Effect of Different Methods of Sealer Activation on Depth of Penetration of Bioceramic Root Canal Sealer

(An In-vitro study)

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By

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بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا

إلا ما علمتنا إنك أنت

العليم الحكيم

صدق الله العظيم

سورة البقرة الآية: ٣٢

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Dedication

To the soul of my father, his body left, but his spirit still flies in the sky of my life.

To my mother, my sisters, and brother, the pillars of my life for their endless support and help.

To my dear wife, for continuous assistance, encouragement and sacrifices throughout the completion of my research.

To my lovely sons, Hoor, Hamza, and Leen.

I dedicate this work……

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List of Abbreviations

Abb.	Full term
3D	*Three dimensional*
A-phase	*Austenitic phase*
CBCT	*Cone beam computed tomography*
C I	*Conventional irrigant*
CLSM	*Confocal laser scanning microscopy*
D T	*Dentinal tubules*
DOM	*Dental operating microscope*
EDTA	*Ethylenediaminetetraacetic acid*
EV	*EndoVAC*
GP	*Gutta-percha*
kHz	*kilohertz*
LM	*Light microscopy*
min	*Minute*
M-phase	*Martensitic phase*
NaOCl	*Sodium hypochlorite*
Ncm	*Newton centimeter*
Neo-EF	*NeoEndo Finishing file*
NiTi	*Nickel Titanium*
PIPS	*photon-induced photoacoustic streaming*
Rpm	*Rotation per minute*
s	*Second*
SEM	*Scanning electron microscopy*
TEM	*Transmission electron microscopy*
UA	*Ultrasonic activation*
XPF	*XP-endo Finisher*

1. INTRODUCTION

In the realm of endodontics, the primary goal is to clean, shape, and obturate the root canal system to prevent future infection and ensure optimal healing (1). In order to reduce bacterial loading inside the root canal, three-dimensional filling of the main canal and its ramifications is a mandatory procedure following the disinfection process (2).

The root canal sealer is an important component in the procedure of root canal filling as it fills isthmuses, ramifications, apical deltas, and dentinal tubules (3). To reach the three-dimensional obturation, the sealers composition and physiochemical characteristics primarily exhibit sufficient dimensional stability (4). The better the penetration of sealer into the dentinal tubules, the higher the adaptability between the filling material and canal wall can be considered (5). Sealers within dentinal tubules may also entomb any residual bacterial effect that will be enhanced the chemical composition of the sealer that exert an antibacterial effect (6).

There are many methods for the activation of irrigants. The introduction of mechanical agitation of the irrigant using endodontic motor driven instruments as plastic file is an option in order to clear the root canal system of debris. Richman (7) introduced the use of ultrasound as a tool for endodontics in 1957. It is currently widely used in a variety of endodontic procedures, from endodontic surgery to coronal opening (8). Greater ultrasound-induced agitation of irrigating solutions increases penetration in anatomically complex areas like the dentinal tubules and enhances cleaning performance (9).

The XP-endo Finisher file is a tool that relied on irrigant activation which is manufactured of special heat-treated nickel-titanium (NiTi) alloy[10]. Due to the XPF characteristic when exposed to body temperature, the instrument changes from a straight to a spoon shape [11]. The instrument's distinct form and flexibility allow it to adapt to the entire anatomy of the canal and make contact with the walls, which can efficiently activate and distribute solutions throughout the root canal system [12].

The impact of these techniques on the activation of endodontic sealers is still not clear despite advancements in root canal irrigant activation methods.

Currently, sealer penetration is evaluated by several microscopic methods, such as stereomicroscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM), and confocal laser scanning microscopy (CLSM) [13]. By using fluorescent Rhodamine-marked sealers, CLSM has an advantage as it can provide detailed information about the presence and distribution of sealers inside dentinal tubules throughout the circumference of the root canal walls at relatively low magnifications and non-hydrated sample [14].

Very little research has been done to evaluate the influence of sealer activation on the depth of penetration of bioceramic root canal sealers. The study spots the light on the effect of different activation methods of bioceramic sealer on its depth of penetration into the dentinal tubules.

2. REVIEW OF LITERATURE

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Review of literature

Three dimensional obturation of the root canal system plays an important role in the treatment outcome. To achieve this goal, beside gutta-percha, root canal sealers are used to obturate the root canal irregularities and fill the dentinal tubules [(15)].

Ideally, root canal sealer should have good adhesion to the canal, sealing ability, be radiopaque, mix easily, have no shrinkage, show no stain on tooth structure, bacteriostatic, set slowly, insoluble, tissue tolerant, and easy to remove by common solvent [(16)].

2.1. Different types of sealers

The current available sealers can be categorized into the following groups: Zinc oxide eugenol-based, calcium hydroxide-based, resin-based, glass ionomer-based, silicone-based, bioceramic based sealers.

2.1.1. Zinc Oxide Eugenol based sealer early root canal sealers formula by Rickerts's [(17)] in 1931 that were commonly used throughout the world. ZOE sealers have antimicrobial properties on different microorganisms, including E. faecalis. ZOE sealer demonstrated a volumetric expansion which aids in sealing the canal [(18)]. However, ZOE based sealers were inferior to other types of sealer in terms of their relatively high solubility. Grossman [(19)] introduced a non-staining, ZOE sealer as a replacement for Rickert's formula in 1958, and this formula was widely used for long time.

2.1.2. Calcium hydroxide-based sealer was introduced by Herman [(20)] to endodontics in 1920 for pulpal repair. It is distinguished by its biocompatibility and high PH due to the hydroxyl ion, which induces hard tissue formation and antimicrobial activity [(21)]. Its widely used as a pulp capping agent for intracanal medicament and as root canal sealer due to these advantages. However, calcium hydroxide-based sealers are not physically reliable as evidenced by significant leakage [22].

2.1.3. Resin-based sealer:

2.1.3.1 Epoxy resin-based sealers the most commonly used clinically available root canal sealers. In 1957, Schroeder [23] introduced the AH series prototype, which had excellent physical properties and sealing capability. AH Plus has been designated as the gold standard due to resorption resistance and relative dimensional stability. There are several disadvantages as hydrophobicity, cytotoxicity and an inflammatory response [24].

2.1.3.2. Methacrylate resin-based sealer is a bondable sealer which will bond to core material and dentin, in turn, forming a mono-block. However, the early generation gutta-percha did not bind with the sealer unless coated with a polybutadiene di-isocyanate methacrylate adhesive [18]. However, a recent study has shown that a methacrylate resin-based sealer contains more voids and gaps than a conventional sealer and gutta-percha. Methacrylate resin- based sealers also exhibited high leakage due to degradation of the polymers over time [25].

2.1.4. Glass ionomer-based sealers (GICs) are made by mixing a fine silicate glass powder with polyacrylic and related acids. When mixed, they form repeating subunits of organic monomer and inorganic ions, creating an ionomer [26]. GICs considered to be biocompatible and show some adhesion to dentin, which are consider as desirable properties in a root canal filling [27]. There main disadvantages of GICs were difficulty of sealer removal if retreatment is required, beside its low antimicrobial activity.

2.1.5. Silicone-based sealer was first introduced in 1984. Polymethyl siloxane is used as a silicone matrix with less than 30-nm gutta-percha particles embedded in the silicone. Silicone sealer shows comparatively minimal leakage, non-toxic. The main disadvantage is lack of antibacterial efficasy (4). Silicone has limited dimensional change while setting at 0.15 percent to 0.6 percent with low water sorption. The presence of silicone was shown to cause this type of sealer to have poor wettability on the root dentin surface (28).

2.1.6. Bioceramic based sealer:

Bioceramic is the broader definition of all “hydraulic calcium silicate cements”. This terminology refers to a new type of material that is tri-calcium silicate–based indicating the change in the cement type and the lack of aluminum in its composition of Portland cement–based.

Portland cement which is derived from the calcination of mixture of the limestones from Portland and silicon-argillaceous materials. Portland cement exhibits both antibacterial and antifungal that are similar to MTA (29). But Portland cements produce amounts of lead and arsenic released from Portland cement added to its high solubility when compared to MTA and it concerns about the safety with respect to the surrounding tissues. Uncontrolled setting expansion of Portland cement could lead to crack formation on the tooth (30).

Mineral trioxide aggregate (MTA) sealers were introduced to the field of endodontics in the early 1990s. It’s calcium silicate cement, consisting of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and bismuth oxide as radiopaque compound (31). The material comes in two forms, grey and white. In the first form grey color is given by iron ions, which were removed to obtain the white form [32]. MTA's setting reaction is by hydration, obtaining hydrated calcium silicate and calcium hydroxide which is released over time. Therefore, the MTA is strongly antimicrobial, MTA's biological integration is due to the calcium ions which form hydroxyapatite in contact with phosphate ions present in body [33].

Bioceramic can be categorized as bioinert with biological systems (alumina, zirconia), bioactive that can undergo interfacial interactions with surrounding tissues (bioactive glasses, bioactive glass ceramics, hydroxyapatite, calcium silicates) [34]. Calcium silicate-based sealers (CSBs) demonstrate favorable properties such as hydrophilic nature, high pH above 12, antimicrobial properties, expansion on setting, insolubility in the presence of tissue fluids and osteogenic potential [35]. The setting reaction of their main component calcium silicate results in precipitation of calcium phosphate. In addition, calcium phosphate enables to form the chemical composition and crystalline structure similar to teeth [36]. The improved bond between a sealer and root dentine encourages bioactivity and tissue growth in comparison to other commercially available root canal sealers [37].

2.2. Sealer penetration:

Sealer penetration into dentinal tubules is considered a positive outcome to prevent bacterial repopulation inside the dentinal tubules as a blocking agent. Also, improve filling material retention within the root canal to mechanical interlocking between sealer and root dentin, and entomb remaining bacteria within dentinal tubules [38]. Therefore, sealer penetration into dentinal tubules is considered clinically relevant. A lot of techniques had been investigated in the literature all of them aimed to increase the penetration of the sealer inside the dentinal tubules.

Penetration of sealer cements into dentinal tubules is influenced by a number of factors including smear layer removal, activation of both irrigant and sealer, filling technique and sealer types.

2.2.1. Factors affecting sealer penetration:

2.2.1.1. Smear layer:

The smear layer is a surface accumulation of debris formed on dentine during instrumentation. It is composed of organic and inorganic components and forms both a superficial, loosely adherent layer and a deeper tightly adherent layer.

Kokkas et al. (39) in 2004 evaluated the effect of smear layer removal on sealer penetration depth of three different root canal sealers: AH plus, Apexit and Roth 811. The teeth were grouped into two groups; group I: no smear layer removal and group II: smear layer removed by repeated irrigation with 17% EDTA & 1% NaOCl. Teeth were prepared and obturated using cold lateral condensation in accordance with the sealer type. All samples were halved longitudinally by means of intentional fracture and observed under scanning electron microscope. The results showed that there was significant difference in sealer penetration among the tested grougs. They concluded that the smear layer removal significant affect sealer penetration.

Turkel et al. (40) in 2017 evaluated the effect of smear layer removal by three final irrigation techniques and sealer penetration depth of 2 different sealers using CLSM. 142 single rooted teeth were divided into 4 experimental groups based on the irrigant activation technique used group I: EndoVAC (EV), group II: photon-induced photoacoustic streaming (PIPS), group III: Conventional irrigant (CI) and group IV: control group. Thirteen teeth from each group were evaluated for debris and smear layer removal using SEM. The remaining 30 teeth per group were divided into 2 subgroups according sealer used: AH Plus and TotalFill BC. Three sections were made at 2, 5, and 8 mm from the root apex. The results showed that there was no significant difference among the different groups regard the technique used. They concluded that PIPS resulted in less debris in the middle third compared with CI. TotalFill BC with EV and CI at 2 mm or PIPS at 5 mm exhibited a higher penetration than that with AH Plus.

Turker et al. [41] in 2018, compared the effect of smear layer removal on different sealers penetration depth. 90 mandibular premolar teeth were assigned into 2 main groups; Group1: Smear layer preserved and Group 2: Smear layer removal, then roots further divided into 3 subgroups according the sealer tested (AH 26, BioRoot RCS& MTA Plus). Obturation was performed with relevant sealers which mixed with .01% rhodamine B dye. One section thick was obtained from the mid third area of each root for calculate the dentinal tubules penetration depth and percentage under CLSM. The result showed that MTA Plus the highest significant different of sealer penetration depth in comparison to other groups. They concluded that the dentinal tubule penetration of root canal sealers had a limited effect on their adhesion to root canal wall.

2.2.1.2. Effect of irrigants activation on sealer penetration:

Irrigants are the chemical agents delivered into the root canal in order to dissolve the tissue remnants, to kill the microorganism, and to clean the root canal effectively and safely without any consequences.

Ismail et al. [42] in 2016 evaluated the effect of different irrigation activation on AH plus sealer penetration depth. In this study; group I: Apical negative pressure (Endovac), group II: Passive ultrasonic irrigation (PUI) and group III: combination of Endovac and PUI. All samples were obturated by lateral compaction technique. The sections were observed under CLSM to evaluate the percentage and maximum depth of sealer penetration. The teeth were sectioned at 1 mm, 3 mm and 5 mm levels. The result showed that in the combination group revealed better sealer penetration at 1 mm and 3 mm than the Endovac and PUI groups. They concluded that combing of the two methods of activation have impact on sealer penetration at 1mm and 3mm levels from the working length.

