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EFFECTIVENESS OF DIFFERENT ACTIVATED IRRIGATION TECHNIQUE IN REMOVING BIOCERAMIC INTRACANAL MEDICAMENT: A MICRO-CT STUDY

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ABSTRACT

Aim: This study aimed to compare the efficacy of three activated irrigation technique in the removal of bioceramic intracanal medicament from root canals using micro computed tomography (micro-CT). **Materials and Methods:** Thirty extracted human mandibular premolar teeth were decoronated and instrumented with ProTaper rotary system up to size F3 and filled with Bio C Temp paste. After 1-week incubation period, the intracanal medicament (Bio C Temp) was removed using one of three activation techniques, (n=10) for each: XP-endo Finisher–activated irrigation, Sonic EndoActivator–activated irrigation, or 940-nm diode laser–activated irrigation. Residual medicament volume was calculated three-dimensionally using micro-CT reconstruction and expressed as a percentage of remaining Bio C Temp. Data were statistically analyzed using two-way ANOVA followed by Duncan‘s multiple range test**. Results:** The activation techniques were not able to completely eradicate (Bio-C Temp) intracanal medicament. The percentage of remaining Bio C Temp was lowest in the XP-Endo Finisher than Sonic EndoActivator and diode laser technique. The apical third showed a significantly higher percentage of remaining Bio C Temp than middle and coronal thirds. **Conclusion**: The XP-Endo Finisher technique showed highest removal efficacy than Sonic Endoactivator and diode laser. the XP-endo Finisher, showed superior cleaning efficacy in the apical area.

KEYWORDS: Bio C Temp, Micro-CT, XP-Endo Finisher, Diode laser, Sonic Endoactivator.

INTRODUCTION

Root canal disinfection is a critical step in endodontic treatment that involves eliminating microorganisms from the root canal system. The goal of root canal disinfection is to create an environment within the root canal system where microorganisms are unable to survive and minimize the available space by the endodontic procedure. This is accomplished through a combination of mechanical instrumentation, irrigation, and the use of intra-canal medicaments together with hermetic obturation of the Root Canals.[1] Bioceramic compounds has recently opened up advanced avenues for enhancement of root canal disinfection. Intracanal bioceramic dressing Bio-C Temp (Angelus, Londrina, Brazil) composed of calcium silicate, calcium tungstate, calcium aluminate, and titanium oxide radiopacifiers, polyethylene glycol, calcium oxide, and base resin. It is specifically used as an intracanal dressing for retreatment, pulp necrosis, and exudate cases. It combines both antimicrobial action and bioactivity. In addition, its high alkalinity (pH = 12), high radiopacity and low solubility permit the extended time of contact between the medication and canal walls, and gradual release of hydroxyl (OH^-) and Ca^{2+} ions. Therefore, the environment becomes unsuitable for bacterial growth.[2]

Following the placement of medicament, before obturation, the medicament must be completely removed from the pulp space. Residual medicaments have known to prevent the sealer penetration in dentinal tubules and leave voids between the filling material and dentin surface, hence facilitating bacterial proliferation. Various methods of irrigant delivery are used to facilitate the removal of medicament from root canals, including passive ultrasonic irrigation, sonic irrigation with EndoActivator or Vibringe, canal brushes, XP Endo Finisher, laser, etc.[3]

A recent nickel–titanium rotary finishing file, the XP-endo Finisher file (XPF; FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), can be used for the activation of irrigants. The XPF file has a small core size of ISO #25 in diameter and zero taper. it is made from special nickel-titanium(NiTi) alloy called MaxWire that permits its expansion and contraction during rotation in the root canal. The XPF file is straight in the martensitic phase when it is cooled. When the file is inserted into the root canal at body temperature, it converts to the austenitic phase with a spoon shape and reaches difficult to cleans areas. it facilitates the removal of medicaments from root canals by guiding the chemical solutions or irrigants in inaccessible areas.[4]

