**A Non -Invasive Evaluation of the Remaining Dentin Thickness and Time Needed to Remove Fiber Post Using Guided Template**

A thesis submitted in partial fulfillment of the requirements for a master's degree in Endodontics

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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 " آية 32 "

# Dedication

*To my family*

-*My father, my wife, my sister, my brother, and my sons. I am grateful for their love, support, encouragement, and, above all, their prayers.*

-*My Mother, you are my inspiration and my destiny. Allah has mercy on you.*

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# List of abbreviations

| No. | Abbreviations | Meanings |
|---|---|---|
| 1 | CBCT | Cone beam computed tomography |
| 2 | DOM | Dental operating microscope |
| 3 | (Er:YAG) | Erbium: yttrium-aluminum-garnet |
| 4 | (Er,Cr:YSGG) | Erbium, chromium: yttrium-scandium-gallium-garnet |
| 5 | Ncm | Newton centimeter |
| 6 | Rpm | Rotation per minute |
| 7 | RDT | Remaining dentin thickness |
| 8 | CAD-CAM | Computer-aided design - computer-aided manufacturing |
| 9 | DNS | Dynamic Navigation System |
| 10 | STL | Surface tessellation language files |
| 11 | DICOM | Digital Imaging and Communication |
| 12 | Micro-CT | Micro Computed Tomography |
| 13 | SEM | Scanning Electron Microscope |
| 14 | CT | Computed tomography |
| 15 | NaOCl | Sodium hypochlorite |
| 16 | EDTA | Ethylenediaminetetraacetic acid |

## 1. Introduction

Restoration of endodontically treated teeth may be a complex procedure because of extensive loss of dental structure, typically restored with endodontic posts when the tooth structure does not adequately retain the restoration[1,2]. Intraradicular posts are commonly used to gain additional retention and adequate support when the remaining coronal tissue can no longer provide it[3,4].

Dental posts may be made of metallic or non-metallic materials. The non-metallic posts may be adhesive-bonded glass, carbon, or quartz fiber. However, these adhesive posts may require removal because of fracture prosthetic problems or endodontic treatment failure[4,5]. These posts adhere chemically to the root dentin; therefore, unlike metal posts, they cannot be removed by breaking up the cement layer between the fiber post and the root dentinal wall[6]. Moreover, the color closely resembles root dentin[7]. Thus, clinicians must drill through the fiber post to remove it and reach the apical area.

Several devices and techniques were available and have been proposed for the removal of different types of posts(8), including ultrasonic, reamers, drill kits, and laser[1,9,10,11]. However, one potential shortcoming of such ultrasonic treatment is the production of heat[12]. Unfortunately, the application of vibration energy for more than 15 seconds may generate a significant temperature increase at the root surface even when higher temperatures are recorded at the post surface than at the root surface(13); this temperature increase could be dangerous to periodontal ligaments and alveolar bone[12,14].

Alternatively, the traditional way of fiber post-removal using drills may lead to root perforation, crack propagation, severe deviations from the root axis, or even root fracture[2,15]. A new technique of post-removal has been developed based on micro-guided endodontics to overcome the disadvantages of the traditional ways of post-removal[16,17,18]. The concept of guided endodontics is to increase the accuracy of the procedure and reduce the potential iatrogenic using cone-beam computed tomography (CBCT) prior to the procedure and the planning of a 3D printed guide during penetration[19,20,21]. This procedure may save the removal time and prevent unnecessary loss of the surrounding root dentin[22,23]. It may also increase the accuracy of the fiber post removal[24,25].

## 2. Review of literature

**<u>Section outline:</u>**

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## 2.1 Reinforcement of endodontically treated teeth.

Endodontic treatment covers all aspects of the repair and treatment of a tooth in which the pulp has been either damaged or exposed, as well as the treatment of peri-apical tissues(25). There are different challenges in restoring the anterior and posterior dentition. The posterior dentition undergoes much higher forces when eating and chewing and is more susceptible to fracture. Anterior teeth are less prone to fracture, but the aesthetic demand is more significant from a patient's perspective(26).

### 2.1.1 Historical.

Because it determines the tooth's long-term prognosis, restoring the endodontically treated tooth is crucial during treatment planning. As a result of past restorations, endodontic access preparation, trauma, and dental caries, the pulpless tooth is typically accompanied by a significant loss of coronal and radicular tooth structure. It is universally believed that this loss of hard tissue results in a decreased endodontically treated tooth's ability to transport stresses. Posts are therefore advised for endodontically treated teeth that are very brittle due to poor coronal tooth structure.

Two major categories of posts exist:

- Custom-made post.
- Prefabricated posts are usually made of
  1- Stainless steel, chromium, or titanium alloy.
  2- The fiber-reinforced polymer posts are also a newer type of prefabricated posts(26).

Historically, casted posts have been the standard for many years and are still used by many clinicians[27]. However, it became less popular due to the extra appointments required and the extra laboratory fees. Moreover, it faces some limitations in restoring anterior esthetic areas[28]. Therefore, prefabricated fiber posts became more popular in teeth restoration in esthetic zones[26].

The idea that the placement of a post does not reinforce a tooth is prevalent and remains debatable. However, this concept was challenged in two recent studies: a two-year and a three-year randomized clinical trial on endodontic-treated premolars restored with crowns and fiber posts reported an increased probability of survival[30, 31].

### 2.1.2 Fiber-reinforced posts.

In 1990, **Duret et al**[31]. introduced a carbon fiber post as one of the several prefabricated fiber post-and-core systems to lower the post-retained restored tooth failure rate. These relatively recent posts have a unique quality known as "anisotropic behavior," in which the substance has distinctive physical properties when loaded in various orientations. They are made of uniformly spaced carbon fibers bonded to an epoxy resin matrix. This property may significantly lower the risk of root fracture and de-cementation, making it relevant to clinical settings.

The goal is to develop a "cement-post-core" system that resembles tooth tissues physically and has uniform qualities. Additionally, quartz and glass fiber posts encased in a resin matrix have been created to meet aesthetic standards. Additionally, restoring endodontically treated teeth with metal-free materials, physiochemically homogenous, and physical qualities comparable to dentin has become a top priority in dentistry. A glass fiber reinforced post's improved light transmission through the root and surrounding gingival tissues provides an aesthetic benefit. Additionally, fiber-reinforced posts avoid the corrosive reaction problems that prefabricated metal alloy posts could have(32).

A recent literature review on clinical studies of fiber posts reported that fiber-reinforced composite posts outperform metal posts in the restoration of endodontic treated teeth; however, the evidence cannot be considered conclusive(33). Fiber post proper elastic modulus, outstanding aesthetic performance, and good bonding characteristics ensure a firm bond with dentin but also increase the difficulty of removal; however, their reduction is achieved by trophing through the post without any additional removal of root or crown dentin(26).

## 2.2 Methods of fiber post-removal.

Many devices and techniques have been described to remove fiber posts. These include ultrasonics, sonics, round burs, drills, and lasers. Recently, with the gradual development of "Guided Endodontics," dynamic navigation systems and static guide technology have also been used to remove fiber posts to avoid unnecessary tooth structure removal(34).

Ultrasonics is highly effective when attempting to remove posts. The post must be separated from the core, ensuring the margins are undermined and any obvious cement lute removed(35). The ultrasonic tip can be applied to the post head and vibrated out by grinding the fiber post with special tips(35). The clinician should always endeavor to work at the lowest power setting with coolant that will efficiently and safely accomplish the task and the ultrasonic device set in endodontic mode. After finishing the fiber post removal, the selected ultrasonic instrument is moved circumferentially inside the root wall to ensure no remnants of cement lute are present(34).

Removal of the fiber post is generally specific to the post system, with different manufacturers supplying different removal drills. A pilot hole must often be created, followed by drilling through the entire post using increasing diameter drills. When hollowing through the post, the removal drills must be orientated centrally to reduce the risk of possible perforation or initiation of vertical fractures(38,20).

Lasers have recently been suggested as an alternative to removing fiber posts, leaving the adjacent dentinal walls almost intact and generating relatively low heat compared to ultrasonic treatments. More specifically, erbium lasers include erbium: yttrium-aluminum-garnet (Er:YAG), which emits at 2940 nm, and erbium, chromium: yttrium-scandium-gallium-garnet(Er,Cr:YSGG), which emits at 2780 nm. Both erbium wavelengths have the advantage of very high absorption coefficients to water compared to the other laser wavelengths (1200 $mm^{-1}$ for Er:YAG and 400 $mm^{-1}$ for Er,Cr:YSGG)(10).

**Abe et al.**(37) in 2014 evaluated the efficiency and effectiveness of three glass fiber post-removal techniques on 45 maxillary teeth that were endodontically treated and cross-sectioned in thirds. The presence of cementing agent and dental structure wear was assessed by analyzing images taken before the luting of the glass fiber post and after the removal procedure. Teeth were divided into three groups: group 1 diamond bur + Largo reamer group, group 2 ultrasonic insert group, and group 3 carbide bur + ultrasonic insert group. Time spent on removal procedures, dental structure wear, and amount of remaining cement agent were recorded. The carbide bur + ultrasonic insert group presented the most effective removal of glass fiber posts. They concluded that there was no significant difference in efficiency among the evaluated techniques.

**Rayyan et al.**[38] in 2014 compared the efficiency (time needed) and the effectiveness (residual material) of four different fiber post-removal techniques according to a 6-degree scale. Fiber posts were cemented using Gradia Core into 36 maxillary first molar teeth after completion of endodontic therapy and post-space preparation. The teeth were divided into four groups according to the technique of post removal: Largo reamers group A, Roane Gates Glidden drills group B, Needle bur group C and Thermail Post Space Bur group D. Results: There was no significant difference degrading the efficiency to remove fiber post using either technique. In contrast, group B scored the longest mean removal time. They concluded that none of the techniques used was significantly effective or efficient in removing fiber posts.

