shaping of the canals.

Er:YAG laser with side-firing endo tip (LiteTouch™, USA) was used for laser assisted irrigation.

Preparation of the specimens

Extracted single-rooted mandibular premolar teeth were obtained from the department of Oral Surgery, GDCRI Bangalore. Premolars with root caries, cracks, wear, structural anomalies, and restorations were excluded from the study.

To eliminate any residual organic matter, all collected samples were immersed in a 2.5% NaOCl solution for 48 hours before further preparation. Afterward, a hand scaler was used to debride the outer surfaces of the root. Next, a 0.1% thymol solution was used for sample disinfection, and the samples were then stored in 4 °C distilled water.

To obtain a standard root length, the crowns were cut and fixed at 19 mm using a diamond bur. Then, the total length was reduced by 1 mm to obtain the working length. ProTaper Ni-Ti rotary instruments

(Dentsply) were used to prepare the samples up to F4 (40 size, 06 taper). After each file, root canals were flushed with 1 mL of 2.5% NaOCl.

For the final irrigation, the samples were divided equally into four groups containing 12 samples each. The groups differed by the distance from the apex that the Er:YAG laser side-firing tip was used: group 1, 1 mm from the apex; group 2, 2 mm; group 3, 3 mm; and group 4, 4 mm.

To determine the amount of extruded irrigant and debris, a cube-shaped piece of oasis (7.6 cm along each edge) was used. Before the irrigation procedure, each oasis cube was weighed three times on a precision balance, and the average value was recorded. A medium-sized rubber dam layer of 0.2-mm thickness was used to prevent leakage. The rubber dam was placed to cover each oasis cube, and its corners were fixed on a cork plate. The tooth was inserted into the oasis through a hole formed in the middle of the rubber dam, up to the cemento-enamel junction. Then, the junction of the tooth and rubber dam was closed using a cyanoacrylate adhesive for a complete seal.

Irrigation procedure

A 2,940-nm Er:YAG laser equipped with a handpiece holding a side-firing endo tip (Lite Touch) was used. The setting parameters were 1.5 W, 150 mJ, 10 Hz, and 60-s duration. The tip was positioned at 1 to 4 mm from the apex, depending on the group. The air and water spray was turned off. A 27 gauge open-ended needle was positioned 2 mm short of the working length, and the canals were irrigated four times with 2 mL of 17% EDTA for 15 s. Before the NaOCl irrigation, the canals were flushed with 2 mL of distilled water. The canals were then irrigated four times with 2 mL of 2.5% NaOCl for 15 s. The total activation time was 60 s for each irrigation solution. Finally, the canals were flushed with 1 mL of distilled water and dried with paper points.

After the irrigation procedure, the teeth were dried and removed from the setup, and each foam cube was weighed on the same precision balance three times, as before, and the average value was recorded. The amount of extruded irrigant and debris was determined by subtracting the initial weight from the post irrigation weight.

Sample size estimation

The present study's sample size was estimated using G Power software, with an effect size of 60% based on previous literature (1). With the study's efficacy set at 80%, a minimum of 48 samples were needed. Thus, each study group consisted of 12 samples (12 samples × 4 groups = 48 samples).

III. Statistical Analysis

Descriptive statistical analysis included weights before irrigation (Table 1) and after irrigation (Table 2), which are reported as the minimum, maximum, and mean and standard deviation (SD) for every group.

For inferential statistics, one-way ANOVA testing was done, after which Tukey's post hoc test was used to differentiate the mean weight before and after irrigation between the four groups. Student paired *t*-test was used to compare the mean weight before and after irrigation in each study group. The significance level was established at $P < 0.05$.

IV. Results

The mean weight of the oasis cubes before irrigation was 9.321 ± 0.1205 in group 1; 9.312 ± 0.5282 in group 2; 9.311 ± 0.212 in group 3; and 9.312 ± 0.384 in group 4. The mean weights of the four groups before irrigation were not significantly different ($P = 1.0$; Figure 1).