Generali et al. [43] in 2017, evaluated the influence of different irrigation system on sealer penetration depth into dentinal tubules. This study included five groups, each with a distinct cleansing system: group I: EndoActivaror, group II: Irrisafe, group III: Self-Adjusting File, group IV: Convetional Needle Irrigation, and group V: EndoVac. Following instrumentation, rhodamine B dye-labeled TopSeal sealer and Thermafil obturators were applied to every tooth. Samples were examined under CLSM after being transversally sectioned at levels of 2, 5, and 7 mm from the apex. Measurements were made of the maximum mean and percentage of sealer penetration inside the dentinal tubules surrounding the root canal. The results showed that there was no significant differences both in mean and in maximum penetration depth were observed among groups, They concluded that the irrigant deliver and/or agitation methods have no effect on sealer penetration into dentinal tubules.

Gu et al. (44) in 2017 evaluated the efficacy of irrigants agitation techniques on AH plus sealer penetration depth. For the final irrigation, either the V-Clean endodontic agitation system, ND: YAG laser, ultrasonic, CI (control), or SI were employed in conjunction with Rhodamine B-labeled NaOCl. Gutta percha and fluorescent isothiocyanate-labeled AH plus sealer were used to obturate the canals. At 2, 5 and 8 mm from the apex, transverse sections were taken and examined under CLSM. Maximum penetration depth and percentage of both irrigant and sealer were recorded. The results revealed that the highest levels of irrigant and sealer penetration depth and percentage were reached by laser agitation. At 2 mm from the apex, sonic and ultrasonic agitation achieved significantly higher penetration percentages than the control group. They concluded that Nd:YAP laser was superior to other agitation techniques in dentinal tubule penetration of irrigant and sealer at one or more sectioned levels from the apex.

Barbosa et al. (45) in 2018 evaluated the influence of the irrigating solutions ultrasonic activation on sealer penetration depth into the lateral canals. Five groups were assigned to fifty maxillary molar palatine roots. group I: EDTA 17% + 5 minutes of manual agitation, group II: EDTA 17% + 15 seconds of ultrasonic activation; group III: 1% NaOCl + 15 seconds of ultrasonic activation; group IV: EDTA 17% + ultrasonic activation for 15 seconds and NaOCl 1% + ultrasonic activation for 15 seconds and group V: negative control. In the middle and apical thirds, the lateral canals were created. Radiographic and microscopic analyzed were performed to evaluate the sealer penetration degree. The results revealed that group 2 and group 4 exhibit high sealer penetration. In both thirds, Group4 results were better than those of the other groups. They concluded that the ultrasonic activation of the NaOCl 1% + EDTA 17% irrigation solution provides greater penetration of the endodontic cement in lateral root canals.

Agrawal et al. (46) in 2019 evaluated the sealer penetration depth into the radicular dentinal tubules following irrigation activation using different methods. Group I: Endo VAC, group II: Endo Activator, group III: Irrisafe, and group IV: Endoirrigator Plus. Teeth were prepared and fluorescent dye-labeled AH plus sealer was used to perform obturation. To measure the depth of sealer penetration, two transverse sections were taken at 2 mm and 4 mm from the apex and analyzed under CLSM. The results demonstrated that the Endoirrigator plus and irrisafe groups had better sealer penetration depths than the EA and EV groups. They concluded that an increasing trend of sealer penetration from the apical to the coronal third was observed in all the groups.

2.2.1.3. Types of root canal sealer:

Chandrasekhar et al. (47) in 2016 evaluated the effect of ultrasonic activation on different sealers penetration depth. Group I: ZOE sealer, group II: AH Plus sealer, group III: Hybrid root seal, and group IV: I Root SP. These groups were subsequently divided into three subgroups (n=5), each based on the study's activation protocol. Subgroup 1: neither the sealer nor the irrigant are activated; Subgroup 2: only the irrigant is activated; and Subgroup 3: both the sealer and the irrigant are activated.

Every sample was sectioned at 2, 4, and 6 mm from the apex. Under CLSM, the percentage of sealer penetration in root canals was examined. The results showed thar the activated I Root SP have the highest significant in comparison to other groups. They concluded that regardless of the activation, physical and chemical properties of the sealer used have a varying effect on sealer penetration depth of the dentinal tubules.

Mokashi et al. [(48)] in 2021 compared the sealer penetration depth of five different sealers. 5 experimental groups were used in this study according to the type of sealer. Group I: Zinc oxide eugenol, group II: Endo Rez, Group III: Sealapex, Group IV: AH Plus and Group V: MTA-Fillapex. Teeth were prepared and obturated by lateral compaction technique using the tested sealers labeled by fluorescent rhodamine B dye. The coronal, middle, and apical thirds were represented by three 1 mm horizontal sections that analyzed by CLSM. The results showed maximum penetration of AH Plus in the coronal and apical thirds, MTA-Fillapex in the middle thirds, while minimum penetration depth was seen in ZOE in the coronal and middle thirds and Sealapex in the apical thirds. They concluded that AH Plus and MTA-Fillapex showed the highest penetration into radicular dentinal tubules, ZOE and Sealapex demonstrated the least penetration.

2.2.1.4. Obturation Techniques

Denis et al. [(49)] in 2016 evaluated the dentinal tubules penetration of root canal sealer. 32 single mandibular anterior teeth were assigned into four groups according to the obturation system; group I: EndoRez, group II: Activ GP, group III: SmartSeal, group IV: AH 26/ Gutta-precha. Teeth were prepared and before the obturation procedure, root canal sealers were mixed with 0.1% rhodamine B dye and placed into the canal by lentulo spiral. One horizontal slice 1 mm thickness was obtained from middle third. The specimens were mounted onto cover glass and observed under CLSM. The result showed that Smart Seal was the least area band depth of tubules penetration while no different among the other groups. They concluded that sealer penetration of resin and glass ionomer-based sealers used with coated core was not superior to resin-based sealer used with conventional GP

Navaro et al. [50] in 2023, evaluated the maximum penetration depth and the percentage of sealant penetration of an endodontic sealer into dentine tubules. Sixty single root teeth were used. Six experimental groups were formed from the three filling techniques using group I: cold lateral condensation, group II: continuous wave and group III: hybrid techniques, and to contrast the effectiveness of two different tapered gutta-percha master cones (0.02 and 0.04). The results indicated a higher penetration depth of hybrid compared with cold lateral condensation in the middle and coronal thirds, and in the apical third, a higher penetration was identified in the hybrid group compared with the continuous wave group. No significant differences in penetration were found comparing 0.02 with 0.04 taper gutta-percha groups. They concluded that the hybrid technique a had higher maximum sealer penetration than the continuous wave in the apical third, and the coronal third hybrid and continuous wave had a higher penetration than cold lateral condensation.

2.2.1.5. Effect of sealer activation on depth of penetration:

The first reached publication was described sealer penetration was by **Jeffrey et al** [51] **in 1986,** evaluated the root canal sealers movement during a gutta-percha insertion inside the simulated canal. They studied three methods of sealer application, using 19 cylinders transparent simulated tooth models: group I: using a reamer, group II: a gutta-percha point, or group III: a Lentulo spiral in straight & 45° apical curvature. Using the same groupings, the experiments were repeated except that the gutta-percha was inserted with repetitive pumping action. There were scales to measure the degree of sealer coverage overall and in apical third, and quantitative extrusion of sealer through the apex. The sealer of the canal space was assessed visually through the transparent specimen using a stereoscopic microscope with a magnification of x 6. The result showed that the Lentulo spiral application method of sealer improved sealer coating specially in curved canals while the gutta-percha point application method alone results lower extrusion scores than using either a reamer or a Lentulo spiral filler and there were no significant differences for two aspects of coating. They concluded that the Lentulo spiral is an effective method and resulted in better coating in sealer application.

Hoen et al [(52)] in 1988, evaluated the effect of ultrasonic sealer placement in comparing to hand instrument. One hundred canals in mesial roots of human mandibular molar teeth were selected. After ultrasonic preparation of the samples to #25 Endosonic & irrigation, the sealer application was placed either by hand instrument (Kerr reamer) or ultrasonic (Endosonic file) for 30 seconds of each. There are five pairs of teeth used as positive control utilizing sealer by Lentulo spiral as a group 3. Each tooth was sectioned horizontally at l mm intervals with an Isomet circular diamond saw. The sections were photographed with a Wild photomicroscope at original magnification x6 and x 12. The sections evaluated were 1, 2, 3, 4, 5, 6, and 7 mm from the tooth apex. The result showed that five positive controls have sealer completely covering the wall of root canal in 94% of the sections. When the root canal sealer was applied ultrasonically, 76% of the sections were found to exhibit complete coverage of the root canal system walls, while was placed using a traditional hand instrument, 27% of the appropriate sections were determined to have complete canal wall coverage. They conclude that the ultrasonic method of root canal sealer application covers canal walls more thoroughly than hand instrument placement.

Wiemann et al. [(53)] in 1991, evaluated the effect of four methods on AH 26 sealer placement. Forty mandibular incisors were prepared by a step-back technique and assigned into four groups according methods of sealer placement: group I: K-Flex file, group II: Lentulo spiral, group III: master gutta-percha cone, and group IV: ultrasonic file. AH 26 was used in this study and mixed with small amount of carbon black powder, and then the canal was obturated with lateral condensation of gutta-percha. All teeth were subjected to decalcification with 5% nitric acid, dehydration in a series of graded alcohols and then cleared with methyl salicylate. The specimens were examined with a stereomicroscope which evaluated for the presence of the sealer in the apical, middle, and coronal thirds of the canal on both sides. The results showed no statistically significant differences among the four groups. The greatest variation in sealer coverage was found in the apical level. Thay concluded that sealer coverage in the coronal and middle thirds was nearly identical regardless of sealer placement technique.

Stamos et al. [(54)] in 1995, evaluated the effect of sealer placement and their distribution in the root canal. One hundred patients each received nonsurgical root canal treatment on a single tooth. Canal cleaning and shaping were performed with the alternative use of reamers and Hedstrom files to the apical stop. Group I: fifty teeth were obturated according to regimen A which no ultrasonic activation for sealer, and group II: fifty were obturated following regimen B which # 20 ultrasonic file coated with sealer, placed into the canal and energized for 5 s with a circumferential motion. The evaluation was done by aids of radiograph. The result showed that the group I, only 4% of this sample demonstrated the presence of sealer in an accessory canal. In groupII, 24%, demonstrated the presence of sealer in accessory canals. They concluded that a final debridement procedure with an ultrasonic file and sodium hypochlorite, ultrasonic sealer placement may significantly influence the filling of accessory canals.

Hall et al. [(55)] in 1996, compared sealer placement techniques in curved canals prepared with Lightspeed instruments. Teeth were randomly assigned to one of three groups after determination of canal curvature and completion of canal preparation. AH-26 sealer with carbon black powder was placed in the canals with either group I: a K-file, group II: lentulo spiral, and group III: the master gutta-percha cone. After the sealer set, the teeth were decalcified, cleared, and photographed. The proximal photographs of the cleared teeth were evaluated for extent of canal wall sealer coverage. The result showed that significant difference in pre-obturation sealer fill between the three groups, ranging from a mean canal fill of 90.2% for the lentulo spiral to a mean canal fill of 56.4% for the master gutta-percha cone and was no statistical difference between the groups after gutta-percha obturation, with no method exceeding an average of 62.5% sealer wall coverage. They concluded that the total wall coverage following obturation might not be achievable and that the dispersion of sealer on the canal walls following obturation is unrelated to the ability to fill the canal with sealer before obturation.

Nakhili and Singh [56] in 2013, evaluated the depth and percentage of sealer penetration with three different placement techniques. Root canals of 30 single-rooted teeth were prepared and AH plus sealer was mixed with Rhodamine B dye and placed using group I: Ultlrasonic file, group II: lentulospiral, and group III: Endoactivator. The roots were sectioned at the 3 and 6-mm levels and examined under CLSM. The result showed that ultrasonic had maximum mean depth of penetration and maximum mean percentage of sealer penetration while endoactivator showed minimum mean depth of penetration and minimum mean percentage of sealer penetration. The study concluded that sealer penetration is influenced by the placement technique and root canal level.

Guimaraes et al. [57] in 2014, evaluated the impact of ultrasonic activation on the filling quality of four epoxy resin-based sealers. The study involved 84 extracted human canines divided into four groups based on the sealer used to obturate the root canals. Group I: AH Plus, group II: Acroseal, group III: AdSeal, and group IV: Sealer 26. The sealers were labeled with rhodamine B dye for confocal microscope analysis. After obturation, the specimens were divided into two groups based on ultrasonic activation: ultrasonically activated and non-ultrasonically activated groups. The samples were sectioned at 2, 4, and 6 mm from the apex and analyzed for dentinal sealer penetration segments. Results showed a significant increase in sealer penetration segments for AH Plus, Acroseal, and Sealer 26 at the 4-mm level and 6-mm level with ultrasonic activation. They concluded that the use of ultrasonic activation of an epoxy resin–based sealer promoted greater dentinal sealer penetration and less presence of gaps.

Nakhil et al. [58] in 2015, evaluated the effect of three root canal sealer activation techniques on the percentage and depth of sealer penetration of MTA Fillapex and AH Plus sealers. Sixty teeth were divided into three groups based on sealer activation technique; group I: Ultrasonics, group II: Lentulo spiral, and group III: Counter-clockwise rotary motion. The results showed that ultrasonic had significantly higher percentage and depth of sealer penetration than other groups. They concluded that sealer penetration percentage and depth depend on sealer type and root canal level; ultrasonic method and MTA Fillapex yield the best results.