**Capriotti et al.**[14] in 2018 evaluated the temperature changes generated on the radicular surface of extracted Forty single-rooted teeth during ultrasonic removal of fiber post. The teeth were divided into two groups according to the type of fiber post used: the first group received quartz fiber posts D.T. Light Post, and the second group cemented silica fiber post-TECHOLE S with a central hole. The removal technique was performed with microblade ultrasonic tips, particularly Start-X #3. The operative protocol provided a succession of dry use of ultrasonic inserts for 25 s, air cooling for 25 s, and water cooling for 25 s until posts entire removal. Thermographic measurements were recorded, taking photographs and videos using Thermal Imaging Camera FLIR-One. Results show that dry use rapidly increases root surface temperature beyond the critical limit, while both air and water cooling decrease it to a lower value for both groups. They concluded that in the case of endodontic retreatment, it would be preferable to use ultrasonic inserts with ‘‘waterport’’ because, among the many advantages, it would effectively lower the temperature on the tip and the work area, safeguarding the health of the tooth-ligament-alveolar bone complex.

**Deeb et al.**[9] in 2019 compared the times and temperatures used to remove a glass fiber post from endodontically treated teeth using Er:YAG compared to the conventional endodontic ultrasonic method. They included thirty-four single-root human extracted teeth that were endodontic treated ex vivo. The post space was prepared to be 7 mm deep, and an 11.4 mm glass fiber post was cemented using composite resin cement. The temperature on the external surface of the root was measured at the coronal, middle, and apical third portions during the laser or ultrasonic applications from 1 to 10 minutes. The specimen surfaces were examined using scanning electron microscopy (SEM). Fifteen specimens were tested in each group. Significant differences existed between temperatures for each treatment. SEM examination showed no visible damage caused by Er:YAG laser treatment. They concluded that Er:YAG laser can remove posts up to 5 times faster than the ultrasonic removal method. The laser causes a lower temperature to increase at the root surface than ultrasonic removal. Er:YAG may be considered a viable alternative to sonication for post-removal.

**Cho et al.**[39] in 2021 compared the post-space volume changes following the removal of glass fiber posts in endodontic treated teeth by using Er,Cr:YSGG laser to the conventional ultrasonic method. They included twelve single-root human extracted teeth cut into 13 mm near the cementoenamel junction (CEJ) and underwent endodontic treatment. Glass fiber posts were inserted with self-curing resin cement. Post-space volumes were measured using microcomputed tomography (micro-CT) before post-cementation and post-removal. Dentin thickness was measured after post-removal at the coronal, middle, and apical third of the root canal space. There was no significant difference between the laser and ultrasonic groups regarding post-space volume changes. Both methods showed a significant volume increase following post-removal. Significantly less dentin was lost when the laser was used for post-removal in the coronal portion of the post space. They concluded that Er,Cr:YSGG laser can be a practical option when removing posts in endodontic treated teeth, comparable to the conventional ultrasonic method. Laser has the potential to provide conservative post-removal.

**Satish Nesari et al.**(40) in 2022 evaluated the efficiency and the effectiveness of fiber post-removal using three techniques, i.e., with a Parapost fiber removal drill kit, D.T Light removal kit, and a combination of diamond bur/Peeso reamer on 60 extracted single-rooted teeth. They observed that the three subgroups did not differ significantly in average removal time. Also, there was no significant difference between the two removal kits and the diamond bur/Peeso reamer combination regarding efficiency for removing fiber posts. They concluded that no difference was reported between the three post-removal systems.

**Özcan et al.**(11) in 2022 evaluated the efficiency of Er:YAG laser in translucent fiber post-removal. They included 60 human single-rooted anterior teeth divided into three groups (n = 20) according to post diameters (Exacto1-E1, Exacto2-E2, Exacto3-E3) and subdivided according to laser application. Fiber posts were cemented to endodontic treated teeth, and the specimens were sliced with a 1.0 ± 0.2 mm thickness. Er:YAG laser was applied, and the push-out bond strength test was performed. They found that push-out bond strengths at the apical area were significantly lower in all test groups. Laser application caused an increase in all radicular thirds, but it was significant for E1 and E3 groups. They concluded that laser application to the post-dentin interface enhances the connection between post and dentin.

## 2.3 Iatrogenic errors during fiber post-removal methods:

Fiber Post removal can be difficult for clinicians, and removing fiber posts from root canals can be dangerous. This is mainly due to the color similarity between the root dentin and the fiber posts. Therefore, procedural errors such as unnecessary removal of sound root dentin, deviations from the root axis, microcracks, perforation, ledge, and root fracture are common iatrogenic mishaps. These errors can worsen the prognosis and jeopardize the success of endodontic retreatment(41).

**Dominici et al.**(12) in 2005 measured the temperature of the root surface and post during the application of ultrasonic vibration to cemented posts to simulate the post-removal procedure. They performed root canal therapy on ten extracted maxillary incisors. A stainless steel Parapost was cemented into each prepared post space. They applied ultrasonic vibration to the post and recorded temperatures at the coronal post and the cervical root surface. They observed a more significant temperature increase at the post than at the root surface. They concluded that ultrasonic application to the post for longer than 15 s generates high temperature on the root surface.

**Aydemir et al.**(1) in 2018 compared two fiber post-removal techniques in terms of fracture resistance and time required for post-removal. They prepared post space to a 9-mm depth in each root canal. The roots were randomly divided into three groups of 15 specimens each. D.T. Light-Posts were cemented in all groups. In group 1, fiber posts were removed using the D.T. Light-Post-removal kit; in group 2, Start-X stainless-steel ultrasonic tips were used. In group 3, fiber posts were left without removal (the control group). The fracture resistance (N) value was measured and recorded using a universal testing machine for all groups. There was no significant difference between the control and removal kit groups for fracture resistance values. The fracture resistance value of the ultrasonic group was significantly lower than that of the control group and the removal kit group. The fiber post-removal time for the ultrasonic group was significantly longer than that for the removal kit group. They concluded that, compared to the removal kit, removing fiber posts with an ultrasonic tip decreases the fracture resistance of the roots, although significantly more time is required.

**Haupt et al.**[8] in 2018 evaluated different techniques for removing fiber posts from root canals in an in vitro study on 153 extracted single-rooted teeth. Teeth were de-coronated, root-canal treated, and divided into three groups (n = 51). Post spaces were prepared for different fiber posts: glass fiber, quartz fiber, and carbon fiber. Each group was divided into three subgroups regarding the post-removal technique (n = 17): SonicFlex Endo, long-shaft round bur, and DT-Post removal kit. They assessed the residual material, loss of dentin, working time, and procedural errors using computed tomography. The highest effectiveness was achieved with the sonic tip and the round bur. A high prevalence of perforations or severe deviations from the root axis was observed for all groups. They concluded that no technique presented favourable results in all assessed parameters. There is a high risk of perforations.

### 2.4 prevention of iatrogenic errors during fiber post-removal:

Clinicians can use the information obtained from 3D CBCT scans to reduce errors. They were developing technology that allows practitioners to remove a fiber post and retreat endodontic disease efficiently and conservatively. The most current technologies introduced and hypothesized to overcome procedural errors that can occur during post-removal are the Guided Endodontic template and Dynamic Navigation System (DNS)[42].

**Maia et al.**[2] in 2019 described a protocol for adhesive fiber post-removal using a prototyped endodontic guide. Computer-aided design and computer-aided manufacturing (CAD-CAM) technology was used to generate guides with prototyping and is a valuable tool for fiber post-removal. They reported that combining intraoral scanning associated with a prototyped endodontic guide is a promising option that is straightforward to execute and offers a safe procedure, avoiding radicular structure reduction, crack propagation, root axis deviation, and perforation.

Current research by **Tobin et al.**[21] in 2022 suggests an emerging value of 3D printed guides used in the endodontic field. Computer-aided design and manufacturing technologies can create 3D-printed guides with endodontic clinical applications. Guided endodontics is a term that has gained popularity and involves 3D planning, 3D models, and 3D printed guides. The review aimed to assess all current applications of 3D guide usage in endodontics, determine when 3D guide use is effective in clinical endodontic settings, evaluate the possible incorporation of 3D guides in the didactic endodontics setting, and analyze the future of this technology. A total of 75 published papers were included. These studies show that 3D printing in endodontics opens the door to promising techniques with highly predictable outcomes and a low risk of iatrogenic damage, especially in complex cases.

CBCT allows endodontists and medical professionals alike to develop 3D diagnostic images that are higher quality and more detailed compared to the 2D images created by traditional X-rays[43]. Cone beam imaging is more accurate than 2D imaging due to its process's ability to reduce scatter radiation[44]. A single CBCT scan can develop various views and capture images of a patient's bone and soft skin tissue[45]. The cone beam scan process is non-invasive, pain-free, and safe for patients, using the lowest radiation dose necessary to create an image quality adequate for accurate diagnosis[48,49,50,48].

**Lo Giudice et al.**[49] in 2018 evaluated the accuracy of CBCT compared to conventional intraoral radiographs used in endodontic procedures. One hundred one patients were included with previous endodontic treatments with the relative radiographic documentation (preoperative, postoperative, and follow-up intraoral X-ray) that had undergone CBCT screening for surgical reasons. Two operators evaluated The CBCT scans independently and compared them with the corresponding periapical images. They found that the two radiological investigations statistically agree in 100% of cases in the group of patients without any endodontic sign. In the group of patients with an endodontic pathology detected with CBCT, endodontic under extended treatments (30.6%), MB2 canals in nontreated maxillary molars (20.7%), second canals in nontreated mandibular incisors (9%), root fractures (2.7%), and root resorption (2.7%) were not always visible in intraoral X-ray. Otherwise, positivity in the intraoral X-ray was always confirmed in CBCT. A radiolucent area was detected in the CBCT exam in 46%, while the intraoral X-ray exam was positive only in 18%. They concluded that some critical radiological signs acquired using CBCT are not always visible in periapical X-rays. Furthermore, CBCT is considered a second-level exam and could be used to solve diagnostic questions essential to adequately managing endodontic problems.

**Alfadda et al.**[50] in 2022 described the usefulness of an endodontic template for removing a fiber post in a case report. A 40-year-old man presented with discomfort in the maxillary left canine. Clinical and radiographic examinations showed the tooth with a permanent core material retained with fiber post and a persistent apical radiolucency. Among the various treatment modalities, non-surgical root canal retreatment with fiber post-removal was proposed using a conservative, fully guided approach. After obtaining the CBCT images and the cast surface scan, their data were merged using implant planning software and superimposed. The drilling space was planned based on the fiber post's location, diameter, and apical extent. It was virtually overlapped and transferred clinically using a resin template to drill through the fiber post. With guides in position over the rubber dam, drilling was made with increments of 2 mm using a size four long shank round bur until it exposed the coronal gutta-percha. When the canal was located, K3 rotary files were used along with chloroform to remove the old obturating materials. They concluded that A guided endodontics template created with virtual planning facilitated the complete removal of the fiber post with no iatrogenic errors observed and shortened treatment time. Furthermore, to produce predictable results, this approach does not necessitate specialized training or extensive clinical experience(51).