A sonic-driven irrigation solution activation system, called the EndoActivator (EA) was manufactured to produce vigorous fluid agitation in the root canals by using flexible, plastic, and non-cutting tips of various sizes. It has been shown that EA has a superior irrigation efficacy when compared to conventional needle irrigation. EA has a non-cutting tip, and the tip generates short vertical strokes by vibration and up-and down movements, which ease the elimination of debris from the root canals.[5]

the Diode Laser (DL) is recommended for endodontic treatment because its wavelength is within the infrared range, also thin and flexible fibers can be used. The use of laser-activated irrigation gained interest in endodontics; as it enhances the warming of the irrigant all while agitating it, improving its impact. Diode lasers have acquired importance due to their convenience of usage, adaptability, portability, and lower price than other lasers.[6]

The Volumetric analysis using micro computed tomography micro-CT has more recently been employed, offering more precise information compared to surface area measurements. Given its advantages, such as high-resolution 3D volume analysis and nondestructive evaluation, the present study employed micro-CT to quantitatively assess the residual amounts of intracanal medicament.[7] The presented study aimed to compare the efficacy of three activated irrigation technique for removing Bio CTemp intracanal medicament from the root canals using micro-computed tomography (CT) analysis. The null hypothesis assumes that the three activated irrigation techniques show no significant differences and are equally effective in removing Bio C TEMP throughout the entire root canal length.

MATERIAL AND METHODS

Samples Preparation

thirty human mandibular premolars with single straight canals and mature apices extracted for orthodontic purpose had been chosen. All sample were disinfected by immersion in 5.25% sodium hypochlorite for 30 minutes, followed by mechanical debridement, and subsequently stored in distilled water to avoid dehydration. Then, preoperative radiographs were taken to check the criteria for teeth selected which must be included: completely formed apices and no calcified canal, no internal resorption, no caries or previous endodontic treatment.[8] then the crowns of the teeth were sectioned at the cementoenamel junction (CEJ) using a 0.2-mm diamond disc (Komet, Germany). The Root lengths were standardized to 15 mm using a digital vernia.[9] Each specimen was embedded in a plastic tube filled with a silicone rubber–based impression material. then, The Working length determination was performed by introducing a size 10 K-file (Dentsply, Switzerland) into the canal until the file tip was visually detected at the apical foramen, after which 1 mm was subtracted from this measurement.[10] To establish a closed-end canal model and to prevent apical extrusion of irrigants and intracanal medicaments, the apical foramen was finally sealed with soft wax.[11] the preparation of root canals was performed using ProTaper Universal NiTi rotary instruments (Dentsply, Ballaigues, Switzerland) driven by an Eighteeth endodontic motor set at a speed of 250 rpm and a torque of 3 N·cm, up to size F3. Throughout instrumentation, apical patency was preserved using a size 10 K-file.[12] During canal preparation, irrigation was carried out with 2 mL of 5.25% sodium hypochlorite (AQUA Medical, Turkey) between each file. after completion of instrumentation, a final irrigation regimen was applied consisting of 5 mL of 5.25% NaOCl, followed by 5 mL of normal saline and 5 mL of 17% EDTA (Imicryl, Turkey) for 1 minute, with a final flush of 5 mL of normal saline and the canals were dried with F3 sterile absorbent paper points.[13]

The Bio C Temp medicament (Angelus, Londrina, Brazil) was inserted into the root canals via a Flex Flo tip (Avalon Biomed, USA) positioned 1 mm short of the apex and 25 Lentulo spiral operated at 800 rpm was used for 30 seconds to ensure uniform distribution and coating along the canal walls, and the procedure was repeated until paste extrusion was observed at the canal orifice[14] the access cavities were temporarily sealed with cotton pellets and temporary restorative material (Cavit, 3M, Germany). the specimens were wrapped in gauze moistened with distilled water and stored in a thermostatic incubator at 37°C with 100% relative humidity for one week to simulate the oral environment.[15] Following the storage period, the coronal access was opened, and a size 15 K-file was inserted to the working length to loosen the intracanal medicament and create sufficient space for the irrigation tips. The specimens were then randomly allocated into three groups (n = 10 each) according to the technique employed for the removal of Bio C Temp medicament.[16]