The mean weight after irrigation was 15.133 ± 0.120 in group 1; 12.664 ± 0.528 in group 2; 9.908 ± 0.341 in group 3; and 9.436 ± 0.378 in group 4. The mean weights of the four groups after irrigation were very significantly different ($P < 0.001$).

Multiple comparison of the mean differences between groups revealed that group 1 had significantly greater apical extrusion of irrigant in comparison with groups 2, 3, and 4 ($P < 0.001$). Group 2 showed significantly higher apical extrusion of irrigant compared with groups 3 and 4 ($P < 0.001$). Group 3 showed significantly higher apical extrusion of irrigant compared with group 4 ($P < 0.001$). In summary, the mean apical irrigant extrusion was significantly higher as the distance to the apex decreased.

V. Discussion

Root canal treatment is a common endodontic procedure aimed at removing infected or necrotic pulp tissue, disinfecting the root canal system, and ultimately filling and sealing the canal to prevent reinfection. During root canal treatment, the mechanical instrumentation and irrigation process often cause the extrusion of debris and irrigant beyond the root apex, which can lead to significant clinical challenges (2,3).

Extruded debris, composed of pulp tissue remnants, microorganisms, and dentinal chips, may contribute to postoperative pain and inflammation in periapical tissues, affecting the overall outcome and patient comfort. Similarly, the extrusion of irrigants such as sodium hypochlorite, which is commonly used for disinfection can cause irritation and damage to periapical tissues due to its cytotoxic properties (2-4).

Efforts to minimize extrusion during root canal treatment are critical for enhancing patient outcomes, reducing postoperative discomfort, and promoting optimal healing. Research suggests that instrumentation techniques, file designs, and irrigation protocols play a key role in limiting the amount of extruded debris and irrigant (2,5,13).

This study evaluated the effect of Er:YAG laser side-firing endo tips at different distances from the apex on the apical extrusion of irrigant. The results demonstrate that extrusion decreased significantly with increased distance of the endo tip from the apex, with the highest extrusion observed at 1 mm and the lowest at 4 mm. These findings indicate that even with side-firing tips, positioning too close to the apex may force irrigant beyond the root canal, potentially causing postoperative complications.

Side-firing tips offer a considerable advantage over conventional front-firing laser tips by delivering energy circumferentially, rather than directly forward, which allows for better lateral cleaning and less apical force. The unique design of these tips, as used in this study, enhances biofilm disruption and smear layer removal along the canal walls while providing a safer approach to apical irrigation. Er:YAG laser side-firing tips have been shown to yield strong antibacterial effects, especially when combined with NaOCl and EDTA solutions, achieving substantial reductions in *Enterococcus faecalis* biofilm in root canals (10,14).

The effectiveness of the side-firing tip's design is due to its hollow, conical structure with a sealed tip and spiral slits, which enables laser energy to radiate laterally for comprehensive coverage of the root canal walls. This lateral emission reduces direct pressure toward the apex, lowering the likelihood of apical extrusion, particularly when the tip is positioned 3–4 mm from the apex. Sahar-Helft et al. (10) noted that this tip structure, specifically designed for endodontic treatments, improves both the disinfection range and depth of laser-activated irrigation while preventing excessive force at the canal terminus.

Another factor to consider in clinical application is temperature control. Laser activation can generate heat, posing a risk of thermal damage to surrounding tissues. However, studies show that continuous irrigation with the Er:YAG laser side-firing tip minimizes temperature increases, making the procedure safer. Sahar-Helft et al. (10) found that continuous or segmented irrigation modes during laser activation significantly reduced outer tooth surface temperature, highlighting the importance of irrigant flow during laser use to avoid potential heat-related complications.

The findings of this study emphasize the importance of precise tip positioning to optimize the cleaning efficacy of laser-activated irrigation while minimizing extrusion risks. They suggest that positioning the tip 3–4 mm from the apex provides an effective balance between thorough canal cleaning and safeguarding apical regions. Moreover, combining side-firing tips with irrigants such as NaOCl and EDTA can enhance cleaning efficiency and offers substantial antibacterial effects, contributing to the success of root canal treatments.