## 2.5 Methods of evaluation:

### 2.5.1 Evaluation of the remaining dentin thickness.

The remaining dentin thickness (RDT) is essential as it gives resistance to the fracture of root canal-treated teeth. As retreatment requires more mechanical manipulations and further preparations of the root canal, some recent studies expressed concern about the damage caused to the root canal wall after these procedures. Thus, instruments with newer designs have been introduced to minimize damage to root dentin and improve working safety(52).

Various methods were employed to assess RDT following retreatment; however, CBCT, a non-destructive technique, has been advocated that provides highly accurate, high-resolution, fully quantifiable three-dimensional images. Thus acknowledging the importance of preserving the remaining dentinal wall by properly using various instrument systems(54,55,56,57).

**Bramante et al.**(57) in 1987 proposed to superimpose photographs of the root canal diameter before and after instrumentation to determine the changes in the amount of dentin removed during endodontic treatment and measure the deviations between the two contours. The centering factor method of measuring dentin thickness before and after treatment can quantify postoperative deviation in the root canal diameter. This method can evaluate the circular removal of root dentin and the frequency of isthmuses. The change in the canal volume after preparation is associated with instrumental and medical treatment. After treatment, the increase in the volume of the internal lumen of the canal is proportionally higher in the coronal and middle third than in the apical one; this is because of the taper, the instruments used, and the application of force during preparation. Clinically, an increase in root canal volume in the coronal and middle third allows for more efficient irrigation of the apical part, but at the same time, suggests that apical mechanical debridement is not as adequate as coronal debridement(58).

**Mangal et al.**(55) in 2018 evaluated, using CBCT, RDT following rotary instrumentation and post-space preparation in buccal and palatal roots of maxillary first premolars. They selected 23 maxillary first premolars with two roots. CBCT images were taken preoperatively, after instrumentation and Parapost 3 and 4 preparations. RDT was measured 5 mm above the apex, 1 mm below furcation, and 1 mm above furcation (Levels 1, 2, and 3). They reported that rotary instrumentation and post-space preparation reduced RDT in all walls of buccal and palatal roots. Post-space preparation with Parapost 3 and 4 reduced RDT in the palatal wall of the buccal root to <1 mm, and Parapost 4 reduced all walls to 1 mm of dentin. They concluded that post-space preparation in maxillary first premolars should be performed cautiously. It is safer to place a post in the palatal root of this tooth and limit preparation to Parapost 3.

**Shaikh et al.**(59) in 2018 aimed in their study to direct linear measurement of dentin thickness and dentin volume changes for post-space preparation with CBCT. They scanned ten maxillary central incisors, before and after the root canal and post-space preparation, with Orthophos XG three-dimensional hybrid unit. Using a proprietary measuring tool, they measured 13 axial section scans of each tooth from orifice to apex and dentin thickness for buccal, lingual, mesial, and distal. They evaluated dentin volume using ITK-SNAP software. They found a significant difference between the dentin thickness pre- and post-instrumentation and between groups. In the shortest post length of 4.5mm, the post-space preparation resulted in a 2.17% loss of hard tissue volume, whereas the 11mm longest post-length post-space preparation resulted in >40% loss of hard tissue volume. They concluded that a CBCT axial section scan for direct measurements of root dentin thickness could be a guideline before and after post-space preparation for selecting drill length and diameter.

**Eldemery et al.**(60) in 2021 compared the radicular dentin thickness in 40 roots of extracted mandibular primary molars before and after instrumentation by manual stainless-steel (K-files) versus rotary files (AF™ Baby File) at coronal, middle, and apical thirds using CBCT. They were divided into two groups. K-files prepared the manual group, and the rotary AF™ Baby File system prepared the rotary group. Samples were subjected to CBCT scan before and after instrumentation for radicular dentin thickness evaluation at three measuring points: apical, middle, and coronal. The average amount of dentin removed was significantly higher in the manual group compared to the rotary group in the three measuring points. They concluded that rotary files could be preferable to manual files in terms of preservation of radicular dentin thickness after root canal instrumentation; therefore, rotary files can be a suitable substitute for conventional manual files.

**Souza et al.**[61] in 2023 measured the tooth root canals' diameter, remnant dentin thickness, endodontic post-to-dentin distance, and resin-matrix cement layer after three types of root canal shaping. Thirty extracted human premolars were endodontic treated, and groups of specimens were divided according to the cementation with two different endodontic posts as follows: A (Fibio Fiberglass Post™, Anthogyr, France;) B multi-filament GFRC (Rebilda GT™, VOCO, Germany). CBCT and conventional X-ray analyses were performed before and after the endodontic post-cementation. After cementation, specimens were cross-sectioned and inspected by optical and scanning electron microscopy. Changes in the shaping of the root canals caused a decrease in the thickness of the remnant tooth tissues. CBCT and microscopic analyses also revealed an evident variation of resin-matrix cement around the glass fiber-reinforced composite (GFRC) posts. A multi-filament GFRC post provided an adequate distribution of filaments, although the resin-matrix cement revealed a high volume among the filaments. An increase in thickness and volume of resin-matrix cement was noticed at the coronal third since the fitting was compromised due to tooth anatomic variations and root canal preparation. Microscopic analyses also detected defects such as macro-scale pores, cracks, and voids. They concluded that root canal shaping could promote a decrease in the thickness of the remnant tooth tissues, which can increase the risks of clinical failures by fracture[62]. The thickness and volume of resin-matrix cement varied around both GFRC posts and increased from the apex to the coronal third due to the lack of fitting.

Modern diagnostic techniques for studying the root canal system include cone CBCT and micro-CT. CBCT allows one to measure the volume of the root canal dentin and its surface area and clarify the anatomy of the root canal before and after preparation. Additionally, micro-CT makes it possible to assess the degree of the untreated canal surface in three dimensions. The remaining dentin volume could predict the success of endodontic and post-endodontic treatment[58].

### 2.5.2 Evaluation of the fiber post and resin cement residuals.

Successful endodontic retreatment requires efficient removal of the posts without leaving residual materials on the root canal walls. **Haupt, Pfitzner, and Hülsmann** [8] in 2018 reported that removal kits left more residue on the root canals than burs and sonic tips, regardless of the fiber post type. **Lindemann et al.** [63] in 2005 compared the efficiencies of a fiber post-removal system recommended by the manufacturer and ultrasonic tips. According to their study results, the removal efficiency of ultrasonic tips was better than that of the kit. However, our study showed that neither ultrasonic tips nor removal kits were able to clean the dentin walls effectively, and there was no significant difference in the amount of residue between the two groups.

**Haupt et al.**[64] in 2022 evaluated the effectiveness of different fiber post-removal techniques and correlated Dentin loss, residual luting material, working time, and the induction of microcracks. They included Forty-five extracted single-rooted teeth that were root canal treated, and fiber posts were adhesively luted. Specimens were divided into three groups (n = 15) using the removal technique: long-shaft round bur, SonicFlex Endo, and D.T. Post Removal Kit. Roots were scanned before post-cementation and after post-removal using micro-computed tomography. They found that Post removal with SonicFlex Endo resulted in the highest amount of removed dentin. No technique was found to remove the fiber post and luting material completely. All techniques induced microcracks, with the D.T. Post Removal Kit presenting the highest number of new defects. Deviations from the original root canal occurred in all groups, but no perforation was observed. They concluded that all techniques resulted in dentin loss, residual luting material, and the formation of microcracks.

**Papoulidou et al.**[10] in 2023 investigated the effectiveness of Er,Cr:YSGG laser (2780 nm) as an alternative fiber post-removal technique and compared it to an ultrasonic method using micro-CT. Fiber posts were removed from 20 endodontic treated single-rooted premolars (n = 10) using an ultrasonic vibrator with a diamond-coated ultrasonic tip (control method) or Er,Cr: YSGG laser irradiation protocol. The number of sections with newly formed microcracks, the loss of dentinal tissue, the amount of residual resin cement, and the removal time were evaluated for both methods. They found that in the laser-treated group, the parameters regarding microcracks formation and removal time (were advantageous compared to the ultrasonic-treated group. They concluded that Er,Cr:YSGG laser could be an alternative fiber post-removal technique.

### 2.5.3 Evaluation the working time for fiber post-removal

In the case of root canal retreatment, a post should be safely and efficiently removed in a less traumatic way to allow for non-surgical root canal retreatment. The capability to remove an existing post relies upon the type of material of which it is made. In many cases of fiber post removal, the clinician usually faces fiber posts of an unfamiliar source. Most removal kits will not work in these cases because the manufacturers specially prepare them. A universal fiber post-removal system would be helpful to enable fiber post-removal in such cases[65].

Non-surgical retreatment provides more favorable, long-lasting results and is preferred over endodontic surgery. However, sometimes, this procedure is complex and risky because of root weakening, perforations, and fractures of the remaining structure of the root. It may be time-consuming, and its success depends on the post type, length, design, cementing agent, operator’s skill, and chosen technique and instruments(65).

**Gesi et al.**(66) in 2003 evaluated the time needed to remove several types of fiber posts using two bur kits. Sixty extracted anterior teeth were treated endodontically. A post space with a standard depth of 10 mm was prepared for each root canal. The sample was randomly divided into three groups of 20 specimens each. Three different types of posts were cemented: group 1, Conic 6% tapered fiber posts (Ghimas); group 2, FRC Poster fiber posts (Ivoclar-Vivadent); and group 3, Composipost carbon fiber posts (RTD). To remove the post, for half of each group’s specimens, the burs from the RTD fiber posts removal kit were used (subgroup A). Posts were removed from the other half of the teeth in each group (subgroup B) using a diamond bur and a Largo bur. They found that the compositor carbon fiber posts (group 3) took significantly less time to remove than the other two types of posts. They concluded that using a diamond and a Largo bur (subgroup B) was significantly less time-consuming. The interaction between the type of post and the type of bur kit used was not significant.