Group 1: XP- Endo finisher activated irrigation
The XP-endo Finisher file (FKG Dentaire, La Chaux-de-Fonds, Switzerland) was operated at 800 rpm and 1.0 N·cm torque using an E-Connect S endodontic motor (Eighteeth, China). The working length was standardized at 14 mm, and the instrument was cooled with a cold spray (Endo-Ice, Switzerland) before activation.[17] The canal was irrigated with 1 mL of 5.25% sodium hypochlorite and activated for 30 s using gentle vertical strokes, followed by rinsing with 3 mL of distilled water. Subsequently, 1 mL of 17% EDTA was activated for 30 s, and the procedure was completed with a final rinse of 5 mL of distilled water.[18]

Group 2:-Sonic- Endoactivator activated irrigation
The EndoActivator system (Eighteeth, China) with a medium polymer tip (25/0.04) was operated at a frequency of 10,000 cycles per minute (cpm) and positioned 1 mm short of the established working length. Initially, 1 mL of 5.25% sodium hypochlorite was activated for 30 seconds using gentle vertical strokes of approximately 2–3 mm, followed by irrigation with 3 mL of distilled water. Then, 1 mL of 17% EDTA was activated for an additional 30 seconds, and the procedure was completed with a final rinse of 5 mL of distilled water.[19]

Group3: Diode laser activated irrigation
A940-nm diode laser unit (Epic 10, Biolase, CA, USA) with a 200-µm fiber-optic tip was operated at 1.5 W in continuous-wave mode. The fiber tip was inserted 1 mm short of the apical foramen and withdrawn coronally with a slow helicoidal motion (≈1 mm/s) in contact with the canal walls. Laser activation was performed in two cycles of 18 s each (total time: 36 s). The first cycle followed irrigation with 1 mL of 5.25% NaOCl and was rinsed with 3 mL of distilled water. The second cycle was applied after irrigation with 1 mL of 17% EDTA, and the procedure was completed with a final flush of 5 mL of distilled water.[20]

Micro‑CT scanning
The micro-computed tomography (micro-CT) scanning was performed using a LOTUS-NDT system (Behin Negareh Co., Iran). Scans were acquired at 60 kV, 50 µA, and 1 s exposure time, with a 0.5 mm aluminum filter to reduce beam-hardening artifacts. A total of 2000 projections were obtained over 360° rotation with a 30 mm field of view. Reconstruction was performed using LOTUS NDT-REC software with the FDK algorithm and automatic artifact correction. The images were exported as DICOM files and analyzed using 3D Slicer software (version 5.7.0). Residual BioCTemp was segmented using standardized grayscale thresholding to differentiate medicament from dentin and volume of Residual medicament was calculated as a percentage of the total canal volume for each root third (coronal, middle, apical).[21]

Statistical Analysis
The data were analyzed using IBM SPSS Statistics 20.0 (IBM SPSS Inc., Chicago, IL, USA). The normality of the data was evaluated using Shapiro–Wilk test and it was found to be normally distributed. two-way analysis of variance test was carried out to evaluate the effect of activation technique, thirds of root canal and interaction between them followed by Duncan‘s multiple range test**.**, The significance level was set at $P \leq 0.05$.

RESULTS
The activation techniques were not able to completely eradicate (Bio-C Temp) intracanal medicament (Fig. 1). There was statistically significant difference ($P \leq 0.05$) for the effect of activation technique, thirds of root canal and interaction between them on the percentage of remaining Bio C Temp (table 1).Regarding the effect of technique types, The XP-Endo Finisher demonstrated significantly the lowest mean percentage of remaining Bio C Temp whereas both the Sonic EndoActivator and the Diode Laser exhibited the high mean percentage of remaining Bio C Temp, with no statistically significant difference between them.

According to root thirds region, The apical third exhibited highest statistically significant difference when compared with the coronal and middle thirds .in XP-Endo Finisher technique showed no significant difference between the coronal and middle thirds, while the apical third demonstrated a significantly lower percentage of remaining Bio C Temp (fig. 2). In contrast, both the Sonic EndoActivator and Diode Laser technique, no significant difference was observed between the coronal and middle thirds, while the apical third exhibited a significantly higher percentage of remaining Bio C Temp (Table 2).