Arslan et al. [59] in 2016, evaluated the effectiveness of sonic and ultrasonic activation of an epoxy-amine resin-based root canal sealer on the penetration of the sealer into lateral canals compared to non-activated filling. Thirty-six single-rooted human anterior teeth were decoronated and prepared and divided into a control group and two experimental groups that received sealer application with either group I: sonic or group II: ultrasonic activation. The root canals were filled using cold lateral compaction, and images were obtained from each lateral canal at 40x magnification. Sealer penetration was evaluated using a four-grade scoring system. The results showed that ultrasonic activation resulted in better sealer penetration compared to non-activated and sonically activated groups. They concluded that sonic activation was not as effective as ultrasonic activation but was more effective than the non-activated group.

Wiess et al. [60] in 2017, evaluated the ultrasonic and sonic activation of two root canal sealers on interfacial adaptation to root canal dentine. The root canals of 78 maxillary canines were prepared and canals were filled using lateral condensation of gutta-percha either group I: AH Plus or group II: MTA Fillapex. Three subgroups were formed according to sealer activation: subgroup 1: no activation (NA), subgroup 2: sonic activation (SA), and subgroup 3: ultrasonic activation (US). In each subgroup, 0.1% rhodamine B was added to the sealer. Three 1-mm-thick slices were obtained from each root third qualitative analysis of interfacial adaptation and voids by CLSM. The results showed that ultrasonic activation was associated with higher values, deeper intratubular penetration, and greater interfacial adaptation to root dentine than sonic activation and no activation techniques.

Kim et al. [(61)] in 2018, evaluated the filling quality of a recently developed premixed calcium silicate-based endodontic sealer (Endoseal MTA) with a single GP cone technique compared to a resin-based sealer (AH plus) with warm vertical compaction. Thirty human single-rooted maxillary premolars with ribbon-shaped canals were prepared and assigned to three experimental groups; group I: EMS, group II: EMS Ultrasonic, and group III: AH Plus Warm. Each tooth was scanned using micro-computed tomography (m-CT), and the proportions of sections with volume percentages were calculated. The tooth was then sectioned transversely and the presence of void in the slices was scored under a stereomicroscope. The results showed no significant difference in the proportion of sections with volume percentage among the groups. They concluded that Endoseal MTA performs best when used with GP cone-mediated ultrasonic activation.

Coronas et al. [(62)] in 2020, evaluated the penetrability of a new bioceramic sealer on the dentinal tubule. 40 distobuccal roots from maxillary molars were selected. Roots were randomly assigned to four groups based on filling procedures; group I: Bioceramic/Lentulo (Sealer Plus BC), group II: Bioceramic/EasyClean, group III: Bioceramic/Irrisonic, and group IV: AHplus/Lentulo. A specific fluorophore (Fluo-3) was mixed with the sealer, and after 72 hours, specimens were transversally sectioned and analyzed using CLSM. Sealer penetration area was measured using Adobe Photoshop. The results showed similar penetrability for both sealers, regardless of the technique used to activate them inside the root canal. The type of instrument used to activate the bioceramic sealer did not affect penetrability.

De Bem et al. [63] in 2020, examined the impact of ultrasonic activation (UA) on dentin tubule penetration to root dentin in endodontic sealers. 100 single-rooted teeth were prepared and divided into two main groups: with or without UA. Five types of sealers were used in this study, three resin-based sealers (MTA Fillapex, Sealer Plus, and AH Plus) and two calcium silicate-based sealers (Sealer Plus BC and EndoSequence BC) were used Fluo-3 and rhodamine B dyes were added to the sealers. UA was performed for 40 seconds followed by lateral compaction. Samples were transversely sectioned to evaluate dentin tubule penetration. Results showed that resin-based sealers showed the highest tubule penetration without UA. UA significantly enhanced MTA Fillapex and Endosequence BC dentin tubule penetration. The study concluded that UA interferes with tubule penetration and bond strength to root dentin of resin- and calcium silicate-based sealers.

Yamini et al. [64] in 2021, evaluated the tubular penetration of modified bioceramic materials using indirect ultrasonic activation. 120 coronal root slices were prepared from mandibular premolars and divided into six groups based on placement techniques: group I: Nano

Biodentine-manual, group II: CaCl2 modified ProRootMTA-manual (MM), group III: Biodentine-manual, group IV: Nano Biodentine: Ultrasonic, group V: CaCl2 modified ProRootMTA-ultrasonic, and Gr VI: Biodentine-ultrasonic (BDU). The samples were kept in a humidifier for four days, sealer penetration was evaluated using CLSM. The results showed that Group VI (BDU) had the greater tubular penetration, while Group II (MM) had the lowest penetration. The study concluded that ultrasonic activation can significantly improve the tubular penetration of modified bioceramic materials.

Song and Yang [(65)] in 2022, evaluated the degree of dentinal penetration between an epoxy resin-based sealer and an ultrasonically activated calcium silicate-based sealer. 45 extracted permanent maxillary premolars were selected to the experiment, with root canals divided into three groups: group I: AH Plus + continuous wave technique (AHC group), group II: AH Plus + single cone technique (AHS group), and group III: Endoseal MTA + single cone technique with ultrasonic activation (EMS group). Sealer penetration depth was observed at 2 mm and 5 mm from the apex using CLSM. The results showed that maximum sealer penetration depth, mean fluorescence intensity, and sum fluorescence intensity values were higher at the 5-mm level than at the 2-mm level. The EMS group showed the lowest value at the 5-mm level. They concluded that AHC group showed the highest dentinal tubule penetration but had questionable filing efficacy in the apical area, which is crucial for root canal treatment success.

Keles et al. [(66)] in 2023, evaluated the impact of various activation techniques on dentin tubule penetration of root canal sealer. 75 teeth with single canals were prepared and a calcium silicate-based sealer was activated using different techniques group I: control (no activation), group II: EDDY, group III: EndoActivator, group IV: ultrasonic and group V: XP-endo Finisher. The sealer penetration was measured at various depth levels of root sections. The XP-endo Finisher showed the highest penetration at 50µm, similar to EDDY at 100 and 200µm, and higher than EndoActivator at 500µm. The study concluded that XP-Endo Finisher can be recommended for activation during sealer placement for better penetration into dentin tubules.

Zhang et al. [67] in 2024, compared the effects of Easydo Activator (EA), a new sonic irrigation system, on sealer penetration at the root apex to needle irrigation (NI) and passive ultrasonic irrigation. Forty-two single-rooted teeth were prepared and divided into three groups (n = 14): group I: Needle Irrigation, group 2: PUI; and group 3: Easydo Activator. A solution of 3% sodium hypochlorite (NaOCl) was used for irrigation. Nine teeth in each group were filled with AH Plus sealer mixed with CY5 fluorescent dye and a single gutta-percha cone. The maximum penetration depth and percentage of sealer penetration at 1 mm and 5 mm from the apex were analyzed by CLSM. The results revealed that Easydo Activator was superior to other groups regarding sealer penetration percentage. They concluded that EA was superior to PUI and NI regarding sealer penetration at the root apex during endodontic treatment, and it could provide a new technical idea for clinical root canal therapy.

Jordani et al. **[68]** in 2024, evaluated the effect of ultrasonic activation of the endodontic sealer on its intratubular penetration and bond strength to irradiated root dentin. Forty human teeth were distributed into 4 groups (n = 10), according to the radiation therapy (RT) exposure—70 Gy and ultrasonic activation (UA) of the endodontic sealer:

group I: RT/UA—irradiated teeth and sealer UA; group II: RT/ no-UA—irradiated teeth and no sealer UA; group III: no-RT/UA—non-irradiated teeth and sealer UA and group IV: no-RT/no-UA—non-irradiated teeth and no sealer UA. Regardless of the irradiation, the results showed that the ultrasonically activated groups showed a more homogeneous adhesive interface, with the presence of sealer tags in greater density and depth. They concluded that the ultrasonic activation enhanced the intratubular penetration of the endodontic sealer to irradiated dentin.

2.3. Methods of evaluation of sealer penetration:

A number of microscopy methods, such as light microscope, stereomicroscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM), and confocal laser scanning microscopy (CLSM), are employed to assess the sealer/dentin interface.

Light microscopy was used to evaluate smear layer removal and penetration of sealer into dentinal tubules. The main drawback of light microscopy was the inability to differentiate between the sealer and the root dentin. Also, the strength of this method depends on the reliability of the methodology supported by the homogeneity of the measurements.

De Deus et al. (69) in 2004, evaluated the effect of the filling technique on the depth of tubular penetration of sealer using light microscopy and digital image processing and concluded that the thermo-plasticized gutta-percha technique shows deeper penetration of root canal sealer into dentinal tubules.

Preparation of root sections for SEM requires samples to undergo a drying process in an oven, by alcoholic solutions and high vacuum as the human teeth samples are extremely hydrated. Also, requires samples to be desiccated, highly polished and contain no surface smear layer. This can lead to loss of the sealer from the dentine surface and thus an under-representation of the depth of penetration. This is important and may explain the low reported depths of penetration in some SEM studies.

Balguerie et al. [70] in 2010, evaluated the tubular adaptation and penetration depth and the adaptation to the root canal walls in the apical, middle, and coronal third. Fifty-two single-rooted teeth were prepared and filled with 5 different sealers and softened gutta-percha cones. Thereafter, the roots were cross sectioned and prepared for evaluation under scanning electron microscopic. The results showed that AH Plus the most optimal tubular penetration and adaptation to the root canal wall of the sealers tested.

Stereomicroscope evaluation:

Ramlan et al. [71] in 2020, compare the effect between different levels of ultrasonic tip activation on the depth of epoxy resin-based sealer (AH plus) dentinal tubules penetration. Single-rooted premolars (n = 60) were randomly divided into three groups and instrumented following the same protocol. Group 1 (control): the sealer was mixed with 0.1% Rhodamine B dye and placed using size 20 K-file. In Group 2: the sealer was passively activated using ultrasonic tip (ISO 25) 10 s mesiodistally and buccolingually at 2 mm from the apex. In Group 3: the sealer was activated in a similar manner at 4 mm from the apex. Samples were sectioned horizontally at 2 mm, 4 mm, and 6 mm from the apex. The samples were analyzed using a **stereomicroscope** for tubular dentine sealer penetration. The results showed that passive ultrasonic activation of sealer placement in deeper sealer penetration into the dentinal tubules even at a higher level of tip activation 4 mm.

Alafandi et al. [62] in 2020, evaluated the effectiveness of ultrasonic activation and BC gutta-percha points in obturating root canals. The sample consisted of 40 single rooted lower premolars. The sample was divided into four groups based on the use of ultrasonic activation and the type of GP Group 1: ultrasonic activation of EndoSequence BC sealer was used with traditional gutta-percha (UAGP), Group 2: ultrasonic activation of EndoSequence BC sealer was used with BC gutta-percha (UABC), Group 3: ultrasonic activation was not used for BC sealer with traditional gutta-percha (NAGP). Group 4: ultrasonic activation was not used with BC GP (NABC). The samples were analyzed using a stereomicroscope for tubular dentine sealer penetration The results showed significant differences in the average amount of microleakage between the filling groups with ultrasonic activation and the non-activation groups. However, using endosequence BC points showed no significant reduction in the microleakage level. The study concluded that ultrasonic activation of EndoSequence BC sealer improves root filling quality.

To overcome the limitations of SEM, confocal laser scanning microscopy was used in the current study to accurately measure sealer penetration. CLSM allows the measurement of sealer penetration below the surface of the dentine, eliminating the need for destructive specimen preparation or smear layer removal which may result in loss of sealer.

Confocal laser scanning microscopy (**CLSM)** is designed to be confocal with a point of light placed in front of the photodetector when the laser beam is concentrated on the sample Thus, the photodetector receives only information from the focus plane of interest. The benefit of this approach is its ability to visualize structures on different layers within a biological specimen.

De Bem et al. [63] examined the impact of ultrasonic activation on dentin tubule penetration to root dentin in endodontic sealers. 100 single-rooted teeth were prepared and divided into two groups: with or without UA. Five types of sealers were used in this study, three resin-based sealers and two calcium silicate-based sealers (Sealer Plus BC and EndoSequence BC) were used Fluo-3 and rhodamine B dyes were added to the sealers. UA was performed for 40 seconds followed by lateral compaction. Samples were transversely sectioned to evaluate dentin tubule penetration. They used CLSM for evaluation. Results showed that resin-based sealers showed the highest tubule penetration without UA. UA significantly enhanced MTA Fillapex and Endosequence BC dentin tubule penetration. The study concluded that UA interferes with tubule penetration to root dentin of resin- and calcium silicate-based sealers.

3. AIM OF THE STUDY

The study aimed to evaluate the effect of different sealer activation methods on the depth of penetration of TotalFill BC Sealer HiFlow using the confocal laser scanning microscopy. The null hypothesis of the current research was that the method of activation has no influence on the sealer penetration into the dentinal tubules.

4. MATERIALS AND METHODS

Section outline:

4.1. Study design and Ethical committee approval.

4.2. Sample size calculation.

4.3. Selection and preparation of the teeth.

4.4. Decornation of the teeth.

4.5. Chemo-mechanical preparation of the samples.

4.6. Grouping of the samples:

Group I: Sealer without activation.

Group II: Sealer activation with XP endo finisher

Group III: Sealer activation with the Irrisafe ultrasonic tip.

Group IV: Sealer activation with Plastic NeoEndo Finisher in reciprocating motion.

Group V: Sealer activation with Plastic NeoEndo Finisher in continuous rotating motion.