**Lindemann et al.**(63) in 2005 determined the efficiency and effectiveness of several techniques for fiber post-removal. They included Four groups of 20 mandibular premolars that were endodontic treated and obturated. Post spaces were prepared for the following post systems: ParaPost XH, ParaPost Fiber White, Lucent Anchors, and Aestheti-Plus. After cementation, ten posts of each group were removed with their corresponding manufacturer’s removal kit, and the other ten were removed with diamond burs and ultrasonics. Removal times were recorded, and the teeth were sectioned vertically and microscopically analyzed for removal effectiveness based on a 0 to 5-point scale. They found that removal kits removed

Luscent Anchors fiber posts the fastest and most effectively, while Aestheti-Plus posts were removed the slowest and least. Diamonds and ultrasonics required an average of 10 additional minutes for each fiber post-system removal, yet removal effectiveness improved by half a point. These results suggest that recommended removal kits were significantly more efficient, while diamonds and ultrasonics were more effective. They concluded that subsequent ultrasonic instrumentation could enhance the removal kits to remove remaining fibers and cement.

**Anderson et al.**[(67)] in 2007 evaluated the working time (efficiency) and effectiveness of 3 different fiber post-removal systems. Fiber posts D.T. Light-Post and ParaPost FiberLux were cemented into 60 single-rooted teeth after endodontic therapy, and post-space preparation was completed. Three methods of fiber post removal were evaluated (D.T Light-Post removal kit, the Kodex twist/Tenax ParaPost fiber post removal drill kit, and a combination of diamond bur/Peeso reamer). They found that the time needed to remove either fiber post was not significantly different. For effectiveness, no difference was observed between post types. Still, effectiveness was higher with the diamond bur/Peeso reamer than with the Kodex twist/Tenax ParaPost drills, which was more effective than the D.T. Light-Post removal kit. They concluded that Fiber posts are efficiently (time) removed by all three methods studied, but the removal effectiveness is higher using the diamond bur/Peeso.

**Frazer et al.**[(68)] in 2008 evaluated the time needed to remove a glass-reinforced fiber post versus a titanium post. Forty extracted anterior teeth were mounted in acrylic blocks and then treated endodontic. They were randomly assigned to three groups. The teeth were sectioned horizontally, with the coronal portion removed. The fiber posts were cemented with resin cement, and the titanium posts were cemented with glass ionomer or resin cement. The fiber posts were removed by coring them out internally. The titanium posts were removed by creating a trough around the post and then vibrating with ultrasonic energy. The teeth were examined visually and radiographically to ensure complete removal of the post and cement. Removal time included the time to make radiographs necessary to ensure complete removal. The post-cement combination significantly affected the median rank of the removal time. The mean rank removal time of titanium posts cemented with resin cement was significantly higher than the mean rank of the other two post-cement combinations. There was no significant difference between the other two combinations. When removing a fiber post, there is no need to create a trough around the fiber post or to use ultrasonic vibration that may weaken the tooth. The canal space can be cleaned and a new post placed, or the canal can be enlarged, and additional retentive features added.

**Arukaslan and Aydemir** (69) in 2019 compared the efficiency of two different fiber post-removal systems, ultrasonic vibration and D.T. Light-Post removal kit, on 30 extracted single-rooted mandibular premolar teeth. Using micro-computed tomography, they assessed Residual material, tooth volume changes, working time, and micro-crack formation. They reported significantly more tooth root volume change in the ultrasonic group than in the removal kit group ($p < 0.05$). Fiber post-removal time for the ultrasonic group was significantly longer than that of the removal kit group ($p < 0.01$). They concluded that the D.T. Light-Post removal kit was faster and more conservative than the ultrasound.

## Aim of the study

This study aimed to evaluate the remaining dentin thickness after fiber post removal, the time needed to remove the fiber post, and the fiber post and resin cement residual remnants using different removal methods (ultrasonic, drill, and drill with guide).

The null hypothesis stated that there will be no significant difference among the tested methods used for fiber post-removal.

# 4. Materials and Methods

**4.1. Study design and ethical committee approval.**

**4.2. Sample size calculation.**

**4.3. Selection and preparation of the teeth.**

**4.4. Fabrication of the molds.**

**4.5. Access cavity preparation of the samples.**

**4.6. Root canal chemo-mechanical preparation of the samples.**

**4.7. Obturation of the samples.**

**4.8. Post-space preparation of the samples.**

**4.9. Fiber post insertion and cementation.**

**4.10. Grouping of the samples.**

**4.11. Pre-intervention CBCT scanning of the samples.**

**4.12. Designing and fabrication of the guide.**

**4.13. Removal of the Fiber posts.**

**4.14. Post-intervention CBCT scanning.**

**4.15 Methods of evaluations.**

- **4.15.1 Evaluation of the remaining dentin thickness.**
- **4.15.2 Evaluation of the fiber post and resin cement residuals.**
- **4.15.3 Evaluation the time needed for fiber posts-removal.**

**4.16 Statistical analysis of the data.**

### 4.1. Study design and Ethical committee approval.

The in vitro study is an experimental, randomized, controlled, interventional prospective study. This study was accepted by the ethical committee of the Faculty of Dental Medicine, Al Azhar University Cairo boys, with the code number (363/353/25/10/19).

### 4.2. Sample size calculation.

The sample size of 16 in each group has an 80% power to detect a difference between means of 6.02 with a significance level (alpha) of 0.05 (two-tailed) and 95% confidence intervals. In 80% (the power) of those experiments, the P value will be less than 0.05 (two-tailed), so the results will be deemed "statistically significant." In the remaining 20% of the experiments, the difference between means will be deemed "not statistically significant[8].

### 4.3. Selection and preparation of the teeth.

A total of recently extracted 65 human mandibular molar teeth were collected from the outpatient clinic of the Oral Surgery Department, Faculty of Dental Medicine, Al-Azhar University. The selected teeth were cleaned from any hard deposits using an ultrasonic scaler (Guilin Woodpecker Medical Instrument Company, Guangxi, China); the teeth were then immersed in 2.5% sodium hypochlorite (NaOCl) (Clorox, Egyptian company for household bleach, Cairo, Egypt) for 30 minutes for disinfection, followed by scraping using a periodontal curette (Gracey curette, LM-Dental™, Finland) to disinfect and remove any soft tissue debris that remained on the root surface.

The teeth were examined under a dental operating microscope (DOM) (OMS2350 Dental Microscope, Zumax Medical Company, Jiangsa, China) at 8x magnification to exclude any teeth that had any external defects like root resorption, fractures, or root caries. Then, the teeth were examined radiographically from buccolingual and mesiodistal directions using a digital intraoral sensor (New IDA, Dabi Atlante, Brazil), size 2, to detect the number of distal root canals. Teeth were selected according to the following inclusion criteria:

- Teeth extracted from patients with an age range from 18 to 40 years old.
- Teeth with mature apices.
- Teeth with straight roots (0-10$^{o}$).
- Distal root with type I canal configuration according to Vertucci's classification[70].
- Teeth with average length (18-20 mm)

Teeth that did not meet the inclusion criteria were excluded from the study, including:

- Teeth with root Caries.
- Teeth with root resorption.
- Teeth with root fractures or cracks.
- Teeth with immature apex.
- Teeth with calcified root canals and pulp stones.
- Teeth with more than one distal root canal.
- Teeth with an average length of more than (20 mm) or less than (18 mm).

Out of 65 collected teeth,48 mandibular first molars were included in this study. The teeth were stored in normal saline solution (0.9%) (Egypt Otsuka Pharmaceutical Co., S.A.E.10th of Ramadan city, A.R.E) till the time of use in the study.

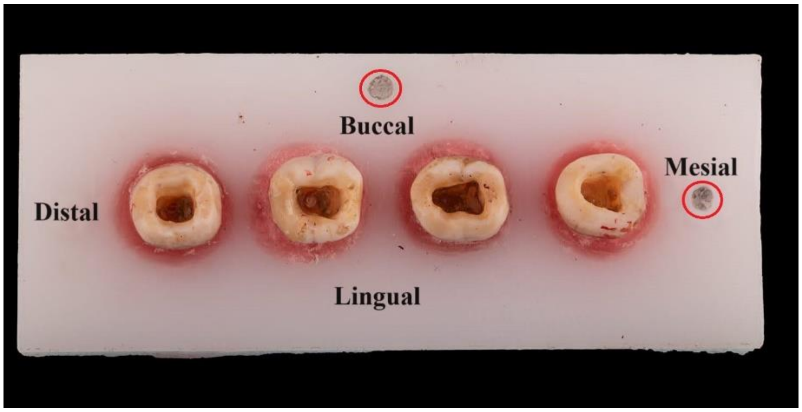
**4.4. Fabrication of the molds.**

Twelve rectangular plastic molds were constructed (85 mm x 35 mm in diameter and 12 mm in thickness) containing four rounded holes (12 mm in diameter and 12 mm in height). The sides of the mold were marked according to the root surfaces as buccal, lingual, mesial, distal, cervical, and apical sides. Two box-shaped cavities were made on the mesial and buccal sides of the mold and were filled with amalgam.

The roots of each sample were painted with two successive layers of colored nail polish (Yolo, Yolo Cosmetics, Cairo, Egypt). Following the placement of the mold on a glass slab (10 X 10 cm), each hole was filled with softened pink wax (El-Kods Wax Company, El-Mansoura, Egypt). The Wax was softened by a laboratory wax heater (Wax Heater Pot 4; DENSHINE) and heated for 5 minutes at 58 °C to produce a flowable consistency. Each sample was embedded in the softened wax till the level of cementoenamel junction (CEJ) while maintaining each surface of the sample in the same position as the corresponding surfaces on the mold (buccal, lingual, mesial, and distal) and the apices of the teeth's roots were visible (fig. 1).

**a**

**b**




**c**

**Figure (1): A photograph showing the plastic mold a) plastic mold empty b) teeth inside plastic mold pre-operative c) teeth inside plastic mold post-operative (red circle around identify dot)**

### 4.5. Access cavity preparation of the samples.

Traditional access cavity was carried out for all samples. Initial penetration and deroofing of the samples were done using a size #3 round bur (Mani carbide bur, 001/012, Mani Inc., Togichi, Japan) mounted on a high-speed handpiece (T3 turbine, T3 mini, Dentsply Sirona, Bensheim, Germany) with water coolant applied at the level of the central fossa. Initial exploration of the root canal orifices was done using No. DG16 endodontic explorer (DG16, Kerr Company, USA). Then, the access cavity walls were finished using Endo-Z bur (Dentsply Maillefer, Ballaigue, Switzerland) . Finally, wall refining of the pulp chamber was done using an ultrasonic wall refining tip (E3D, Guilin Woodpecker Medical Instrument Company, Guangxi, China).

