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EFFICACY OF DIFFERENT FINAL IRRIGANT ACTIVATION PROTOCOLS ON THE PENETRATION DEPTH OF A CALCIUM SILICATE-BASED BIOCERAMIC ROOT CANAL SEALER

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ABSTRACT

Introduction: The purpose of the research was to assess the impact of the final irrigant activation of ER: YAG laser with PIPS technique and ultrasonic irrigant activation by Ultra-X endoactivator (Changzhou Sifary Medical Technology, China) on the penetration depth of the bio-ceramic sealer (Meta Biomed Ceraseal, Korea).

Methods: 60 human mandibular premolars were utilized in the investigation. The access cavities were made. To achieve a size #40 apical preparation, all teeth were instrumented using a crown-down technique, using a set of ProTaper Next rotary instruments. Following biomechanical preparation, teeth were divided equally into 4 groups (n=15) G1 (Manual dynamic agitation), G2 (Passive ultrasonic instrumentation), G3 (PIPS technique), and G4 (No activation). The sealer was combined with the Rhodamine B dye to analyze the penetration of the sealer through the CLSM. Obturation was performed out in a single cone approach. Three slices (2 mm) were cut off from each root to symbolize the coronal, middle and apical thirds. The finding was tabulated and subjected to statistical analysis.

Results: There was substantial variation among different groups. The PIPS group had the greatest value, followed by PUI, then MDA, while the lowest value was found in No activation group.

Conclusion: The final irrigant activation strategy had a considerable impact on sealer penetration into the dentinal tubule. Use of PIPS tip or PUI seems advantageous in dentinal tubule penetration of a calcium silicate bioceramic sealer.

KEYWORDS: Confocal laser scanning microscopy, dentinal tubules penetration, PIPS, PUI, bioceramic sealer.

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INTRODUCTION

The main goal of root canal therapy is eliminating germs and prevent recontamination from the root canal system. However, it is hard to ensure a complete root canal cleaning using solely instrumentation approaches due to the complicated anatomical nature of the root canal system. Therefore, irrigation is a crucial component of root canal therapy since it enables cleaning that goes beyond the root canal tools.

For these irrigants to work, they need to come into direct touch with the entire wall. Replenishment and fluid exchange only go a short distance past the irrigating needle's tip during traditional needle irrigation. Consequently, in order to improve fluid dynamics and increase irrigation's reach, many theories, apparatuses, and instruments have been employed to activate it [1]. Numerous activation techniques, including sonic and ultrasonic devices as well as manual dynamic agitation, were studied in detail.

Various laser types were studied for irrigant activation, with varying parameters and delivery conditions; however, photon-induced photoacoustic streaming (PIPS) is an approach that seems to be a promising technique [2,3]. It uses an Er:YAG laser, which has a wavelength that absorbs water very well. Accordingly, intense photoacoustic shock waves and quick fluid motion brought on by the expansion and implosion of laser-induced bubbles would only require sublative parameters.

It is possible for microorganisms to persist in the root canal even following biomechanical techniques. Assuring appropriate root canal system filling is the goal of filling procedures. Any remaining bacteria are entombed by sealer cement inside dentinal tubules, keeping them away from nutritional supplies. Deep penetration of the endodontic sealer reduces the interface area between the filling material and the root dentin and may enhance filling mass retention owing to mechanical locking.

Calcium silicate-based sealers (CSBS), also referred to as "bioceramic" sealers, have been available for use over the past ten years. In contrast to traditional root canal sealers, CSBS is hydraulic and hygroscopic with a specific setting procedure. CSBS has numerous intriguing features, including biocompatibility, antibacterial capabilities, and bioactivity. Nonetheless, research on the dimensional stability of CSBS produced contradictory findings; while few demonstrated no shrinkage after setting, others showed a small expansion. In a biological context, mineral layer development in setting promotes a chemical connection with dentin walls, which adds to their sealing capacity [4].

Based on the high importance of reaching a sufficient cleaning during root canal treatment and obturation components could attach to the root canal wall via sealer interlock in the dentinal tubules resulting in a hermetic seal, the present study highlights efficacy of irrigant agitation with PIPS using 2940nm Er: YAG laser and ultrasonic activation with Ultra X device and their effects on the penetration depth of the bioceramic root canal sealer of endodontically treated teeth.