4.7. Obturation of the samples.

4.8. Sectioning of the specimens.

4.9. Confocal laser scanning microscopic evaluation of the specimens.

4.10. Statistical analysis of the data.

List of materials, instruments and devices:

Table (1):

Item	Origin
TotalFill BC Sealer Hiflow, XP-endo Finisher file	FKG Dentaire SA, La-Chaux-de-fonds, Switzerland.
Sodium hypochlorite	Egyptian Company for House hold Bleach, Cairo, Egypt.
Periodontal curette	Gracey curette, LM-Dental™, Finland
Dental operating microscope	Zumax Medical Company, Jiangsu, China.
Digital sensor	Dabiatlante, Brazil.
CBCT	Planmeca, Helsinki, Finland.
K-files #10, 15, 20 & 40	Mani, Tochigi, Japan.
Endostar E3 Azure rotary files	Poldent, Warsaw, Poland.
Endodontic torque-controlled motor	E-cube, saeshine, Korea. E-connect, Eighteeth Medical Technology Co., Changzhou, China
30-gauge side vented endodontic irrigating needle	Ultradent, South Jordan, UT.
EDTA	Cerkamed, Stalowa Wola, Poland.
Gutta-percha points #40 /04 Absorbent paper points #40/04	Meta Biomed, Cheongju-si, Chungbuk, Korea.
Rhodamine B dye (0.1%)	Sigma-Aldricj, St. Louis, MO, USA.
Plastic NeoEndo finishing File	Orikam, Healthcare India Pvt, Ltd.
Ultrasonic Irrisafe tip & Satelec Ultrasonic activation device	Acteon, Merignac, France.
Resin-modified glass ionomer filling	GC Fuji, Tokyo, Japan.
Linear precision saw	IsoMet 4000; Buehler, Lake Bluff, IL
Conofocal laser scanning microscope (CLSM)	Carl Ziess, Jena, Germany.
CLSM image software	ZEN 3.2.

Materials and Methods

4.1. Study design and Ethical committee approval

This is an in-vitro, randomized, interventional, prospective study. The ethical committee of The Faculty of Dental Medicine, Al Azhar University Cairo boys accepted the study with the code number (804/3588).

4.2. Sample size calculation:

Based on the results of De Bem IA et al [63], for penetration of a bioceramic root canal sealer into dentinal tubules, we conducted a power analysis (G power version 3.1 statistical software, Franz Faul, Universität Kiel Germany). An ANOVA: Fixed effects, omnibus, one-way analysis was performed to compute the required sample size given α, power, and effect size. The input parameters were α error probability of 0.05, an effect size (f) of 0.50, a power of 0.90 and the number of groups of 5. The findings indicated a total sample size of n = 50 samples, (10 samples for each group).

4.3. Selection and preparation of the teeth:

Out of 83 teeth, 50 extracted human mandibular premolars teeth were selected from the outpatient clinic of The Oral Surgery Department, Faculty of Dental Medicine, Al Azhar University. The teeth were extracted for other reasons not related to the study. The selected teeth were immersed in 5.25% sodium hypochlorite (NaOCl) (Egyptian Company for House Hold Bleach, Cairo, Egypt) for 10 minutes for disinfection and rinsed with distilled water. The teeth were cleaned of calculus and soft tissue using a periodontal curette (Gracey curette, LM-

Dental™, Finland). The teeth were evaluated under a dental operating microscope (DOM) (S2350, Zumax Medical Company, Jiangsu, China) at 8x magnification. Initial radiographic evaluation was taken from buccolingual and mesiodistal directions using a digital sensor size 2 (Dabi-Atlante, Brazil) to assess the type I root canal.

Teeth were selected according to the following inclusion criteria:

- Mature single-rooted mandibular premolar teeth with type I root canal according to Vertucci's classification [3].
- Teeth were extracted from patients aged range from 18 to 40 years old.
- Teeth with root canal curvature range from 0° to 15° according to Schneider's method of evaluation [72].
- Teeth with lengths from 20 to 22mm.
- The initial file size is not larger than #20.

The teeth were saved in a jar containing normal 0.9% saline solution (Egypt Pharmaceutical Company, 10th of Ramadan City, Egypt) at room temperature until the time of the study.

Preparation of mold:

Prior to cone beam computed tomography (CBCT), five plastic square molds were made (5cm in diameter and 1.7 cm in thickness) containing 10 circular shapes openings (1 cm diameter). Mold was created of acrylic blocks as a modification of Alkhawas et al [73]. Holes of each mold were filled with softened pink wax (Al-Quds company, Mansoura, Egypt) in which the teeth were embedded (Fig. 1). For identification of the location of each tooth after scanning, there was one hole alone in the fore of the mold. The mold was put on a square glass slab (10x10 cm.). The root portions were embedded in the wax while maintaining the long axis of the roots to be parallel to each other and running parallel to the mold's surfaces.

Figure (1): A photograph showing a plastic mold empty and with the teeth inside.

Pre-intervention CBCT scanning:

A preoperative CBCT scanning was done using Planmeca ProMax® 3D plus machine (Planmeca, ProMax 3D MID; Planmeca, SN TFD770038, Helsinki, Finland) voxel size=200 µm with 90 kV, 12 mA, and the 4.035-seconds exposure time was made of the mold with the embedded teeth for confirmation of type I root canal system. Teeth with internal root resorption, calcified root canals or pulp stones were excluded (Fig. 2).

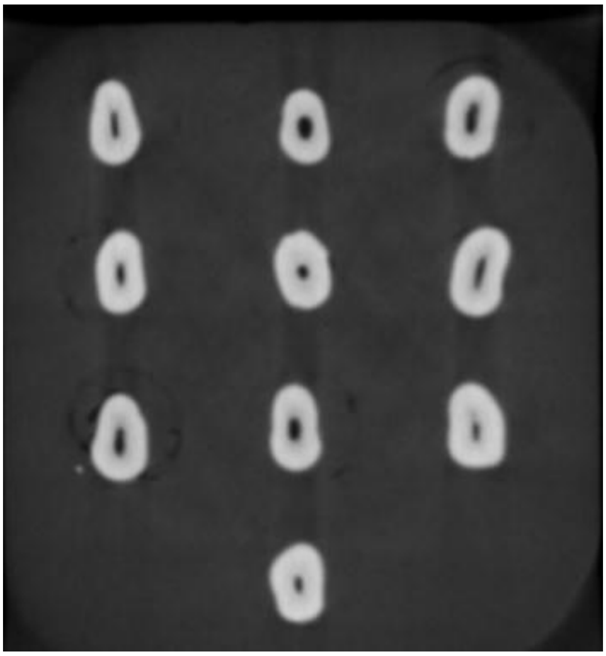

Figure (2): A photograph showing CBCT image of an axial view for the teeth.

4.4. Decornation of the teeth:

Teeth were decornated using a diamond disc mounted in a low-speed straight handpiece with water coolant while the teeth were in the mold (Fig.3). For standardization, the mold was fabricated to be 17 mm in thickness to make the root portions 17 mm in length from the apex.

Figure (3): A photograph showing a plastic mold with the decornated teeth inside.

4.5. Chemo-mechanical preparation of the samples:

Before instrumentation, the working length of the canal was determined by introducing a size #10 k-file (Mani inc., Togichi, Japan) into the canal until it appeared at the apical foramen then 1 mm subtracting from this length. Root canal preparation was done using Endostar E3 Azure rotary files system (Poldent, Warsaw, Poland) mounted on an endodontic torque-controlled motor at a torque of 2.1 N/cm and speed of 300 revolutions per minute (RPM) as recommended by the manufacturer. Each canal was prepared with a sequence, size 30/ .08 taper orifice opener for coronal third, the middle and apical thirds of the canal were prepared with # 20,25,30,35, and 40/.04 taper. The patency of the canal was maintained with #10 K-file between each rotary file. During the chemo-mechanical procedure, 3 ml 5.25% NaOCl was used after each instrument. The master cone gutta-percha #40/.04 (Meta Biomed®, Cheongju-si, Chungbuk, Korea) was checked clinically and radiographically. The master cone was put aside until the activation of irrigation and sealer application were performed. After instrumentation, ethylenediaminetetraacetic acid (EDTA) (Cerkamed, Stalowa Wola, Poland) solution was used as the final rinse. The irrigation was activated in the following manner; firstly, 3 ml NaOCl was delivered inside the root canal and the tip of the ultrasonic was activated for 30 seconds. Secondly, 3 ml 17% EDTA was activated for another 30 seconds, the sample was irrigated with 3 ml distilled water between the two irrigants and final rinse before drying the sample by #40/04 paper points (Meta Biomed).

Sealer application:

TotalFill BC Sealer Hiflow (FKG Dentaire SA, 2103SPWF, La-Chaux-de-fonds, Switzerland) is supplied in a 1.5 gm premixed syringe (Fig. 4). The sealer was mixed with the Rhodamine B fluorescent dye (Sigma-Aldricj, St. Louis, MO, USA) for analysis of the sealer penetration under the confocal laser scanning microscope. One gm of the sealer was mixed with 0.001 gm of the Rhodamine B dye [13]. So, the amount of Rhodamine B dye (.0015 gm) was measured by micropipette and mixed with the sealer on a mixing pad. The sealer was inserted into the canal using master cone gutta-percha.

Figure (4): A photograph showing TotalFill BC sealer Hiflow.

4.6. Grouping of Samples:

Based on the method of sealer activation, the samples were coded and randomly divided using randomized website (http://www.randomized.org) into five groups (n=10):

Group I: Sealer without activation (control group):

The master gutta-percha cone # 40/04 was coated with a thin layer of BC sealer. The gutta-percha cone was introduced slowly into the root canal until the full working length.

Group II: Sealer activation with XP-endo Finisher file:

The sealer was activated using XP-endo Finisher file (XPF) (FKG Dentaire, La Chaux-de-Fonds, Switzerland) ISO 25 in diameter and zero taper (Fig.5). The XPF file is supplied in a blister pack and each file comes placed in a graduated plastic tube with an attached stopper. The file was removed from the blister pack and mounted to the handpiece of an endodontic motor (E-connect Promax, Eighteeth Medical Technology Co., Changzhou, China) by applying lateral movement against the blister wall to ensure the file remained straight. The working length. was determined using the graduated plastic tube and stopper to be 2 mm shorter than the working length. The file was adjusted to be rotated at 1000 rpm and 1 Ncm torque according to the manufacturer's instructions. The file was inserted into the canal, once the tip was inside the motion control was turned on using slow and gentle up-and down movements to the adjusted working length. After 20 seconds, the file was withdrawn from the canal while rotating.

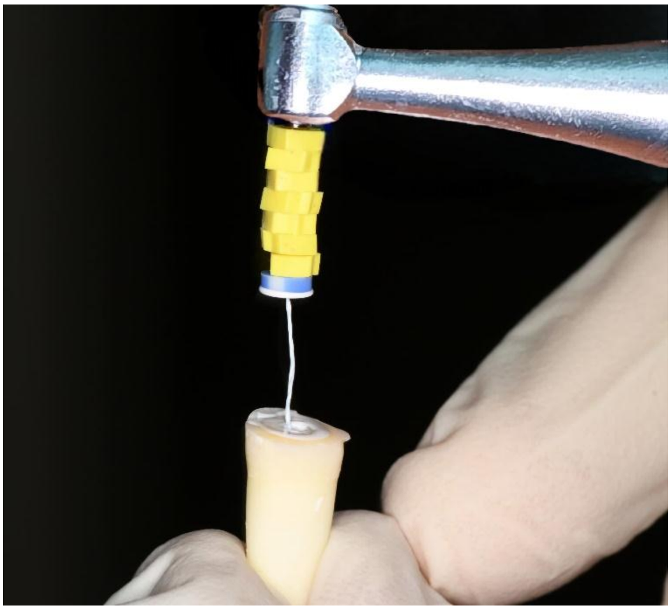

Figure (5): A photograph showing XP endo finisher file.

Group III: Sealer activation with Irrisafe ultrasonic activation tip:

The sealer was activated using a passive ultrasonic activation Irrisafe tip (Acteon, Merignac, France) (Fig.6). The tips are manufactured with stainless steel and come in a blister pack of 4 units. The Irrisafe tip was used size 0.25 mm, .02 taper and 25 mm in length with non-cutting parallel edges and smooth end. The tip was adapted into an ultrasonic unit (Acteon Satelec Newtron P5, Merignac, France) at a power setting of 3. The tip was adjusted to be 2 mm shorter than the working length and activated inside the canal with a pull stroke and backwards movement. The tip was activated for 10 seconds in the buccolingual and the mesiodistal directions for 10 seconds.