Irrigation of the pulp chamber using 2 ml of 5.25% NaOCl using a 30-gauge double-side-vented irrigation needle (NaviTip needle, Ultradent Products Inc., South Jordan, UT, USA.) mounted on Luer-lock 3 ml plastic syringe. The root canal orifices were explored and negotiated with K-file #8 (Mani stainless steel K-file, Mani Inc., Togichi, Japan). The resultant outline form of the access cavity was triangular, with the base directed to the mesial and the apex directed distally.

### 4.6. Root canal chemo-mechanical preparation of the samples.

Root canal preparation was carried out for all canals of all samples. A size #10 K file was inserted into each canal to achieve canal patency until the file's tip was visible at the apical foramen. The working length was determined by subtracting 1 mm from this length. Preparation was carried out with AF Blue rotary files (Fanta Dental CO., Ltd, Shangai, China) (fig. 2).

**Figure (2): A photograph showing the AF Blue rotary files kit**

These instruments were set into rotation at the speed of 350 revolutions per minute (rpm) with a rotary file handpiece powered by an electric endo motor (C-smart-7, Coxo, Foshan City, China), and the torque setting was set equivalent to 2 Ncm according to the manufacturer's instructions. The file size #17/0.12 was first used as an orifice opener and inserted slowly forward without pressure in an in-and-out pecking motion till 2/3 of the file length, and once resistance occurred, the file was removed from the canal. A file size #20/0.04 was then slowly introduced in a pecking motion to full working length. File size #25/0.04 was introduced in a pecking motion without pressure to full working length. A file size #30/0.04 was a master apical file used in a pecking motion to full working length.

During instrumentation, irrigation was done after each file using 3 mL of NaOCl alternated with 17% ethylenediaminetetraacetic acid (EDTA) (MD-Cleanser, Meta Bio-med, Chungcheongbuk-do, South Korea) for all root canals of all samples. The irrigant delivery rate was set to 1 ml/min. The irrigant solution was delivered using a 30-gauge double-side-vented irrigation needle mounted on a Luer-lock 3 ml plastic syringe placed 2 mm short of the working length. After complete preparation, the root canals were rinsed with 3 ml of normal saline (Egypt Otsuka

Pharmaceutical Company, 10th of Ramadan City, Egypt) as a final rinse to stop the action of EDTA.

**4.7. Obturation of the samples.**

After cleaning and shaping all canals, the root canals were obturated using lateral compacton technique. The canals were dried with paper points size #30/0.04 taper (Meta Biomed company, Korea). The master gutta-percha cone size is #30/0.04 taper (Meta Biomed company, Korea) for all canals. Radiographs were taken for master gutta-percha cones using digital intraoral sensor to confirm their length and fit in canals. A resin-based root canal sealer (Adseal, Meta Biomed Co, Cheongju, Korea) was mixed. The mixture was applied to the root canals, and then the master cone was slowly inserted into the working length.

The spreader was fit within 1 to 2 mm of the prepared length, and when introduced into the canal with the master cone in place, it would be within 2 mm of the working length. The spreader was then removed by rotating it back and forth as it was withdrawn from the canal, and an auxiliary cone was inserted in the space. The auxiliary cones were selected based on the spreader's size, the canal's size, and the position of the space created inside the canal.

A finger spreader size #30 (Mani Inc., Tochigi, Japan) was introduced between the master cone and the dentin walls to make room for the first auxiliary cone size #30/0.02 taper. The process was repeated with spreader size #25/0.02 taper and size #20/0.02 taper until there was no more room for inserting the spreader or additional auxiliary cones. Excess coronal gutta-percha was removed with a heated plugger to the level of the orifice. The pulp chamber is cleaned with cotton pellets soaked in alcohol to remove any gutta-percha or sealer residual particles.

Radiographs were taken from the buccolingual and mesiodistal directions using a digital sensor to ensure the quality of the obturation. All molds were stored at room temperature for one week on moistened gauze in a sealed container to ensure the complete setting of the sealer.

**4.8. Post-space preparation of the samples.**

A standardized post space, 14 mm deep from the tip distobuccal cusp fixed reference point. Post spaces were prepared using a drill designed for Olipost Light fiber posts with 1.2 mm diameter (Olident, Cologne, Germany) (fig. 3), leaving 4-5 mm of gutta-percha apically for apical seal. The drill was mounted on a low-speed handpiece (NSK Pana Air, Japan) connected to an electric motor (Surgic AP, NSK, Tochigi, Japan) (fig. 4) at a rotation speed of 10,000 rpm with a torque of 5 Ncm. For each 5 mm depth progression inside the root canal, the drill path was rinsed with 2 ml of normal saline using a 30-gauge double-side-vented irrigation needle mounted on a Luer-lock 3 ml plastic syringe. The drill flutes were cleaned with moistened gauze after each penetration depth till they reached the complete post-space preparation.

Digital periapical radiographs were taken to ensure removal of all gutta-percha from the wall of the post-space length. The root canals were irrigated with 5 ml distilled water to remove excess root canal filling materials and dried with paper points. The glass fiber post was seated into the canal with its rubber stopper adjusted to the required length (14 mm) to ensure full post seating in the preparation space.

**4.9. Fiber post insertion and cementation.**

**S**elf-adhesive resin cement Pentron Breeze (Pentron clinical, USA; BR) was injected into the post spaces (fig. 5). The post was seated in a pumping motion, allowing full seating without voids. Excessive cement was removed with hand scalers (Gracey scaler, LM-Dental™, Finland) and light-cured for 40 seconds. All posts were trimmed to the orifice using no. 2-round carbide bur under water coolant.

**Figure (3): A photograph showing Olipost Light fiber post and its drill**


**Figure (4): A photograph showing NSK electric motor**


**Figure (5): A photograph showing Pentron Breeze resin cement**

#### 4.10. Grouping of the samples.

Samples were divided into three main groups (n= 16) according to the type of fiber post-removal method applied:

- **Group A:** Fiber post removal using ultrasonic tips.
- **Group B:** Fiber post removal using fiber post drill.
- **Group C:** Fiber post removal using fiber post drill with guide.

#### 4.11. Pre-intervention CBCT scanning of the samples.

A Pre-intervention CBCT by Vatech Green X™ (Vatech, Seoul, Republic of Korea) (voxel size = 0.150 mm with 94 kV,13.3 mA, and 2.9-second exposure time) was obtained for all molds after fiber post-cementation. The image contrast and brightness values were constantly adjusted using the software image-processing tool to ensure optimal standardization.

#### 4.12. Designing and fabrication of the guide.

CBCT images were stored as Digital Imaging and Communication (DICOM) files. Surface scanning was done for molds using a 3D intraoral scanner (Medit i500.Medit Corp. Seoul, South Korea) to create surface tessellation language files (STL). CBCT data were uploaded into software designed for guided implantology using Blue Sky Plan (V4.1.0; Blue Sky Bio, Grayslake, IL).

STL files were uploaded to guided implant software and superimposed with CBCT data by aligning crowns and roots of teeth to create templates, and information on the fiber post position was considered in the planning. The STL files allowed a 3D printer (Phrozen Sonic 4K, Phrozen, Taiwan) using a photosensitive liquid resin (Phrozen ABS-like grey resin, Phrozen, Taiwan) to produce two templates[15]. The first template design guides the drill for only the first 3 ml of the fiber post; the second template design guides the drill for the whole length of the fiber post (fig. 6).

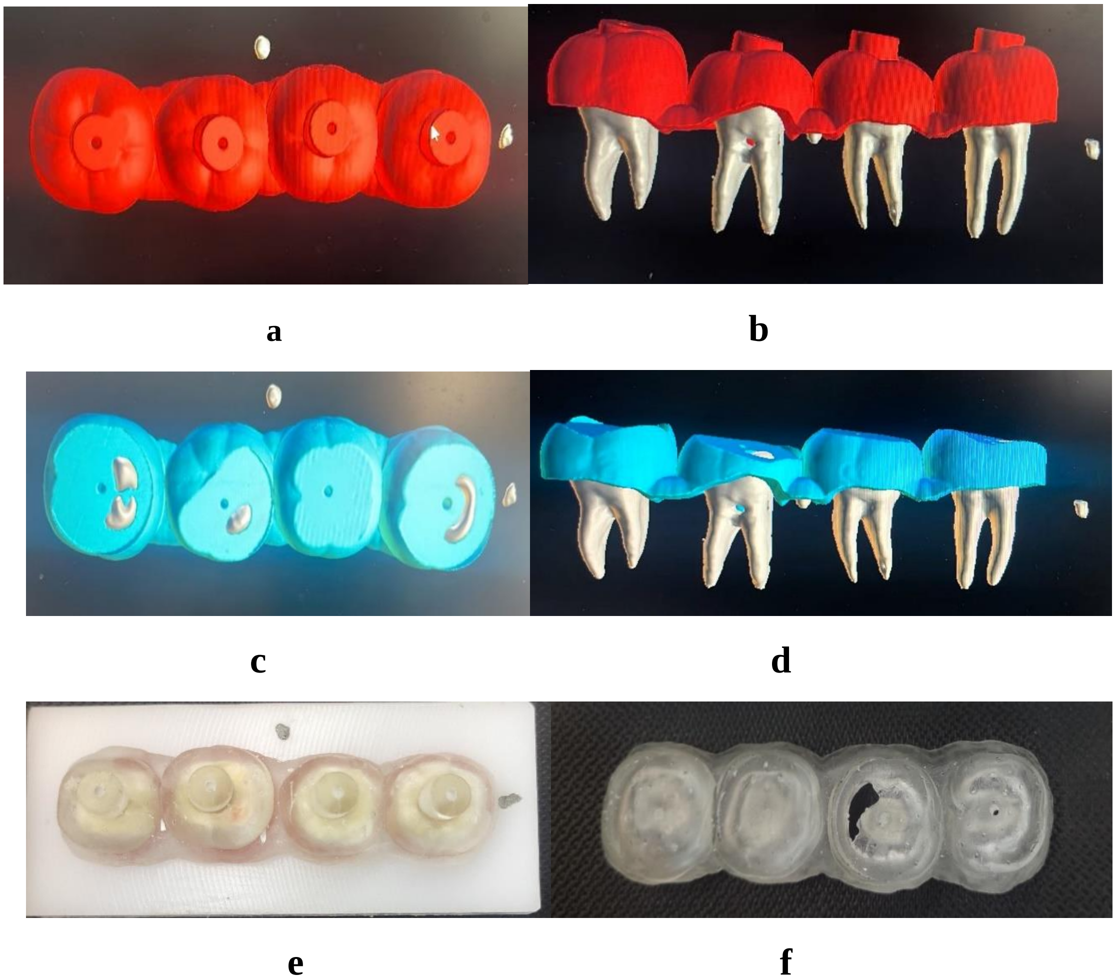



**Figure (6): A photograph showing the steps of guide design a) the first guide design at occlusal view b) the first guide design at proximal view c) the second guide design at occlusal view d) the second guide design at proximal view e) the fabricated first guide f) the fabricated second guide**

## 4.13. Removal of the Fiber posts.

**Group A:** Fiber post removal with ultrasonic tips:

The fiber post was removed with a diamond-coated ultrasonic tip (RT2, EMS SA, Nyon, Switzerland) (fig. 7 b) powered by an ultrasonic generator (DTE, D5, Woodpecker, China) set to maximum power at Endo mode with water coolant and the tip directed parallel to the long axis of the root and fiber post direction. The application of the tip pressure stopped every 15 seconds to prevent fracture of the tip and decrease heat generation. The force of the tip was applied at the center of the fiber post till the gutta percha appeared. The removal process was assessed by taking periapical radiographs at intervals to ensure accuracy.