MATERIALS AND METHODS

Sixty individual mandibular premolars recently gathered for orthodontic purposes were collected. The selected teeth were radiographically examined in mesiodistal and buccolingual view to verify the existence of a sole canal. Samples were immersed in 5.25% NaOCl for half an hour then all teeth were completely cleaned from any soft or hard tissue deposits, and then tested under adequate illumination and magnification for the subsequent inclusion traits: no obvious crown or root caries, fissures, or evidence of external or internal resorption or calcification. After that, the teeth were set to a specified length of 18 mm using a high-speed diamond disc under coolant, the teeth were not fully decoronated, and the crowns were left in place to act as a reservoir for the irrigant fluid.

Sample preparation:

Access cavity preparation was made under coolant using carbide round burs and endo z burs, then the root canal was negotiated by 21mm #10 K–file (DENTSPLY Maillefer, Ballaigues, Switzerland) to provide a glide path for further instrument and to establish the working length. Canals were prepared by utilizing Protaper Next rotary nickel-titanium system according to the manufacturer's instruction (Dentsply Maillefer, Ballaigues, Switzerland) till X4 (40/0.6) at 300 RPM and a torque of 2 Ncm with motor E-connect eighteeth. First, the canals were instrumented using X1, then X2 and X3 ending with X4. Between successive files, the canals were irrigated with 5mml of 5.25% sodium hypochlorite (NaOCl) using conventional needle irrigation by a 27 G side vented needle attached to a handle held syringe and lubricated with EDTA gel.

Classification of the specimens:

Specimens were categorized into randomized four equal groups (n=15) based on the final irrigation approach as follows:

- ***Group I (manual dynamic activation):*** In the MDA group, 5ml of 5.25% NaOCl preceded by 5ml of 17% EDTA was each activated. The irrigant was flowed into the canals, and push-pull strokes were manually applied to the WL at a rate of around 100 strokes per minute using a size 40/6% taper gutta-percha cone.
- ***Group II (passive ultrasonic irrigation):*** In the PUI group, 5ml of 5.25% NaOCl perceded by 5ml of 17% EDTA was activated by using noncutting, flexible, and soft silver tip (21 mm, size 20 taper 2) that was fitted passively reaching 2 mm short from the working length in short vertical strokes. The tip is operated by Ultra X device (Changzhou Sifary Medical Technology, China) at the maximum power of 45 kHz.
- ***Group III (PIPS using 2940 nm Er:*** YAG laser): The root canals were irrigated with 5ml of 5.25% NaOCl and 5ml of 17% EDTA following PIPS protocol, using a newly designed tapered and stripped tip and a minimally ablative laser setting of 20 mJ, 15 Hz, and 50 µs was used to produce photon-induced photoacoustic streaming of irrigants. The laser system's water and air were turned off. When PIPS was activated, the irrigant was constantly supplied into the pulp chamber while the PIPS tip remained stationary in the coronal aspect of the access preparation rather than inside the canal.
- ***Group IV: No activation.*** For all three groups, Activation of 5.25% NaOCl was performed for 60 seconds, then 3ml of saline were used to flush the canal followed by EDTA 17% with an activation time of 30 seconds. Finally, the canals were flushed with 3 ml of saline.

Obturation of the specimens:

The root canals were dried with absorbent paper points following mechanical preparation and final irrigation, and they were obturated using the gutta-percha single cone technique using F4 (40/0.6) (ProTaper F4, Dentsply Maillefer) in combination with a calcium silicate-based sealer (Meta Biomed Ceraseal, Korea). To facilitate the evaluation using confocal laser microscopy, the sealer was combined with 0.1% Rhodamine B dye as a tracing substance. 0.001 grams of the 0.1% Rhodamine B dye was combined with 1 gram of the calcium silicate-based sealant. Since the Rhodamine B dye is light- and heat-sensitive, the sample's obturation was done under low light. Following obturation, access cavity was enclosed with a temporary material Cavit G (3M, ESPE, St.Paul, MN) and the samples were coated with two layers of nail polish and kept in a 100% humidity at room temperature for 1 week.