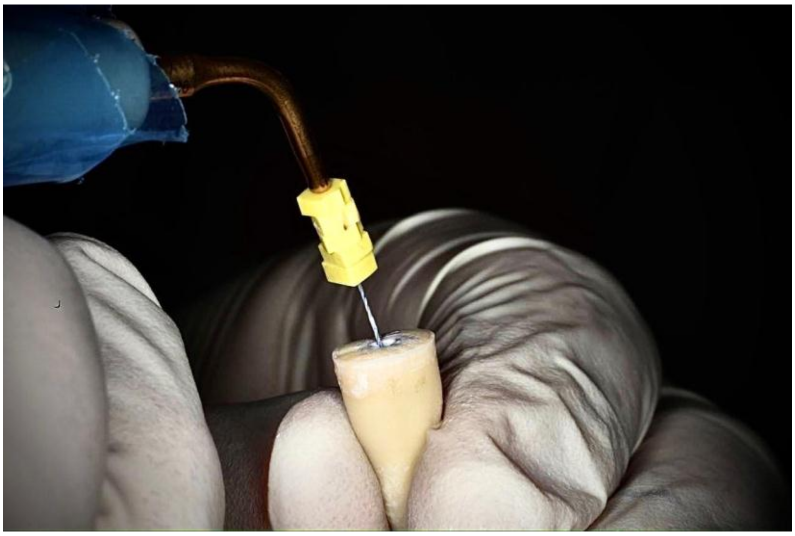

Figure (6): A photograph showing Irrisafe tip

Group IV: Sealer activation with Plastic NeoEndo Finishing file in reciprocating motion:

The sealer was activated using a Plastic NeoEndo Finishing file (Orikam Healthcare India Pvt, Ltd.) in reciprocating motion. The file is made of plastic polymer with a parallel offset flute design with a tip size of 0.2 mm, .04 taper and 25mm in length (Fig.7). The file was mounted to the endodontic motor (E-connect Promax) and adjusted to be shorter than the working length by 2 mm. The motor was adjusted to be used in angulation (150º) clockwise and (30º) anticlockwise. The file was introduced passively into the canal and worked along the dentinal wall for 20 seconds.

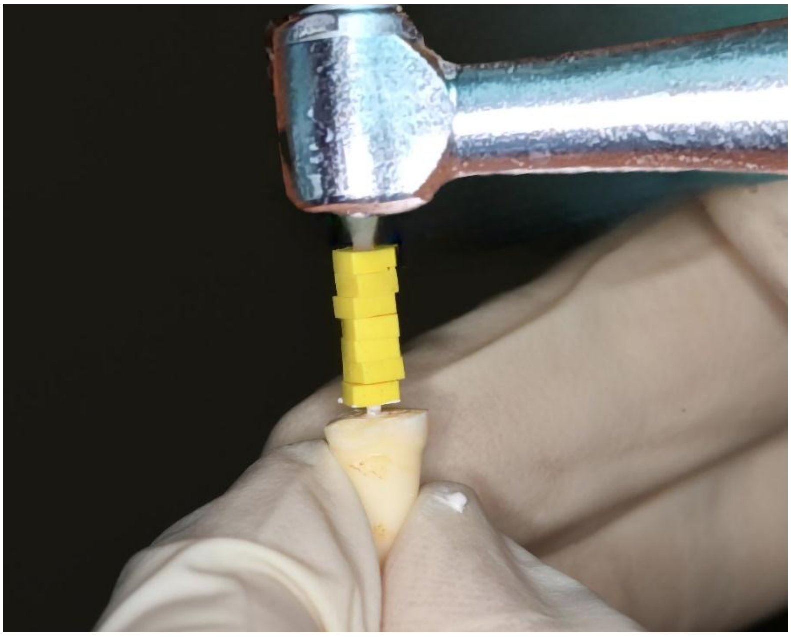

Figure (7): A photograph showing plastic Neo Endo finishing file.

Group V: Sealer activation with Plastic NeoEndo Finishing file in continuous rotation motion:

The sealer was activated using a Plastic NeoEndo Finishing file. The file was mounted to the endodontic motor (E-connect Promax) used at 600 rpm and 0.5 Ncm torque according to the manufacturer's instructions. The file was adjusted to be shorter than the working length by 2 mm with rubber stoppers. The file was introduced passively into the canal and circumferentially worked along the dentinal wall for 20 seconds.

4.7. Obturation of the samples:

The single-matched cone technique was selected for the obturation of the samples. Additional amounts of fluorescently labelled sealer were gradually introduced until the canal was filled. The premeasured master cone was slowly inserted into the canal to the full working length. A post-operative radiograph was done to confirm the quality of the filling (Fig.8). Excess coronal gutta-percha was seared off with a heated instrument 2 mm below the canal orifice. Then the cervical portion of the roots was sealed using resin-modified glass ionomer filling material (GC Fuji, Tokyo, Japan). The samples were stored in an incubator at 37 °C 100% humidity for one month to ensure complete set of the sealer.

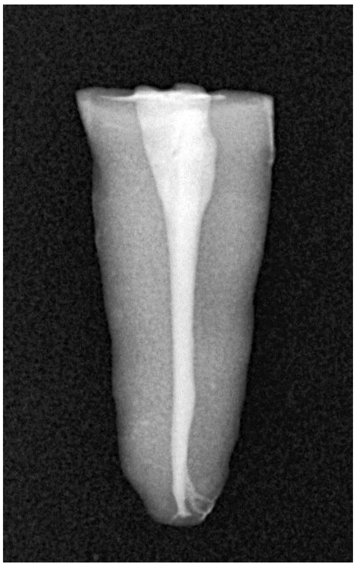

Figure (8): A photograph showing peri-apical radiograph for the obturation.

4.8. Sectioning of the samples:

The samples were loaded onto resin stubs then serially sectioned horizontally using a precision saw (IsoMet 4000; Buehler, Lake Bluff, IL) at a slow speed under water cooling to prevent frictional heat. Each sample was sliced into three slices with approximately 1 mm thickness at

3, 6, and 9 mm (apical, middle, and coronal) depths from the apex. was used for polishing the specimens. The specimens were fixed by placing them on glass slides properly after polishing by silicon carbide abrasive paper. (Fig.8).

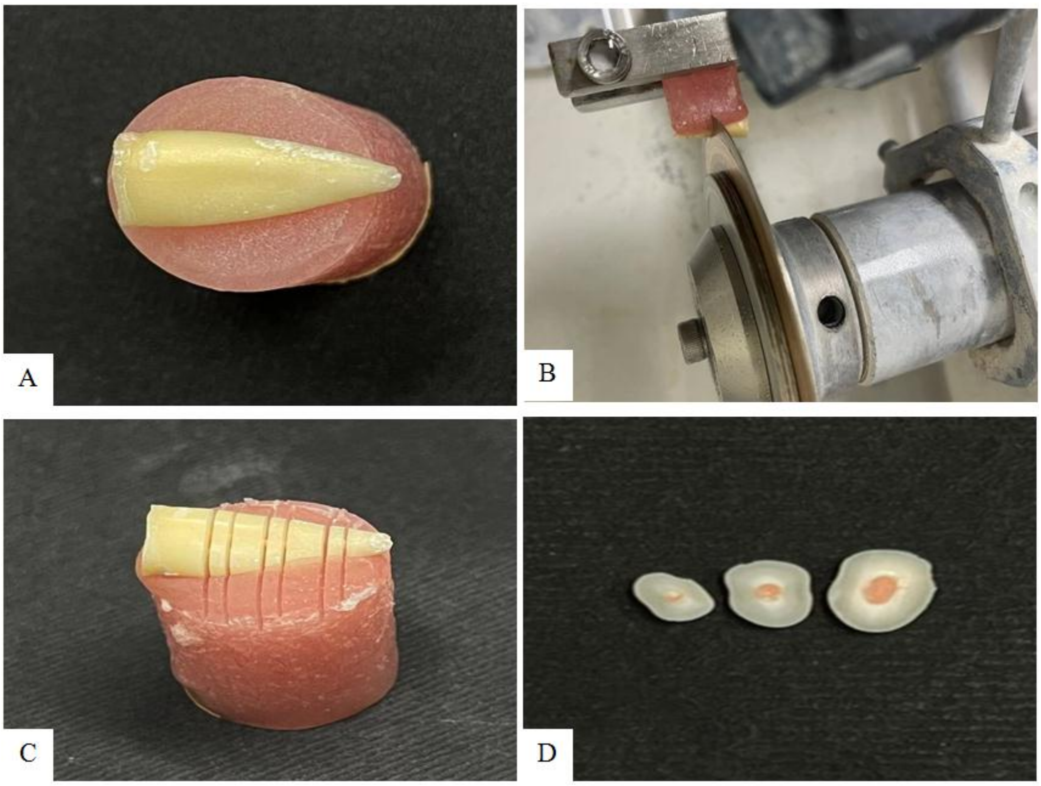

Figure (9): A photograph showing; A) the tooth loading in resin stub, B) isomet linear precision saw, C) sample after sectioning, and D) three slices of the sample.

4.9. Confocal laser scanning microscopic evaluation:

The specimens were evaluated under the confocal laser scanning microscopy (CLSM) (Carl Ziess, Jena, Germany) (Fig. 10). The images were analyzed by using ZIESS software. A helium-neon laser was used as the light source, and the excitation light source had a wavelength of 543 nm. The fluorescent light was collected beyond 560 nm. CLSM images were recorded in the fluorescent mode. All samples were examined from a coronal view. The full sample acquisition was imaged with a 10x objective lens in the format of 1,024 × 1,024 pixels. While the 40x oil lenses confirm the content of the sealer inside the dentinal tubules.

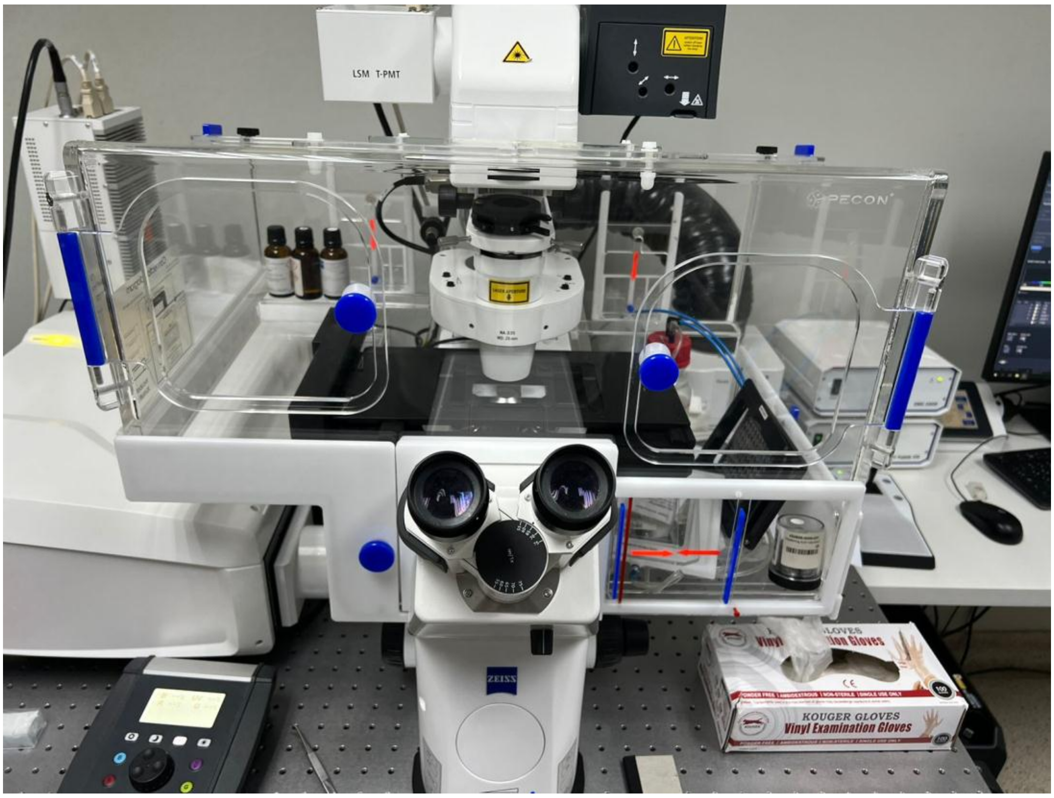

Figure (10): A photograph showing confocal laser scanning microscopy

Each sample was evaluated for a consistent fluorescent ring around the canal wall, indicating the sealer dye distribution. The depth of penetration of the sealer into the dentinal tubules was illustrated by the fluorescence, which was traced from the sealer-dentin junction until the maximum depth. The measurements were recorded by using the digital measuring ruler, which is present on the CLSM image software (ZEN 3.2.) (Fig. 11). The following formula [74] was used to calculate the percentage of sealer tubular penetration:

Dentin area= Total area – root canal area

Measurements of the sealer penetration percentage:

$$\textit{Percentage of sealer penetration} = \frac{\textit{maximum area filled by sealer} - \textit{root canal cross sectional area}}{\textbf{Dentin area}} \times \mathbf{100}$$

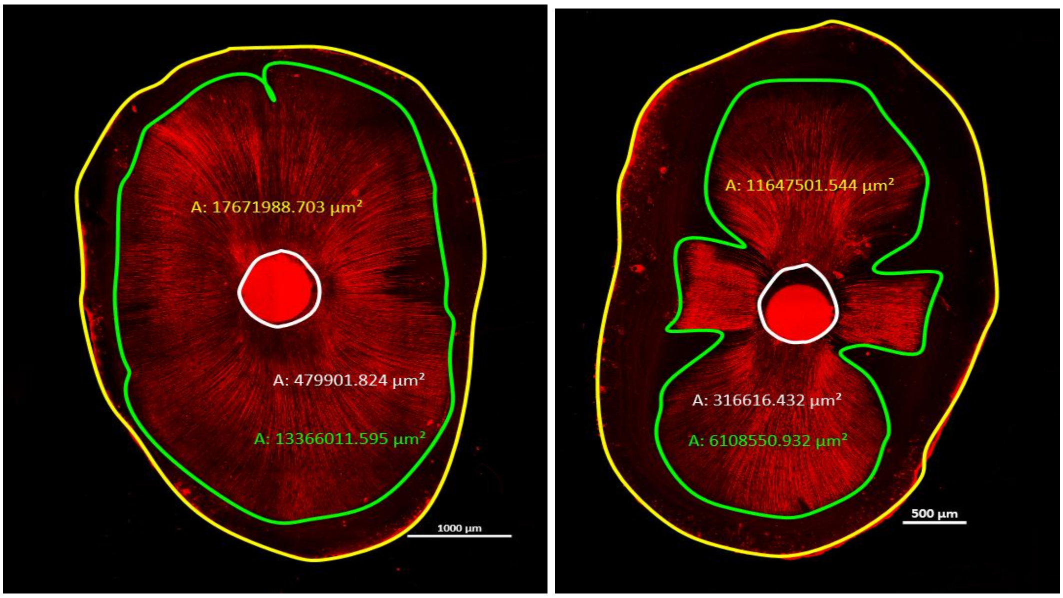

Figure (11): A photomicrograph showing CLSM image analysis; total cross section area of the root (yellow area), area filled by sealer (green area)- root canal area (white area)