**Group B:** Fiber post removal with fiber post drill:

The fiber post was removed using a Hi-Rem fiber post drill (Overfibers, Bologna, Italy) with a 1.4 mm diameter (fig. 7 b). The drill was mounted on a low-speed handpiece connected to an electric motor at a rotation speed of 10,000 rpm with a torque of 5 Ncm. For each 5 mm depth progression inside the root canal, the drill path was rinsed with 2 ml of normal saline using a 30-gauge double-side-vented irrigation needle mounted on a Luer-lock 3 ml plastic syringe. After each penetration depth, the drill flutes were cleaned with moistened gauze until they reached the total fiber post-removal. The removal process was assessed by taking periapical radiographs at intervals.

**Group C:** Fiber post removal with fiber post drill with a guided template:

The fiber post was removed through the fabricated endodontic guides by attaching templates to the teeth on the mold and then using the fiber post drill with a 1.4 mm diameter through the two fabricated guides to drill out the fiber post (fig. 7 b). The drill was mounted on a low-speed handpiece connected to an electric motor at a rotation speed of 10,000 rpm with a torque of 5 Ncm. The guide was removed for each 5 mm depth progression inside the root canal, and the drill path was rinsed with 2 ml of normal saline using a 30-gauge double-side-vented irrigation needle mounted on a Luer-lock 3 ml plastic syringe. The drill flutes were cleaned with moistened gauze after each penetration depth till the complete removal of the fiber post. The removal process was assessed by taking periapical radiographs at intervals (fig. 8).

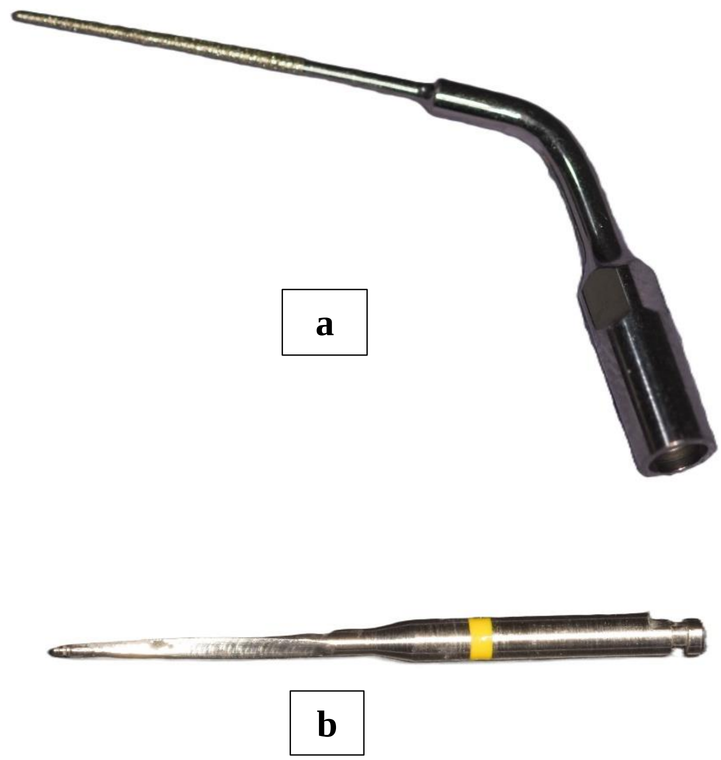



**Figure (7): A photograph showing the tips used in fiber post removal a) the diamond coated ultrasonic tips b) the Hi-Rem fiber post drill (1.4 mm)**

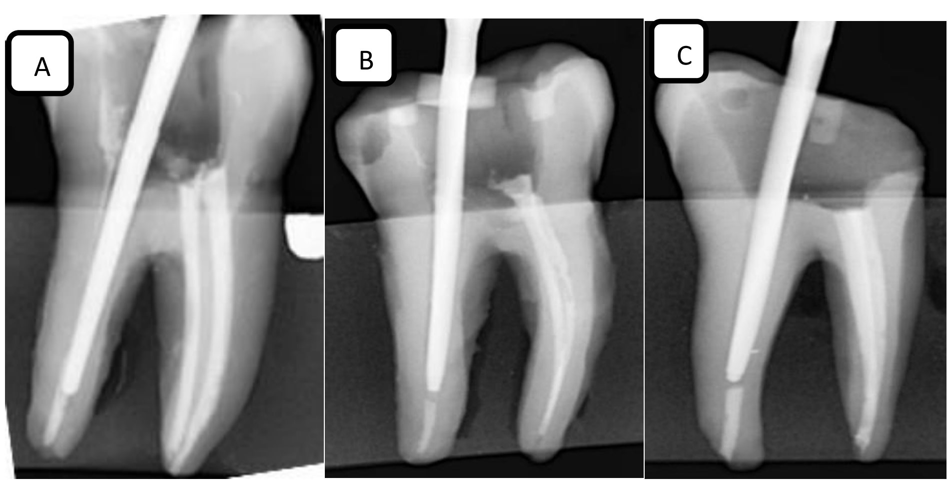



**Figure (8): Digital periapical x-rays showing samples after fiber post removal after using the tested removal groups (A) ultrasonic group (B) drill group (C) drill with guide group**

### 4.14. Post-intervention CBCT scanning.

CBCT images were obtained after removing the fiber posts for all molds with criteria and settings followed in pre-intervention CBCT scanning.

### 4.15. Methods of evaluations:

#### 4.15.1 Evaluation of the remaining dentin thickness.

For dentin thickness evaluation, InVivo 5 software (Anatomage, San Jose, Calif) was employed to superimpose preoperative and postoperative scans, guaranteeing dentin thickness at the exact level. A superimposition module was used to superimpose the postoperative scan over the preoperative one, where the software performed automatic registration. The superimposition sequence was repeated for each group individually.

After the fusion of pre-operative and post-operative scans, both were reconstructed at the same layer. For measuring dentin thickness, the orifice of the distal canal was located, and then, three vertical lines of lengths, two, four, and six millimeters, were drawn from the orifice downwards. Axial levels assigned for recording dentin thickness were decided by the end of these three lines. At each axial image, dentin thickness at buccal, lingual, mesial, and distal aspects of the canal lumen were measured at both scans simultaneously. The procedures were repeated at the three axial levels for each tooth at coronal, middle, and apical sections. The results were then collected and tabulated for statistical analysis.

#### 4.15.2 Evaluation of the fiber post and resin cement residuals.

Scoring (0 and 1) was given for each post-intervention CBCT for each tooth third to evaluate the fiber post and resin cement residuals using an adaptation of the scores developed by Vasconcelos et al(71). Score (0) means no fiber post and resin cement residuals were found, while score (1) means fiber post and resin cement residuals were found(72,73).

### 4.15.2 Evaluation of time needed for fiber posts-removal.

The time needed to remove the fiber post was recorded using a stopwatch, commencing when the removing tool was actively cutting in the fiber post, pausing when the tool was stopped, and ending when the tool reached the whole length of the fiber post.

### 4.16. Statistical analysis of the data.

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. The remaining dentin thickness and time data showed a parametric (normal) distribution, while remnants data (Scores) showed a non-parametric (not-normal) distribution. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