Evaluation of sealer penetration:

After obturation and complete setting of the sealer, the roots were mounted onto resin stubs before being sliced transversely with a microtome. Three slices were taken from each root, illustrating the coronal, middle, and apical region (3, 6, and 9 mm from the root apex). With the use of a microtome making a 2 mm thickness slice. Following that, the slices were extensively examined using a CLSM. Zeiss Microsystems software (LAS-X) was implemented to analyze the photos. The light source was a helium-neon laser with a 543 nm wavelength for the excitation. Beyond 560 nm, fluorescent light was gathered. Fluorescent mode was used to capture the images from the Confocal laser scanning microscope. A uniform fluorescent ring around the canal wall, signifying the sealer-dye distribution, was assessed for each 10x sample. The deepest penetration region was noted and magnified 20 times. The fluorescence was traced down to the greatest depth, showing the sealer's penetration depth into dentinal tubules. The ImageJ (ImageJ software, NIH) was used to import digital pictures and calculate the total dentinal tubule penetration area. For statistical analysis, the dentinal tubule penetration area was transformed from micrometers (μm) to square millimeters (mm2). The penetration of the tubular dentin sealer was calculated utilizing the following formula:

penetration of the tubular dentin sealer was calculated=

$$\frac{\text{area filed by the sealer-root canal area}}{\text{dentin area}} \times 100$$

. One value was obtained for each section by averaging the data. To rule out any discrepancies, the entire specimen was examined by a single operator.

RESULTS

When matching root canal thirds were compared between groups, there was a significant difference (p<0.001). Using the PIPS approach yielded the greatest value, followed by the PUI group, the MDA group, and the No activation group yielded the lowest value. All post hoc pairwise analysis were statistically significant (p<0.001). The coronal third had the highest sealer penetration, followed by the middle third, while the apical third area had the lowest.

TABLE (1) Mean and standard deviation values of penetration depth (%) for different groups

Section	Penetration depth (%) (Mean±SD)				p-value
	MDA group	PUI group	LAI group	No activation group	
Coronal	33.54±3.48^{Ca}	53.71±4.31^{Ba}	72.94±4.00^{Aa}	24.52±2.03^{Da}	<0.001*
Middle	24.24±2.27^{Cb}	44.82±2.64^{Bb}	64.81±1.01^{Ab}	15.66±1.42^{Db}	<0.001*
Apical	15.16±3.00^{Cc}	37.57±1.47^{Bc}	56.79±0.64^{Ac}	6.85±1.96^{Dc}	<0.001*
p-value	<0.001*	<0.001*	<0.001*	<0.001*	