Table 1: Two-way Anova of Bio C Temp intracanal medicament for effects of technique of removal ,thirds of root and interaction between them.

Intracanal medicament		Type III Sum of Squares	df	Mean Square	F	Sig.
Bio CTemp	Technique	38851.500	2	19425.750	2720.368	0.000
	Third	556.425	2	278.213	38.961	0.000
	Technique * Third	5424.967	4	1356.242	189.927	0.000
	Error	578.409	81	7.141		
	Total		90			
	Corrected Total	45411.302	89			

df: degree of freedom.

Table 2: Duncan's multiple range test of BioC Temp intracanal medicament for effect technique of removal, thirds of root and interaction between them.

	Type of Technique			Total	
The root third	**DiodeLaser**	**Sonic EndoActivator**	**XP EndoFinisher**		
	Mean% ±S.D.	Mean% ±S.D.	Mean% ±S.D.		
Coronal	57.57 ± 1.3(b)	49.12 ± 4.5 (b)	22.27 ± 2.15 (c)	**B**	**P=0.00 ****
Middle	55.23 ± 2.9(b)	54.31 ± 2.55 (b)	18.81 ± 2.32 (c)	**B**	
Apical	64.74 ± 3.1(a)	75.03 ± 2.72 (a)	4.7 ± 0.41 (d)	**A**	
Total	**A**	A	**B**		
	P =0.00 **				

** Highly statistically significant differences at (P<0.05). The variable letters mean significant difference exist.

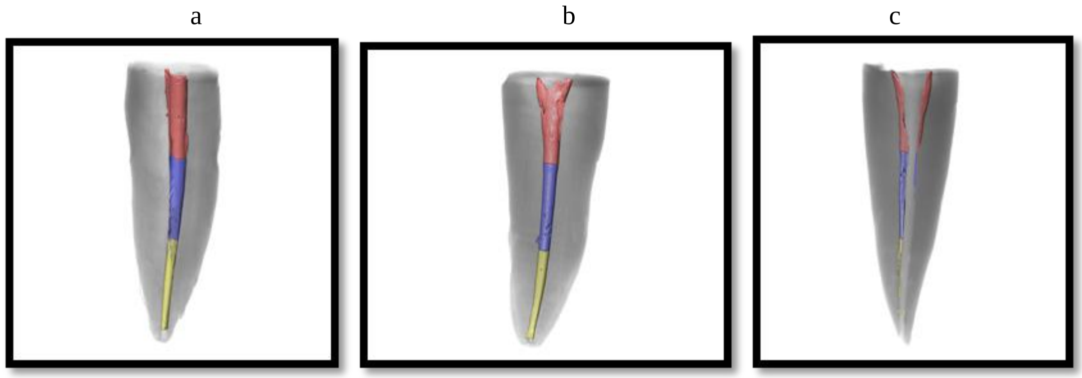

Figure 1: Three-dimensional micro-CT images after Bio C Temp removal using (a)Diode Laser, (b) Sonic Endo Activator, and (c) XP Endo Finisher technique.