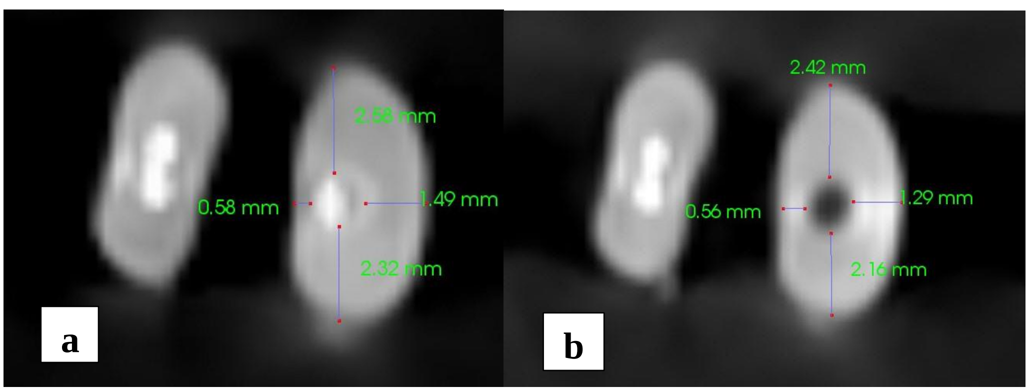



**Figure (9): Radiograph showing sample at a) pre-intervention CBCT scanning b) post-intervention CBCT scanning**

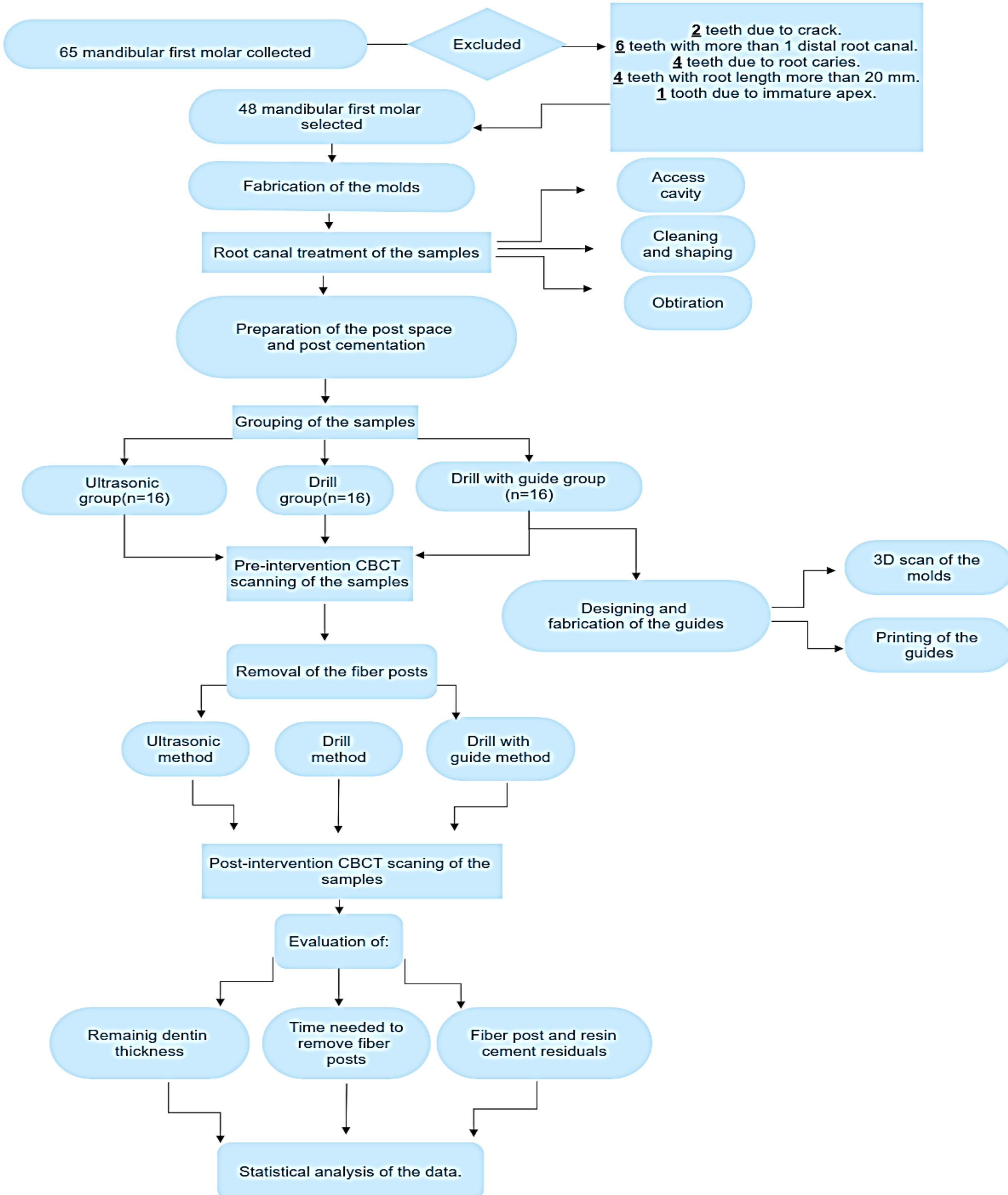



**Figure (10): A flow chart representing a review of materials and methods used in the study**

# 5. Results

## 5.1 Evaluation of the remaining dentin thickness results.

5.1.1 Comparison between removal methods.

a. At coronal section.

b. At middle section.

c. At apical section.

5.1.2 Comparison between root sections.

a. Using ultrasonic removal method.

b. Using drill removal method.

c. Using a drill with a guided template removal method.

## 5.2 Evaluation of residual remnants of fiber post and cement.

5.2.1 Comparison between removal methods.

5.2.2 Comparison between root sections.

## 5.3 Time needed to remove the fiber post.

5.3.1 Comparison between removal methods.

## 5.1 Evaluation of the remaining dentin thickness.

Data in this section were statistically analyzed using the ANOVA test to compare more than two groups in related samples. A paired sample t-test was used to compare two groups in related samples. Further, the Tukey Post Hoc and one-way ANOVA tests were used to compare more than two groups in non-related samples when there was a significant difference.

### 5.1.1 Comparison between removal methods.

#### A. At coronal section.

- **Distal:**

The highest mean of dentin removal was recorded in group A (0.174±0.002), followed by group B (0.099±0.002). The lowest mean of dentin removal was in group C (0.093±0.003). There was a significant difference between group A and the other two groups. No significant difference was found between groups B and C(*p-value*<0.001).

- **Mesial:**

The highest mean of dentin removal was recorded in group A (0.246±0.006), followed by group B (0.108±0.002). The lowest mean of dentin removal was in group C (0.086±0.002). There was a difference between all groups (*p-value*<0.001).

- **Buccal:**

The highest mean of dentin removal was recorded in group C (0.209±0.012), followed by group A (0.33±0.016). The lowest mean of dentin removal was in group B (0.14±0.007). There was a difference between all groups (*p-value*<0.001).

- **Lingual:**

The highest mean of dentin removal was recorded in group A (0.236±0.011), followed by group B (0.138±0.007). The lowest mean of dentin removal was in group C (0.107±0.003). There was a difference between all groups (*p-value*<0.001).

**Table (1): Mean values and standard deviation of remaining dentin thickness for coronal section.**

| Variables | Coronal section | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distal | | Mesial | | Buccal | | Lingual | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Group A** | 0.174 [a] | 0.002 | 0.246 [a] | 0.006 | 0.33 [a] | 0.016 | 0.236 [a] | 0.011 |
| **Group B** | 0.099 [b] | 0.002 | 0.108 [b] | 0.002 | 0.14 [c] | 0.007 | 0.138 [b] | 0.007 |
| **Group C** | 0.093 [b] | 0.003 | 0.086 [c] | 0.002 | 0.209 [b] | 0.012 | 0.107 [c] | 0.003 |
| ***p-value*** | **<0.001*** | | **<0.001*** | | **<0.001*** | | **<0.001*** | |

Means with different superscripts in the same column indicate significant differences. (One-Way ANOVA followed by Tukey post hoc test)

*; significant (p<0.05)     ns; non-significant (p>0.05)

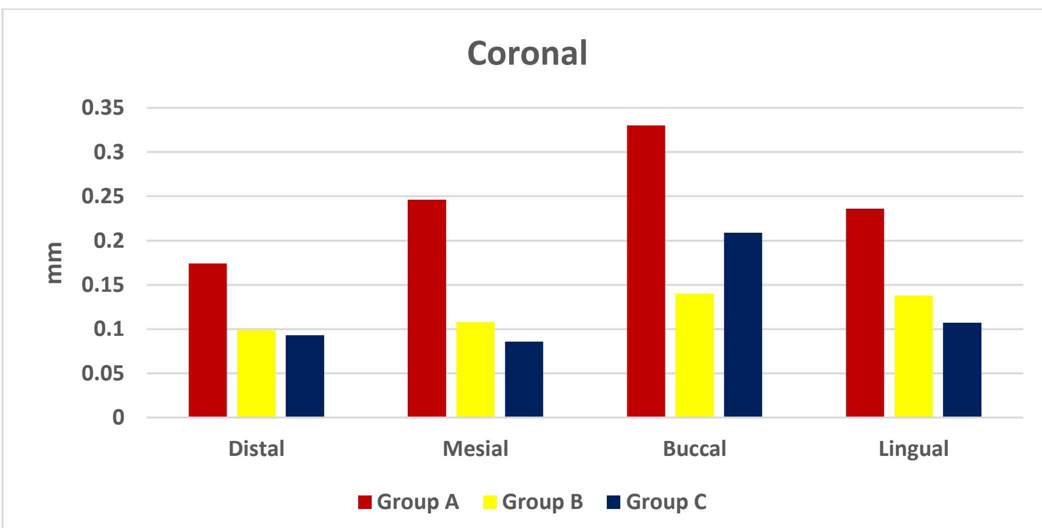



**Figure (11): Bar chart representing the effect of walls on remaining dentin thickness coronal section**

**B. At middle section.**

- **Distal:**

The highest mean of dentin removal was recorded in Group A (0.181±0.002), followed by Group B (0.108±0.005). The lowest mean of dentin removal was at Group C (0.099±0.002). There was a significant difference between group A and the other two groups. No significant difference was found between groups B and C (*p-value*<0.001).

- **Mesial:**

The highest mean of dentin removal was recorded in Group A (0.155±0.006), followed by Group B (0.093±0.002). The lowest mean of dentin removal was at Group C (0.091±0.002). There was a significant difference between group A and the other two groups. No significant difference was found between groups B and C (*p-value*<0.001).

- **Buccal:**

The highest mean of dentin removal was recorded in Group A (0.307±0.008), followed by Group C (0.202±0.012). The lowest mean of dentin removal was at Group B (0.167±0.008). There was a difference between all groups (*p-value*<0.001).

- **Lingual:**

The highest mean of dentin removal was recorded in Group A (0.242±0.005), followed by Group B (0.156±0.008). The lowest mean of dentin removal was at Group C (0.101±0.001). There was a difference between all groups (*p-value*<0.001).