4.10. Statistical analysis of the data:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values. Repeated measures ANOVA test was used to study the effect of activation technique, root level and their interactions on different variables. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

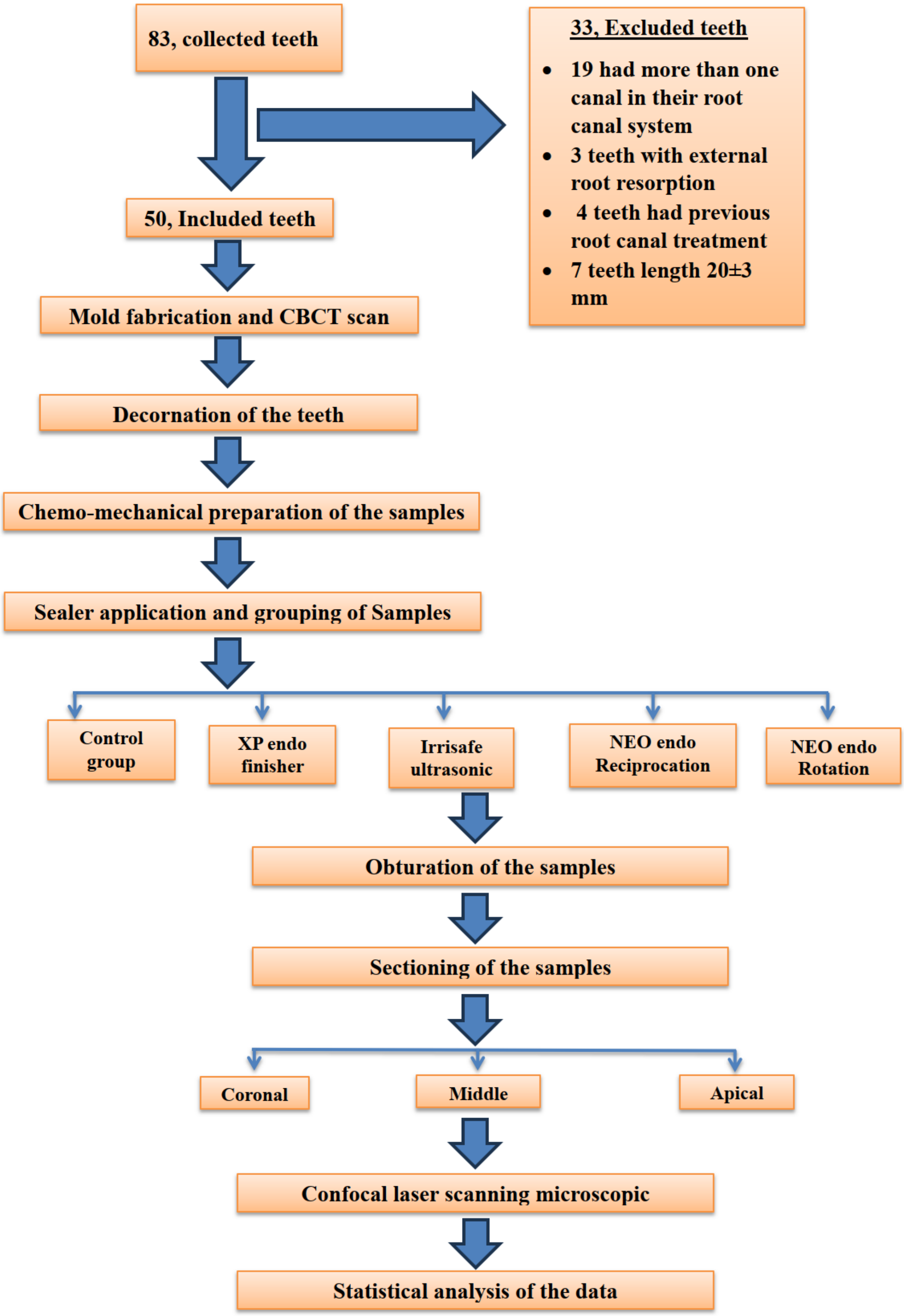

Figure (12): A flow chart representing a review of materials and methods used in the study

5. RESULTS

5.1. Evaluation of percentage of depth of penetration of the bioceramic sealer.

5.1.1. Effect of activation method (regardless of root level).

5.1.2. Effect of root level (regardless of activation method).

5.1.3. Effect of different interactions of variables on percentage of sealer penetration.

5.1.3.1. Comparison between different activation methods.

5.1.3.2. Comparison between different root levels.

Results

5.1. Evaluation of percentage of depth of penetration of the bioceramic sealer.

5.1.1. Effect of activation method (regardless of root level):

There was a statistically significant difference among activation methods. Pair-wise comparisons revealed that XP-endo Finisher (XPF) (75.4±16.8) showed the highest mean percentage of sealer penetration with non-statistically significant difference from Neo-Finishing (Neo-EF) in reciprocating motion (68.2±15.7) and a statistically significant difference from other methods (fig. 17&19 respectively). There was no statistically significant difference between US Irrisafe activation (62.1±15.7) and Neo-EF in rotating motion (59.6±9.4) (fig. 18& 20 respectively). Control group (47.2±12.4) showed the statistically significantly lowest mean sealer penetration percentage (fig. 16). (Data showed in table 2 and fig. 13).

Table (2): The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between sealer penetration (percentage) of different activation methods regardless of root level

Activation method	Mean	SD	*P*-value	*Effect size (Partial Eta squared)*
Control	47.2 C	12.4	<0.001*	0.987
XP Finisher	75.4 A	16.8		
US Irrisafe	62.1 B	11.5		
Neo/Reciprocating	68.2 AB	15.7		
Neo/Rotation	59.6 B	9.4		

**: Significant at P ≤ 0.05, Different superscripts indicate statistically significant difference between methods*

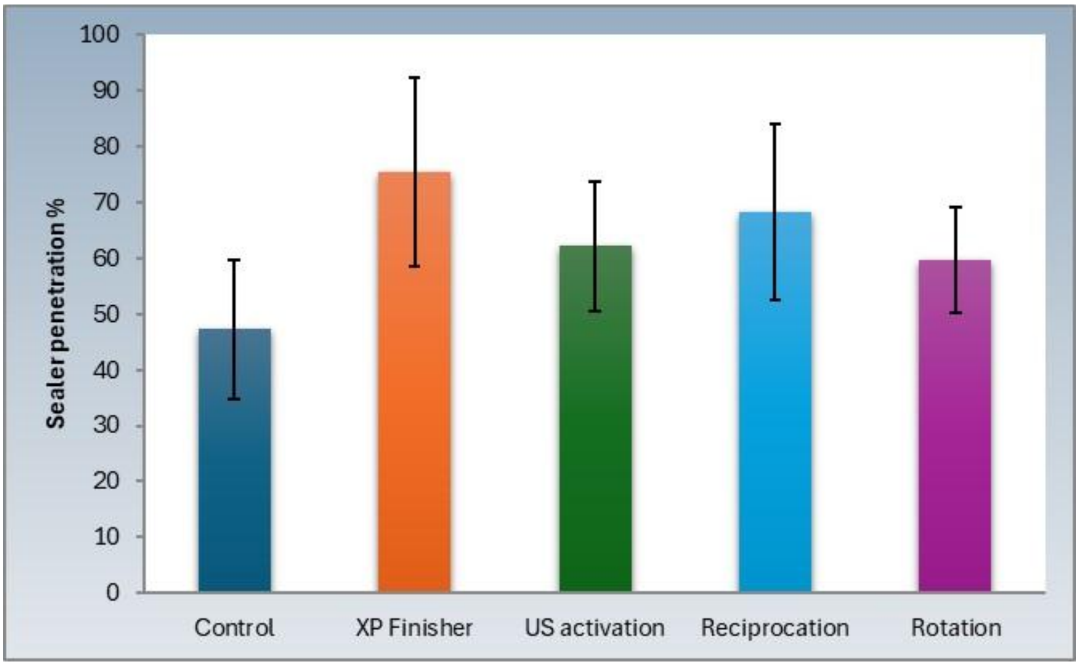

Figure (13): Bar chart representing mean and standard deviation values for sealer penetration (percentage) of different activation methods regardless of root level

5.1.2. Effect of root level (regardless of activation method):

There was a statistically significant difference between root levels. Pair-wise comparisons revealed that coronal level (73.4±13.3) showed the statistically significantly highest mean percentage of sealer penetration followed by middle root level (64.8±13.2). Apical root level showed the lowest mean percentage of sealer penetration (49.3±12.2) (table 3 and fig. 14). P value <0.001*.

Table (3): The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between sealer penetration (percentage) at different root levels regardless of activation method

Coronal		Middle		Apical		*P*-value	*Effect size (Partial Eta squared)*
Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**		
73.4^{A}	13.3	64.8^{B}	13.2	49.3^{C}	12.2	<0.001*	0.848

**: Significant at P ≤ 0.05, Different superscripts indicate statistically significant difference between root levels*

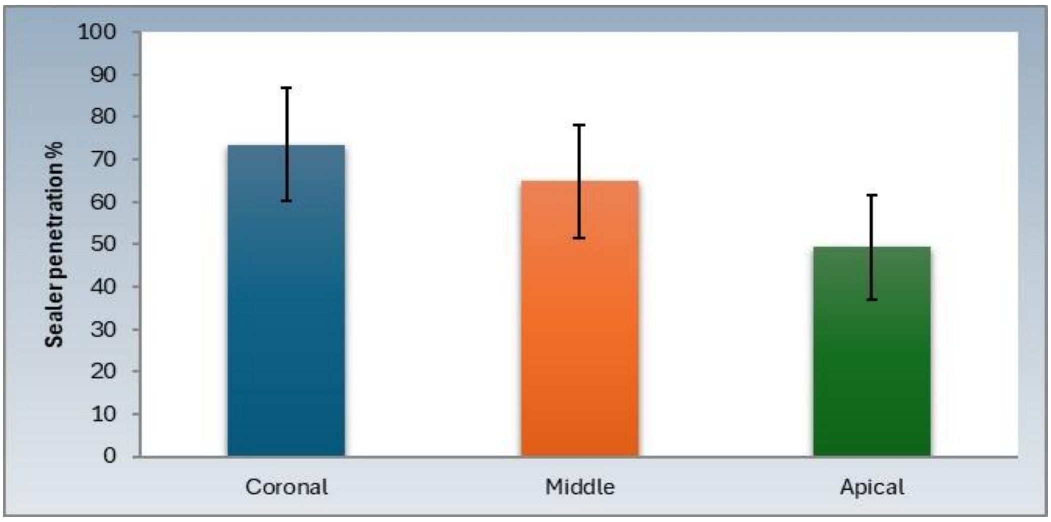

Figure (14): Bar chart representing mean and standard deviation values for sealer penetration (percentage) at different root levels regardless of activation method

5.1.3. Effect of different interactions of variables on sealer penetration percentage

5.1.3.1. Comparison between different activation methods

At the coronal root level, there was a statistically significant difference among sealer activation methods. Pair-wise comparisons revealed that XPF showed the statistically significantly highest mean percentage of sealer penetration (90.4±3.8) followed by Neo-EF in reciprocating motion which showed (80.4±9.7). There was no statistically significant difference between US Irrisafe activation (72.1±5.9) and Neo-EF in rotation (67.4±6.9), both showed statistically significantly lower mean percentage of sealer penetration. Control group showed the statistically significantly lowest mean percentage of sealer penetration (56.6±6.8). P value <0.001*.

At the middle root level, there was a statistically significant difference among activation methods. Pair-wise comparisons revealed that XPF showed the highest mean percentage sealer penetration (76.5±12.7) with non-statistically significant difference from Neo-EF in reciprocating motion (72.4±9.7) and a statistically significant difference from other methods used for sealer activation. There was no statistically significant difference between ultrasonic activation (64.8±7.3) and Neo-EF in reciprocating motion (72.4±9.7), however, US Irrisafe activation showed statistically significantly higher mean percentage of sealer penetration than Neo-EF in rotating motion (61.5±5.3). Control group showed the statistically significantly lowest mean percentage of sealer penetration (48.8±10.3). P value <0.001*.

At the apical root level, there was a statistically significant difference among activation methods. Pair-wise comparisons revealed that XPF showed the highest mean percentage of sealer penetration (59.4±14.4) with non-statistically significant difference from Neo-EF in reciprocating motion (51.8±11.1) and a statistically significant difference from other methods used. There was no statistically significant difference between US Irrisafe activation (49.3±5.7), Neo-EF in reciprocating motion (51.8±11.1) and Neo-EF in rotating motion (49.9±5.8). Control group showed the statistically significantly lowest mean percentage of sealer penetration (36.4±10.8) (table 4 and fig. 15). P value <0.001*.