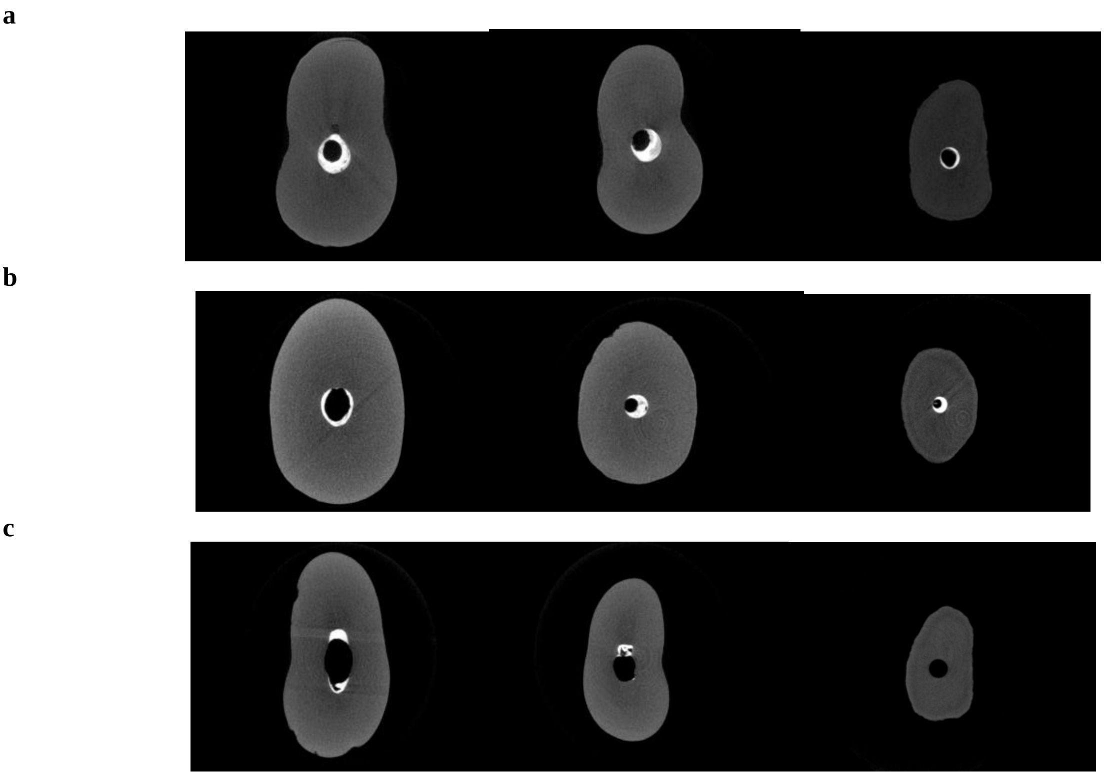

Figure 2: Cross-sectional micro-CT images of slices (coronal, middle, apical) thirds obtained after Bio C Temp removal using (a) Diode Laser, (b) Sonic Endo Activator, and (c)XP Endo Finisher techniques.

DISCUSSION

Microorganisms are central to the development of pulp and periapical diseases. While cleaning and shaping the root canal substantialy reduces the bacterial population, it often fails to achieve complete elimination. Therefore, intracanal medicaments are employed to eradicate bacteria within the root canal system, inhibit bacterial regrowth between appointments, and establish a physicochemical barrier that blocks nutrient access to any residual microorganisms, thereby preventing reinfection.[22] Based on recent dental literature and research reviews, using natural tooth roots in scientific studies provides unparalleled advantages in replicating biological, biomechanical, and structural properties that cannot be fully matched by synthetic materials.[23]

Bio-C Temp is a ready-to-use bioceramic tricalcium silicate paste designed for intracanal dressing, offering high efficiency with fewer sessions. it provides the added benefits of low solubility, allowing prolonged contact with canal walls, a steady and gradual release of hydroxyl (OH^-) ions over time. These features make it a promising choice for intracanal medicament application. Therefore, it was used in this study as limited research is available on its removal from the canals, despite the favourable properties, thus emphasizing the need for further research.[24]

in the present study, NaOCl and EDTA were used as irrigating solutions for the removal of the intracanal medicament. The improved removal efficacy may be attributed to the combined chemical action of these two solutions, particularly the ability of EDTA to chelate calcium ions and remove the inorganic components of dentin. EDTA, a widely used chelating agent, effectively removes the smear layer and chelates calcium ions from dentin surfaces. Since bioceramic materials tend to bond with dentin through calcium interactions, EDTA application may assist in breaking these bonds and thus aid in the removal of the dressing material.[25]

This study evaluated the efficacy of three different activation systems in removal of Bio C Temp intracanal medicament using micro computed tomography. The result demonstrated that the XP Endo finisher resulted in significantly greater removal of Bio C Temp medicament across the coronal, middle, and apical thirds of the canal when compared to the other techniques evaluated. Based on these outcomes, the null hypothesis was rejected. The XP-Endo Finisher showed the lowest mean percentage of remaining Bio C Temp than the Sonic EndoActivator and Diode Laser technique, which exhibited the highest mean percentage of remaining Bio C Temp.