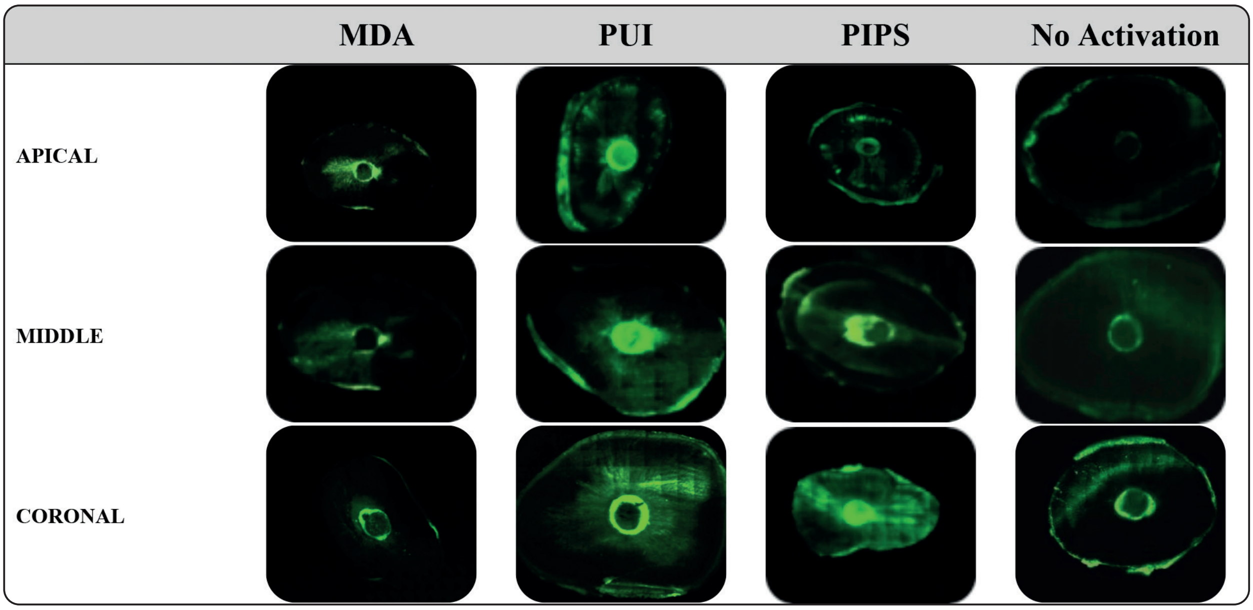

Fig. (1) CLSM images from each group showing sealer penetration at apical, middle and coronal section

DISCUSSION

As we aspire for minimal invasiveness to the root canal system while achieving the best cleaning and debridement with boosting of the sealing capability and retention of the sealer, this study was designed to test and contrast the efficiency of the final irrigant activation of ER: YAG laser with PIPS approach and passive ultrasonic irrigant activation by Ultra-X device on the penetration depth of the bioceramic root canal sealer.

For mechanical phase and irrigating protocols, various methods of activating the rinse solution are used in conventional endodontic therapy. ***Gu et al.*** [5] mentioned that the influence of irrigant agitation on tissue dissolution was greater than that of irrigant temperature, as continuous agitation of sodium hypochlorite led to faster tissue dissolution. The final irrigant utilizing in this investigation linked to Er: YAG laser with PIPS technique. An Er: YAG laser was used with sub-ablation parameters of 20 mJ at 15 Hz and an average power of 0.3 W. No thermal damage to organic dentin structures occurs on using this technique compared to conventional ultrasonic technology as the tip was only placed in the coronal portion [6].

The PIPS approach differs from other agitation procedures in that it depends on photoacoustic and photomechanical activity without the requirement for reaching the root apex. Similarly, with this method, each impulse interacts with the water molecules, leading to the formation of expansion and serial shock waves that result in the creation of a powerful flowing fluid[7]. According to ***Dahwan et al.*** [8] Pressure waves created after laser administration greatly assist endodontic irrigant in eliminating the smear layer and permitting optimal sealer penetration and adaptation to dentinal walls.

Also, Passive ultrasonic irrigation (PUI) was employed to activate the irrigating solution by using the Ultra X device at 45,000 kHz. It was affirmed by ***Walters et al.*** [9]; ***Sabins et al.*** [10] that the advantage of the passive ultrasonic irrigation technology over the active system is that it preserves the root canal's morphology after treatment. The irrigation solution is recognized to be activated by acoustic streaming and cavitation processes. The creation of a fluid circulation or vortex surrounding the vibrating device is referred to as acoustic streaming. Cavitation is the creation of submicroscopic voids caused by the ultrasonic instrument tip's alternating, high-frequency movement of the fluid medium. Waves can push a solution, no matter how little or difficult to reach, into every dimension of a given system as they continue. The outcome could produce the best possible cleaning and scrubbing mechanism [11].

A manual agitating technique was also applied in our investigation. Many general practitioners and endodontists still find this method to be quite satisfactory. One of the benefits of MDA is that it allows for relatively simple regulation of the amount of irrigant discharged through the canal.

Regarding the material, CeraSeal bioceramic sealer was selected for our study. It is an injectable calcium-silicate-based root canal sealer, this sealer as sugessted by the manufacturer has excellent sealing ability, unique stability. From another angle, bioceramic sealers promote dentine re-mineralization, show an antibacterial effect, and have great dentinal tubule penetration [12–15]. The capacity of root canal filling materials to penetrate dentinal tubules and exert an antibacterial effect may also help prevent residual bacterial colonization and root canal reinfection [16,17]. Using various obturation procedures, it was shown that bioceramic sealers facilitate penetration into dentinal tubules at a distance of 2 mm from the apex [18].