5.1.3.2. Comparison between different root levels

With all activation methods, there was a statistically significant difference among root levels. Pair-wise comparisons revealed that coronal level showed the statistically significantly highest mean percentage of sealer penetration followed by middle root level. Apical root level showed the statistically significantly lowest mean percentage of sealer penetration (table 4 and fig. 15).

Table (4): The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between sealer penetration (percentage) with different interactions of variables

Activation method	Coronal		Middle		Apical		*P*-value	Effect size *(Partial eta squared)*
	Mean	SD	Mean	SD	Mean	SD		
Control	56.6 [DE]	6.8	48.8 [DF]	10.3	36.4 [CG]	10.8	<0.001*	0.570
XP Finisher	90.4 [AE]	3.8	76.5 [AF]	12.7	59.4 [AG]	14.4	<0.001*	0.768
US Irrisafe activation	72.1 [CE]	5.9	64.8 [BCF]	7.3	49.3 [BG]	5.7	<0.001*	0.617
Neo/Reciprocation	80.4 [BE]	9.7	72.4 [ABF]	9.7	51.8 [ABG]	11.1	<0.001*	0.713
Neo/Rotation	67.4 [CE]	6.9	61.5 [CF]	5.3	49.9 [BG]	5.8	<0.001*	0.488
P-value	<0.001*		<0.001*		0.002*			
Effect size *(Partial eta squared)*	0.760		0.543		0.381			

**: Significant at $P \leq 0.05$, A,B,C,D superscripts in the same column indicate statistically significant difference between methods,*

E,F,G superscripts in the same row indicate statistically significant difference between root levels

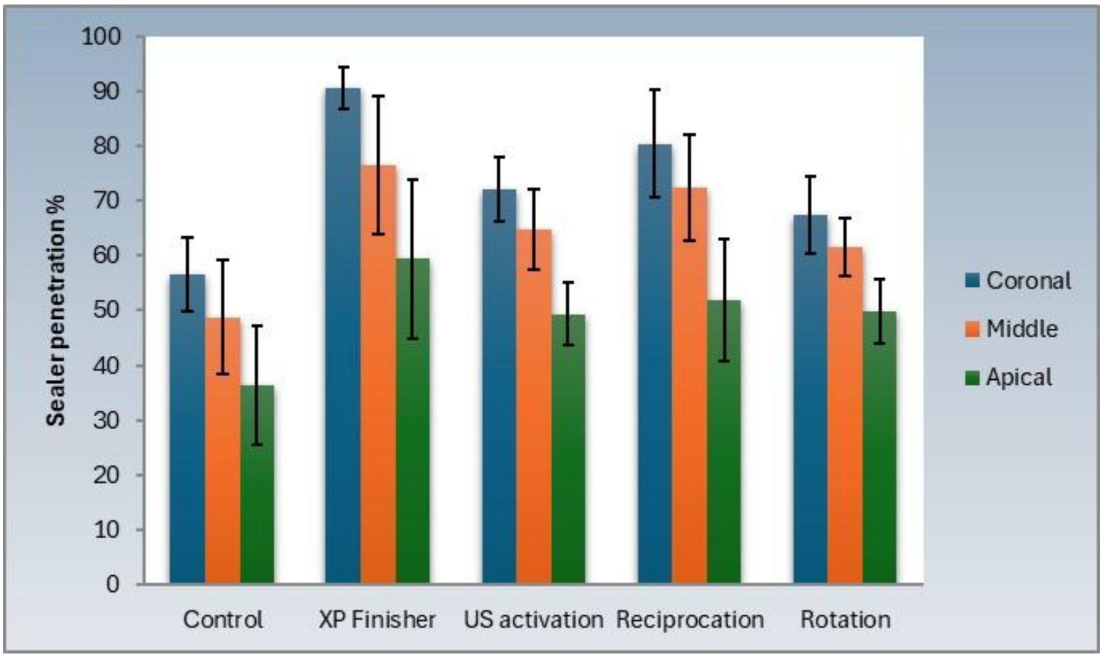

Figure (15): Bar chart representing mean and standard deviation values for sealer penetration (percentage) with different interactions of variable.

Repeated measures ANOVA results

The results showed that activation technique (regardless of root level) had a statistically significant effect on mean sealer penetration. Root level (regardless of activation technique) had a statistically significant effect on mean sealer penetration. The interaction between variables also had a statistically significant effect on mean sealer penetration. Since the interaction between the variables is statistically significant, the variables are dependent upon each other (table 5).

Table (5): Repeated measures ANOVA results for the effect of different variables on mean sealer penetration (%)

Source of variation	Type III Sum of Squares	Df	Mean Square	*F*-value	*P*-value	Effect size *(Partial eta squared)*
Activation technique	10584.769	4	2646.192	14.860	<0.001*	0.987
Root level	11870.698	2	5935.349	194.791	<0.001*	0.848
Activation technique x Root level interaction	584.950	8	73.119	2.400	0.024*	0.215

*df: degrees of freedom = (n-1), *: Significant at P ≤ 0.05*

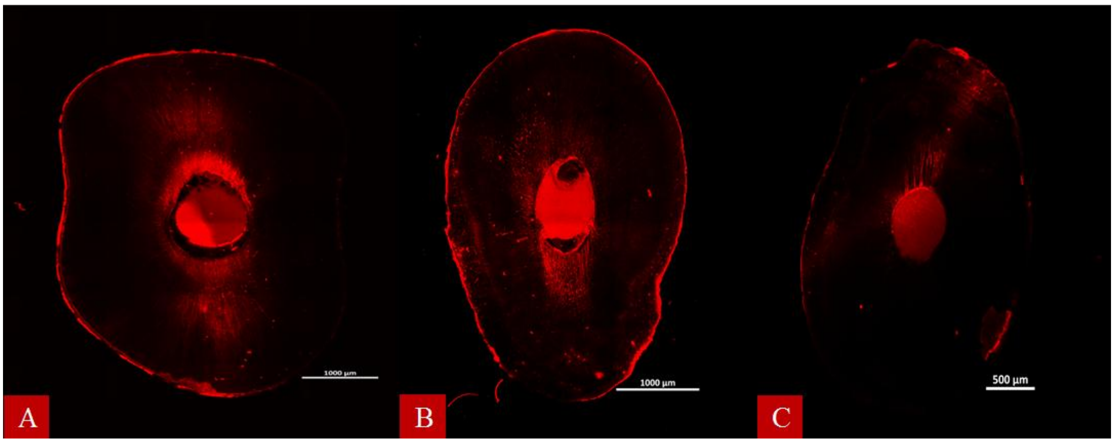

Figure (16): A photomicrograph showing CLSM image of three thirds of control group, A) coronal, B) middle, C) apical.

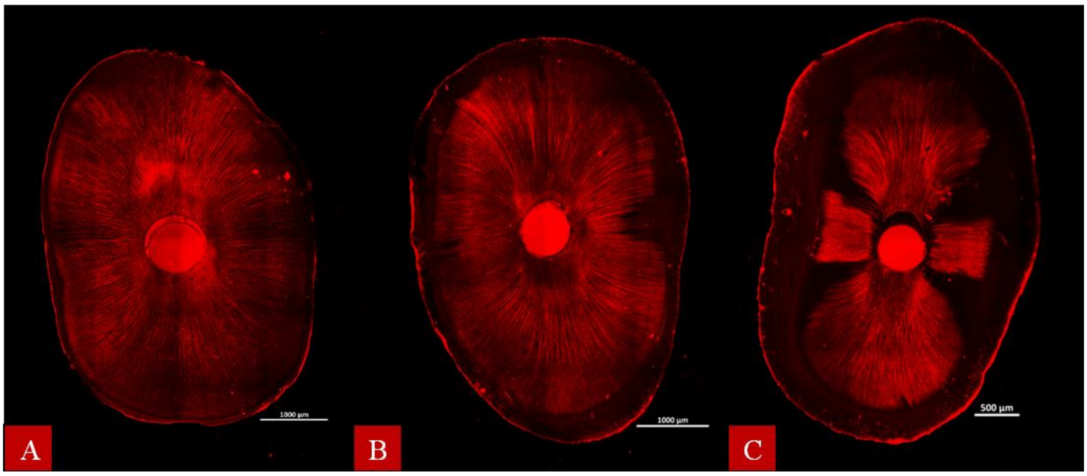

Figure (17): A photomicrograph showing CLSM image of three thirds of XPF group, A) coronal, B) middle, C) apical.

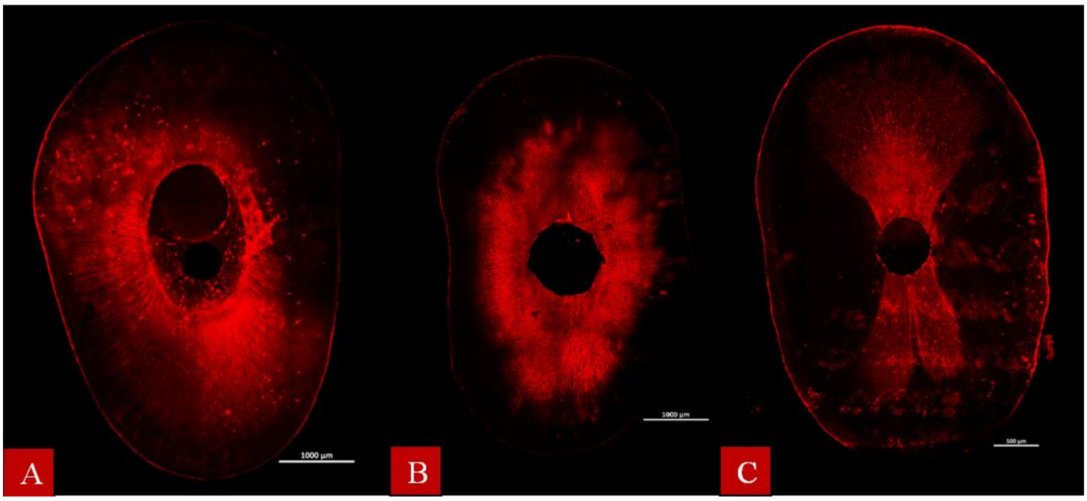

Figure (18): A photomicrograph showing CLSM image of three thirds of US Irrisafe ultrasonic group, A) coronal, B) middle, C) apical.

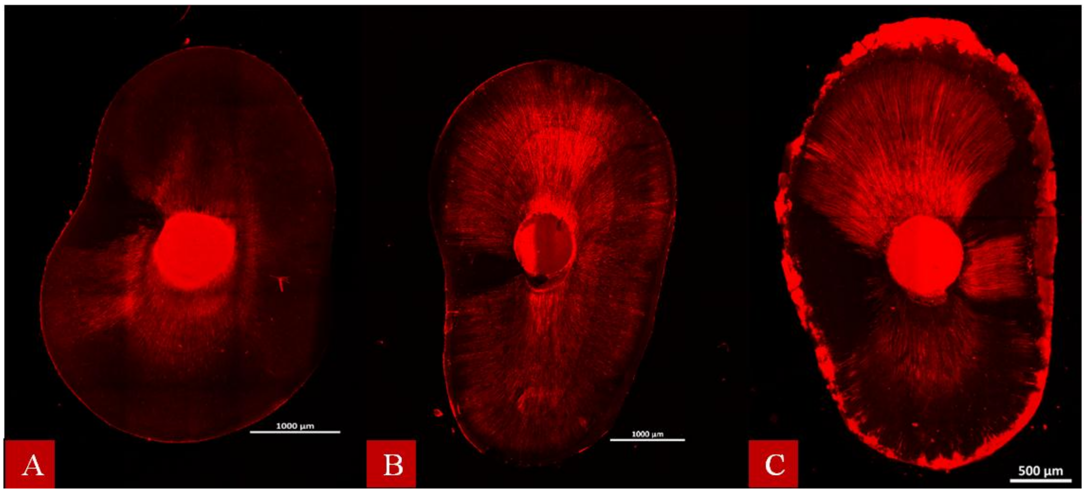

Figure (19): A photomicrograph showing CLSM image of three thirds of Neo-EF reciprocation group, A) coronal, B) middle, C) apical.

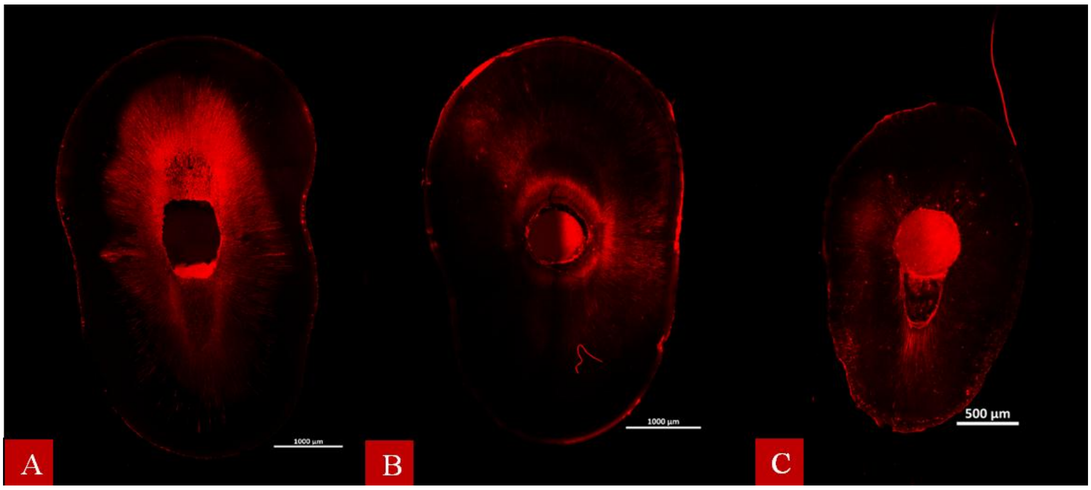

Figure (20): A photomicrograph showing CLSM image of three thirds of Neo-EF rotation group, A) coronal, B) middle, C) apical.