The XP-Endo Finisher showed the highest removal efficacy, This could be attributed to the ability of the XPF to physically interact with the canal walls and clean previously inaccessible areas. This is achieved by the alloy's property of shape-memory which allows the transition of the alloy from the martensitic to austenitic phase at canal temperature, causing expansion and contraction, thus adapting to the canal anatomy and enabling mechanical cleaning of previously inaccessible canal areas.[26] Nasr El-Din et al. observed that both XPF and PUI enhanced canal cleanliness during ICM removal, proving superior to conventional irrigation.[27] the XP-Endo Finisher showed highest removal efficancy in the apical third due to the XP-Endo Finisher based on the shape-memory principles, has high flexibility and can expand up to 6 mm in diameter according to the root canal anatomy, enabling it to access and scrape areas that are impossible to reach with standard instruments.[28]

The EndoActivator Technique showed the lowest removal efficacy of medicament, this could be explained by the lot of contact of the EA tip with the dentinal walls, thereby inhibiting the free oscillation of the tip required to generate efficient irrigant streaming and cavitations' effect.[29] Similar findings have been reported by Al-Shahrani et al.,[30] in which the Endo Activator system did not improve $Ca(OH)_2$ removal.

while numerous studies have investigated the effectiveness of diode laser–activated irrigation in smear layer and debris removal, limited evidence is currently available regarding its ability to eliminate Bio-C Temp intracanal medicament from root canals. In the present study, diode laser–activated irrigation resulted in the highest percentage of remaining Bio-C Temp across all root canal thirds. This reduced performance may be related to the photothermal interaction mechanism of diode lasers and their limited absorption in water, which restricts cavitation and irrigant agitation. Consequently, irrigant activation is based primarily on heat generation rather than effective hydrodynamic cleaning, thereby decreasing its ability to dislodge and remove intracanal medicament.[31] the findings of the present study are in agreement with previous investigations that reported inferior cleaning efficacy of diode laser–activated irrigation compared with erbium laser systems. Al-Farawn et al.[32] demonstrated superior smear layer removal when 17% EDTA or 5.25% NaOCl was activated using Er, Cr:YSGG lasers, compared with diode lasers operating at 940 nm.

The effectiveness of Bio CTemp intracanal dressing removal was evaluated, and complete elimination was not achieved by any techniques. This outcome is consistent with previous studies evaluating tricalcium silicate dressing removal. The carrier type of root canal dressing material directly affects ion release and the close relationship between bioceramic materials and dentin walls. Bioceramic products can react with the dentin and induce hydroxyapatite formation, which could compromise its removal from the canal.[33] Peña-Bengoa et al,[34] reported that Bio-C Temp exhibited significant penetration into dentin, which may be attributed to factors such as particle size and the characteristics of the carrier substance. The viscous propylene glycol vehicle in Bio-C Temp may reduce surface tension and enhance penetration into dentinal tubules. However, this property may hinder removal. Moreover, low solubility and the strong molecular interactions within its structure likely contribute to the difficulties associated with its removal.

CONCLUSION

Bioceramic-containing medicaments, like other bioceramic-containing canal sealers, are very diffcult to remove from root canal. Within the limitations of this study, none of the activation techniques were able to complete removal of Bio C Temp from the root canal system. The XP-Endo Finisher demonstrated the highest efficacy in Bio C Temp removal, whereas sonic activation using the EndoActivator and diode laser activation showed the lowest effectiveness. The XP-Endo Finisher demonstrated superior cleaning efficacy in the apical third compared to alternative techniques.

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Ethical approval statement
Since the study utilised human teeth that had been taken for orthodontic purposes, it was authorised by the Research Ethics Committee of the College of Dentistry at University of Mosul in Iraq. With the REC reference number UoM. Dent. 25/1023, it was officially cleared.

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Conflict of interest
There are no conflicts of interest in this study.

Data availability
Data is available upon reasonable request from corresponding author.

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