Focusing on sealer penetration was seen to be more relevant in this study than sealer adaptation as the distance that the sealer would travel in the dentinal tubules reflects the amount of cleaning. Regarding sealer penetration evaluation, confocal laser scanning microscopy was used as it is considered the best method to evaluate sealer penetration. Confocal laser scanning microscopy has certain advantages over scanning electron microscopy and other techniques. It decreases the technical artifacts and eliminates the need for sample processing. Rhodamine B permits CLSM evaluation of the sealer without affecting its physical or chemical characteristics. The sealer was combined with 0.1% Rhodamine Bisothiocyanate as a fluorescent substance in the current work to allow visualization of its penetration into the tubules. Furthermore, the CLSM with high-contrast spots allows detection of the sealer within the dentinal tubules [19–21].

Based on our finding, sealer penetration was deeper and more evenly distributed in the coronal third than in the middle and apical thirds. The outcomes are consistent with previous research by ***Akcay et al.*** [6]; ***Mamootil et al.*** [22]. The narrow diameter of dentinal tubules, a decrease in tubule number in the apical section, ineffective irrigant delivery in this portion, and increased tubule sclerosis in the area could all be contributing factors to the lower penetration in the apical portion.

According to the current study, PIPS and PUI both achieve greater dentinal penetration than MDA and CI, with a statistically significant difference with the superiority of the PIPS group over the other groups. The reason for this increase of sealer pen-etration following PIPS is that the Er: YAG laser-activated irrigation creates explosive vapor bubbles that have a secondary cavitation effect and encour-age high-speed fluid motion in the root canal [23,24] and allows effective cleaning of the smear layer and debris from complicated root canal networks [25,26].

DiVito E et al. [7]; ***Peters et al.*** [27] shown that, when compared to conventional and ultrasonic methods, the use of an ER: YAG laser at extremely low intensity in conjunction with irrigants produced greater debris and smear layer removal and bacterial decrease without causing thermal damage to the organic dentinal structure.

Moura-Netto et al. [28] demonstrated that dentin fusion and recoagulation were enhanced by both the Nd:YAG laser and the diode laser, resulting in the blockage of some dentin tubules. Conversely, dentin surface ablation was brought about by Er: YAG laser irradiation, and this effect was more noticeable in intertubular dentin than in peritubular dentin. Compared to utilizing a diode laser, this led to more exposed dentinal tubules, better sealer penetration when using Er: YAG, and superior sealing qualities of the final endodontic restoration.

The higher efficiency of Er: YAG lasers over Nd: YAG lasers can be since Er: YAG lasers have been extensively studied for hard-tissue set up, and these wavelengths are greatly absorbed via water, allowing for enhanced tissue elimination by thermomechanical ablation [29]. Nd: YAG laser, in contrast, appears to be absorbed via mineral components like phosphates and carbonate hydroxyapatite and destroys crystal materials through thermomechanical reaction. This causes resolidification and melting events on the dentin surface, which minimizes dentinal permeability through facilitating nearly full occlusion of dentinal tubules just before root canal filling [30].

In accordance with the present result, ***Akcay et al.*** [6] found that Er: YAG laser activation with PIPS technique and PUI had remarkable better dentinal sealer penetration than CI, also a study by ***Abdel-Gawad et al.*** [31] reported that the Er: YAG laser (PIPS) possessing the ideal sealing ability and sealer penetration when compared to diode laser and CI. Furthermore, when equivalent root canal thirds were compared, the current results correlate with ***Eldeeb et al.*** [32] who demonstrated greater sealer penetration following PIPS activation with the exception of the apical third, which had root canal preparation of 25/4%. Also, ***Aksel et al.*** [33] reported that PUI showed a significantly higher amount of sealer penetration compared to standard needle irrigation. The result of a study via ***Machado et al.*** [34] too illustrated that EAS, EVS, and PUI achieved a better degree of tubular dentin sealer penetration than CI.

In contrast, ***Generali et al.*** [35] concluded that the irrigant administration and/or agitation methods investigated did not influence sealer penetration into dentinal tubules. Also, ***Yilmaz et al.*** [36] concluded that irrigation with PUI, SI, and MDA didn't significantly enhanced sealer penetration.

CONCLUSION

Within the limitation, this in vitro investigation found that irrigant activation using PIPS and PUI allow more penetration of sealing material into the dentinal tubules when compared to MDA and CI. Tubular penetration in coronal region had the highest value and decreased as it approached toward the apex.

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