6. DISCUSSION

Successful endodontic treatment necessitates proper sealing of the root canal system. Basically, obturation of the root canals is done with gutta-percha core material and an endodontic sealer that acts as an interface between the filling material and the complex anatomy of the root canal system [(75)]. However, the conventional placement of sealers within the canal space is not sufficient to ensure optimal sealing [(4)]. Activation of sealers enhances the flow, adaptation and penetration of the sealers into the dentinal tubules which reach deeply within the tooth structure and create a secure seal [(76)]. With advancements in the activation methods of root canal irrigants such as using rotary finishing files whether metal or plastic in addition to the motion used, the effect of these methods remains unclear when they activate the endodontic sealers. This randomized, interventional prospective study aimed to evaluate the effect of different activation methods in improving the depth of penetration of bioceramic sealers into the dentinal tubules.

Single-rooted mandibular premolars with type I root canal system according to Vertucci [(3)] were selected as it the most extracted single-rooted teeth with single root canal during orthodontic treatment [(77)]. The age of the patients ranges between 18 to 40 years to minimize the difference between samples considered dentin nature as deposition of secondary and sclerotic dentin [(78)].

Fifty mandibular premolars teeth were chosen to be included in this study out of eighty-three teeth. Thirty-three teeth were excluded for the following reasons: nineteen had more than one canal in their root canal system, three with external root resorption, four teeth had previous root canal treatment, four teeth +22 and three teeth - 20 mm.

A pre-operative radiograph was taken in buccolingual and mesiodistal directions to detect teeth morphology that is verified with CBCT scanning [79,80].

The chemo-mechanical preparation was done using Endo Star E3 Azure rotary file system, which is heat-treated, highly flexible rotary files with high fracture resistance [81]. The master apical preparation was done using a 40/04 rotary file to shape the root canal allowing for deeper penetration of both irrigating solution and the root canal sealer [82]. Irrigation between each file was done using 5,25% NaOCl due to the capacity to dissolve organic matter and act as a lubricant for all shaping files. After instrumentation, EDTA solution was used as a chelating agent in the final rinse protocol due to its ability to dissolve the inorganic part of the smear layer [83,84]. Passive ultrasonic irrigation (PUI) was used to activate both irrigants as it enhances the root canal irrigant dispersion and allows for deeper penetration into inaccessible areas through acoustic streaming and cavitation bubbles [85].

Bioceramic sealer was used due to gained popularity in endodontic practice which demonstrates many desirable properties. Biocompatibility properties due to their similarity to biological hydroxyapatite, chemical stability, hydrophilicity, flowability, radiopacity, and slight expansion tendencies provide a perfect hermetic seal [38,86]. TotalFill BC sealer HiFlow was selected as it was claimed by the manufacturers that this type of bioceramic sealer resists heat which can withstand any heat may excreted during sealer activation [87].

A single-matched cone obturation technique was selected for the obturation of the samples as it is easily used in clinical practice compared to the lateral compaction technique protecting against initiation and propagation of vertical root fractures (88,89).

Rhodamine B was used as an indicator for sealer penetration due to its fluorescent effect as reported in the literature (90,91,92,93).

Confocal laser scanning microscopy was used to accurately measure the depth of sealer penetration. It has several advantages which provide detailed information about the presence and distribution of sealers inside the dentinal tubules in the total circumference of the root canal walls at a relative low magnification of 10X (94). By using fluorescent Rhodamine-marked sealers, artifacts could practically be excluded. In addition, it uses non-decalcified or hard tissue samples that do not require a specific section technique or applying a gold coating which may damage the sample (12).

Based on the current results, the XP-endo Finisher (XPF) and Neo Endo finishing (Neo-EF) in reciprocating motion are the most effective methods that are associated with the highest depth of penetration of the endodontic sealers.

XP-endo Finisher is manufactured with Max-wire technology allowing the file to transform from martensite to austinite phase with a spoon-like shape at body temperature. This could make it attainable for the instrument to physically contact a larger portion of the canal while it is in eccentric rotating motion (95). Besides, it could expand and adapt to the canal's shape (96). This unique manufacturing design and alloy technology could have increased the dispersed amount of sealer that improved its penetration into the dentinal tubules. In accordance with the current study, **Keles et al.** (66) compared the depth of penetration of the sealer when using XPF, Endo activator, EDDY tip and ultrasonic activation. XPF showed the highest penetration depth of the sealer. They attributed their results to the flexibility and adaptability of XPF to the root canal irregularities. In contrary to current results, **Zand et al.** [97] found that XPF have a lower penetration power of sealer after using it for irrigant activation. The comparability of both results is impossible due to the difference in methodology.

The penetration of the sealer associated with the Neo-EF in reciprocating motion as an activation method may be due to the adequate swirling of the sealer and churning effect which carried the sealer to deeper dentinal tubules. Additionally, the agitation action occurs along the whole length of the instrument is unimpeded by contact of the instrument with canal walls. In contrast to current results, **Coronas et al.** [62] found that there was no difference between reciprocation and ultrasonic on sealer activation. The discrepancy may be due to the methodological differences between both researches in master apical preparation, taper, fluorescent dye and the teeth type included in the study. However, very little research studied the effect of reciprocating motion for sealer activation on its penetration depth.

The lower penetration depth of the sealer when using ultrasonic Irrisafe for sealer activation may be due to the same causes for the limited irrigant activation power of the ultrasonics. The size of the tip (25/.02), might be very small for this larger canal preparation (40/.04). That doesn’t allow for contact between the US Irrisafe tip and the canal walls making the sealer less dispensable into the dentinal tubules [98]. Also, the power used might be produced heat that decreases the setting time and flowability of the sealer [99]. In contrary to current results, **De Bem et al.**

[63], found high penetration of two bioceramic sealers when activated ultrasonically. This may be attributed to the difference in activation time they used which is 40 Sec and the power setting which is 5. While other study explained the higher intratubular penetration of the sealers by the heat produced during ultrasonic reduces the sealer viscosity and promotes flowability [100]. Tooth type, canal shape, taper and apical diameter may have impact on the depth of penetration [101,102].

While the sealer activation with Neo-EF in rotating motion showed a lower depth of penetration of the sealer which may be due to the speed of the file which adjusted to be 600 rpm with a torque equal 0.5 Ncm. In the same frame, **Paragliola et al.** [103] found the plastic file in continuous rotation have a lower rank than ultrasonic activation method with non-difference between them in the agitation of irrigants. In conversely, **Duque et al.** [104] found rotation is more efficient than reciprocating motion for the speed of rotation and degree of reciprocating angle during activation of irrigant solutions likely make a difference between the research.

On the base of the root level, the highest penetration power of the sealer is at the coronal level and it decreases in an apical direction which may be attributed to the anatomical consideration at each level of the root canal in concomitant with increasing in the inaccessible areas toward the apical level. Similarly, a study showed the highest densities are at the coronal and middle levels than the apical level [105,106]. The apical portion is a less permeable areas of the tooth with irregular dentin direction, less smear layer removal, and a higher frequency of sclerotic dentin [107,108]. Also, a study found that XPF showed a higher penetration depth of the sealer at levels close to the canal wall than that at the outer surface of the root [75]. Based on the results of current study, the null hypothesis is rejected as there is variability in the depth of penetration of the sealer among the tested groups. That opens the door towards future recommendations in that field.

The limitation of current study staining of sealer using fluorescent dye, such as Rhodamine B leached from sealer investigated which passively infiltrate the dentinal tubules. However, a study evaluated dentinal tubule penetration of calcium silicate-based sealer under CLSM which used Fluo-3 dye and concluded that Rhodamine B dye has a lower affinity for the calcium in the sealer composition compared to the Fluo-3 [109].

7. SUMMARY

Three-dimensional obturation of the root canal system is the final objective of root canal therapy. Sealer penetration refers to the ability of endodontic sealers to flow into and fill the intricate network of root canal spaces, including the tiny accessory canals and lateral branches that may not be fully accessible with just gutta-percha alone. The penetration of sealer into dentinal tubules is considered to be a desirable outcome as it can entomb any residual bacteria within the tubules and improve mechanical locking.

Fifty mandibular premolars were selected according to inclusion criteria and then prepared until master apical file #40.04. The teeth were assigned into five groups according to the method of sealer activation, group 1: no activation, group 2: XP-endo Finisher, group 3: Irrisafe ultrasonic tip, group 4: Neo Endo finisher in reciprocating motion, and group 5: Neo endo finisher in rotating motion. Samples were obturated using TotalFill BC sealer HiFlow labelled with rhodamine B dye for evaluation under confocal laser scanning microscope. The samples were sectioned horizontally into three slices at 3, 6, and 9 mm (apical, middle, and coronal) depths from the apex.

The results showed that the activation of sealer by XP-endo Finisher showed the highest mean sealer penetration percentage with non-significant from Neo-EF in reciprocation technique. There was no difference between ultrasonic Irrisafe activation and Neo-EF in rotating motion groups. The control group showed the lowest mean sealer penetration percentage. With regard to root level, the coronal level showed the highest mean sealer penetration percentage followed by the middle root level. The apical root level showed the lowest mean sealer penetration percentage.

8. CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1- Activation of bioceramic root canal sealer enhances its penetration power into the dentinal tubules.

2- XP-endo Finisher has a positive impact on the penetration power of bioceramic root canal sealer.

3- Using Plastic Neo endo finishing file in reciprocating motion increase the penetration power of bioceramic root canal sealer.

4- Th sealer penetration power increases in apico-coronal direction along the length of the root canal.

9. RECOMMENDATIONS

1- Further research should be done using new methods of sealer activation to improve adaptation between the root canal sealer and the canal wall.

2- Further research should be done using other types of fluorescent dyes like Fluo-3.

3- Further research should be done to evaluate the effect of different instrumentation techniques on the depth of penetration of bioceramic sealers.

4- Further research should be done to evaluate the effect of different nano particles irrigating solutions on the depth of penetration of bioceramic sealers.

5- Further research should be done to evaluate the effect of different obturation techniques on the depth of penetration of bioceramic sealers.

6- Further research should be done to evaluate ultrasonic activation penetration power at different time of activation.

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الملخص العربى

إن سد قناة الجذر ثلاثي الأبعاد هو الهدف النهائي لعلاج قناة الجذر. يشير اختراق المادة المانعة للتسرب إلى قدرة المواد المانعة للتسرب في علاج لب الأسنان على التدفق وملء الشبكة المعقدة من فراغات قناة الجذر، بما في ذلك القنوات الملحقة الصغيرة والفروع الجانبية التي قد لا يمكن الوصول إليها بالكامل باستخدام مادة الجوتا بيرشا وحدها. يعتبر اختراق المادة المانعة للتسرب في الأنابيب العاجية نتيجة مرغوبة حيث يمكنها دفن أي بكتيريا متبقية داخل الأنابيب وتحسين القفل الميكانيكي.

تم اختيار خمسين من الضواحك السفلية وفقًا لمعايير الاشتمال ثم تم تحضير القنوات حتى الملف القمي الرئيسي رقم ٠٤/٤٠ وبعد ذلك تم تقسيم الأسنان إلى خمس مجموعات وفقًا لطريقة تنشيط حشو القنوات، المجموعة ١: لا يوجد تنشيط، المجموعة ٢: الاكس بي اندو فنشر، المجموعة ٣: بالموجات فوق الصوتية ايري سيف، المجموعة ٤: نيو إندو فنشر في الحركة التبادلية، والمجموعة ٥ : نيو إندو فنشر في حركة دورانية. تم حشو العينات باستخدام مانع التسرب توتال هاي فلو المتصبغ بصبغة رودامين بي للفحص تحت مجهر المسح بالليزر متحد البؤر. تم تقسيم العينات أفقيًا إلى ثلاث شرائح بأعماق ٣ و٦ و٩ مم (قمي ومتوسط وإكليلي) من ذروة السن.

أظهرت النتائج أن الاكس بي اندو فنشر أظهر أعلى متوسط نسبة اختراق للمادة المانعة للتسرب مع عدم وجود أهمية من تقنية المعاملة بالمثل. لم يكن هناك فرق بين التنشيط بالموجات فوق الصوتية، والدوران. أظهرت المجموعة الضابطة أقل متوسط لنسبة اختراق مادة السداد. وفيما يتعلق بمستوى الجذور، أظهر المستوى الإكليلي أعلى متوسط لنسبة اختراق السدادات. أظهر مستوى الجذر الأوسط قيمة متوسطة أقل. أظهر مستوى الجذر القمي أقل متوسط لنسبة اختراق السداد.

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تأثير طرق التنشيط المختلفة للاصق السيراميك الحيوى على عمق إختراق لاصق قناة الجذر

(دراسة خارج الجسم الحي)

رسالة مقدمة كجزء من مقومات الحصول على درجة الماجيستير في تخصص علاج الجذور

مقدمة من

الطبيب / عمر عبد العزيز أحمد إمام

بكالوريوس طب وجراحة الفم والأسنان (٢٠١٤ م) - كلية طب الأسنان- بنين- القاهرة
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جامعة الأزهر

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