Although promising, this study may not fully replicate the dynamic conditions of a living root canal system owing to the in vitro design. Future research could explore patient-reported outcomes such as postoperative pain to better understand the clinical benefits of optimized laser settings and tip placement. Additionally, testing variable laser power and frequency settings could provide more insights into the balance between cleaning efficacy and patient comfort.

VI. Conclusion

Within the confines of this in vitro study, it can be inferred that Er:YAG laser-assisted endodontic irrigation using a side-firing endo tip can be performed safely when positioned 3 mm short of the apex. This placement could optimally balance efficient canal cleaning with patient safety by minimizing apical extrusion. Further in vivo research is recommended to confirm these benefits under clinical conditions and to assess patient-centered outcomes such as postoperative comfort and healing.

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Figure 1: Comparison of the weights (mg) before and after irrigation by group.

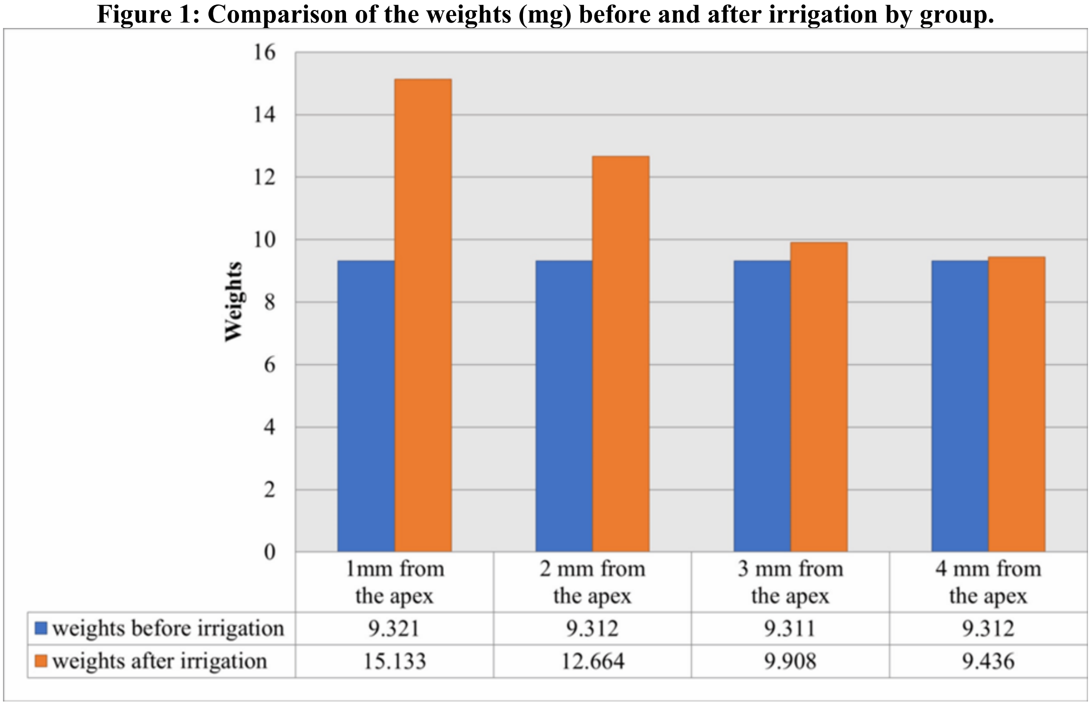

Table 1: Descriptive statistics of weights (mg) before irrigation among the different levels from apex

Distance from Apex	Minimum	Maximum	Mean	SD	*P*-value
1 mm	9.02	10.28	9.321	0.1205	1.000 NS
2 mm	9.06	10.06	9.312	0.5282	
3 mm	9.09	9.71	9.311	0.212	
4 mm	9.01	10.06	9.312	0.384	

NS: Not significant

Table 2: Descriptive statistics of weights (mg) after irrigation among the different levels from apex

Distance from Apex	Minimum	Maximum	Mean	SD	*P*-value
1 mm	14.96	15.34	15.133	0.120	<0.001**

2 mm	12.09	14.06	12.664	0.528	
3 mm	9.26	10.65	9.908	0.341	
4 mm	9.15	10.23	9.436	0.378	

**Statistically very significant