**Table (2): Mean values and standard deviation of remaining dentin thickness for middle section.**

| Variables | Middle section | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distal | | Mesial | | Buccal | | Lingual | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Group A** | 0.181 [a] | 0.002 | 0.155 [a] | 0.006 | 0.307 [a] | 0.008 | 0.242 [a] | 0.005 |
| **Group B** | 0.108 [b] | 0.005 | 0.093 [b] | 0.002 | 0.167 [c] | 0.008 | 0.156 [b] | 0.008 |
| **Group C** | 0.099 [b] | 0.002 | 0.091 [b] | 0.002 | 0.202 [b] | 0.012 | 0.101 [c] | 0.001 |
| ***p-value*** | **<0.001*** | | **<0.001*** | | **<0.001*** | | **<0.001*** | |

Means with different superscripts in the same column indicate significant differences. (One-Way ANOVA followed by Tukey post hoc test)

*; significant (p<0.05)     ns; non-significant (p>0.05)

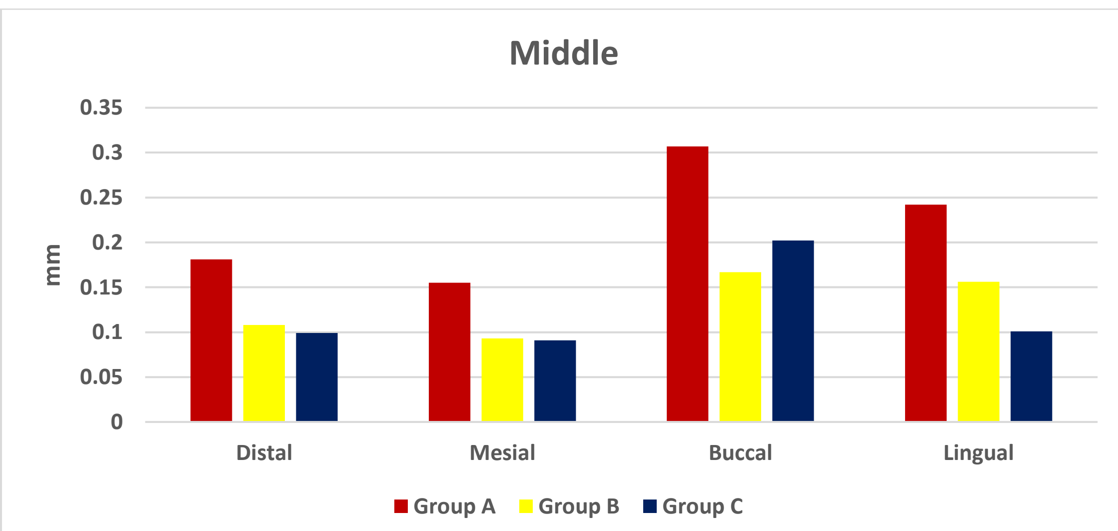



**Figure (12): Bar chart representing the effect of walls on remaining dentin thickness middle section**

**C. At apical section.**

- **Distal:**

The highest mean of dentin removal was recorded in Group A (0.173±0.004), followed by Group B (0.113±0.002). The lowest mean of dentin removal was at Group C (0.106±0.003). There was a significant difference between group A and the other two groups. No significant difference was found between groups B and C(*p-value*<0.001).

- **Mesial:**

The highest mean of dentin removal was recorded in Group A (0.114±0.002), followed by Group B (0.086±0.002). The lowest mean of dentin removal was at Group C (0.071±0.002). There was a difference between all groups ($p<0.001$).

**Buccal:**

The highest mean of dentin removal was recorded in group A (0.249±0.009), followed by group B (0.142±0.005). The lowest mean of dentin removal was at group C (0.076±0.002). There was a difference between all groups ($p<0.001$).

- **Lingual:**

The highest mean of dentin removal was recorded in group A (0.268±0.016), followed by group B (0.103±0.007). The lowest mean of dentin removal was in group C (0.1±0.005). There was a significant difference between group A and the other two groups. No significant difference was found between groups B and C(*p-value*<0.001).

**Table (3): Mean values and standard deviation of remaining dentin thickness for apical section.**

| Variables | Apical section | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distal | | Mesial | | Buccal | | Lingual | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Group A** | 0.173 [a] | 0.004 | 0.114 [a] | 0.002 | 0.249 [a] | 0.009 | 0.268 [a] | 0.016 |
| **Group B** | 0.113 [b] | 0.002 | 0.086 [b] | 0.002 | 0.142 [b] | 0.005 | 0.103 [b] | 0.007 |
| **Group C** | 0.106 [b] | 0.003 | 0.071 [c] | 0.002 | 0.076 [c] | 0.002 | 0.1 [b] | 0.005 |
| ***p-value*** | **<0.001*** | | **<0.001*** | | **<0.001*** | | **<0.001*** | |

Means with different superscripts in the same column indicate significant differences. (One-Way ANOVA followed by Tukey post hoc test)

*; significant (p<0.05)   ns; non-significant (p>0.05)

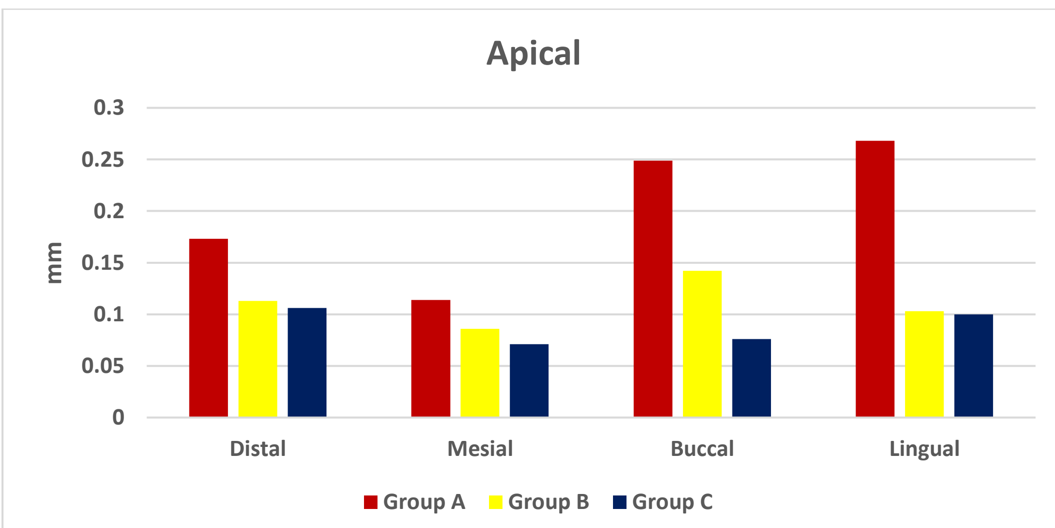



**Figure (13): Bar chart representing the effect of groups on remaining dentin thickness apical section**

### 5.1.2 Comparison between root sections.

### A. Using ultrasonic removal method.

- **Distal:**

The highest mean of dentin removal was recorded in the middle section (0.181±0.002), followed by the coronal section (0.174±0.002). The lowest mean of dentin removal was at the apical section (0.173±0.004). There was a statistically significant difference between the middle and apical sections. No significant difference between the coronal and the other two-sections (*p-value*=0.040).

- **Mesial:**

The highest mean of dentin removal was recorded at the coronal section (0.246±0.006), followed by the middle section (0.155±0.006). The lowest mean of dentin removal was at the apical section (0.114±0.002). There was a statistically significant difference between all sections (*p-value*<0.001).

- **Buccal:**

The highest mean of dentin removal was recorded at the coronal section (0.330±0.016), followed by the middle section (0.307±0.008). The lowest mean of dentin removal was at the apical section (0.249±0.009). A statistically significant difference existed between the apical section and the other two sections. There is no significant difference between the coronal and the other two- sections (*p-value*<0.001).

- **Lingual:**

The highest mean of dentin removal was recorded at the apical section (0.268±0.016), followed by the middle section (0.242±0.005). The lowest mean of dentin removal was at the coronal section (0.236±0.011). There was no statistically significant difference between all sections (*p-value*=0.097).

**Table (4): Mean values and standard deviation of remaining dentin thickness for ultrasonic group (A).**

| Variables | Group A | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distal | | Mesial | | Buccal | | Lingual | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Coronal** | 0.174 [ab] | 0.002 | 0.246 [a] | 0.006 | 0.330 [a] | 0.016 | 0.236 [a] | 0.011 |
| **Middle** | 0.181 [a] | 0.002 | 0.155 [b] | 0.006 | 0.307 [a] | 0.008 | 0.242 [a] | 0.005 |
| **Apical** | 0.173 [b] | 0.004 | 0.114 [c] | 0.002 | 0.249 [b] | 0.009 | 0.268 [a] | 0.016 |
| ***p-value*** | **0.040*** | | **<0.001*** | | **<0.001*** | | **0.097ns** | |

Means with different superscripts in the same column indicate significant differences. (Repeated measure ANOVA followed by paired sample t-test)

*; significant ($p<0.05$)   ns; non-significant ($p>0.05$)

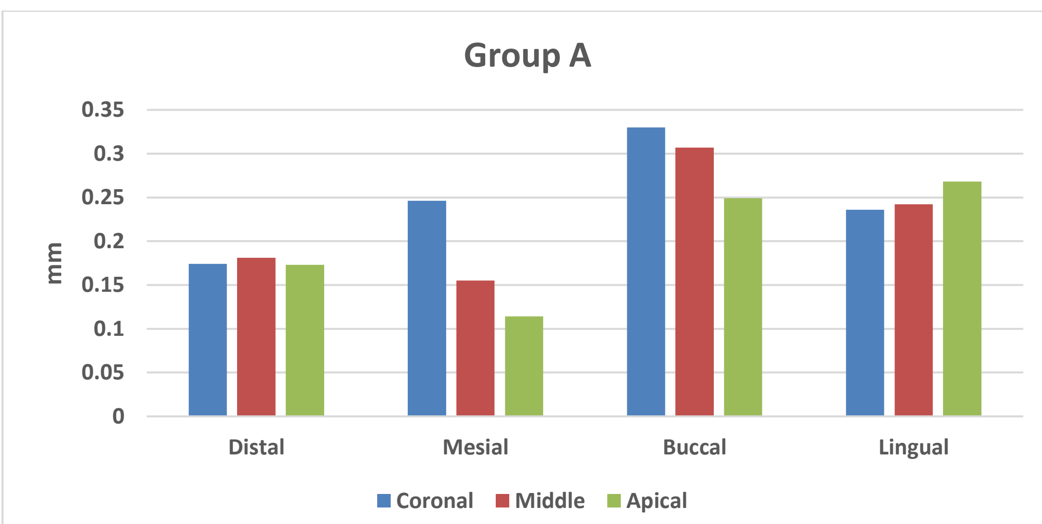



**Figure (14): Bar chart representing the effect of walls on remaining dentin thickness group A**

**B. Using drill removal method.**

- **Distal:**

The highest mean of dentin removal was recorded at the apical section (0.113±0.002), followed by the middle section (0.108±0.005). The lowest mean of dentin removal was at the coronal section (0.099±0.002). There was a significant difference between coronal and apical sections. There is no significant difference between the middle and the other two sections (*p-value*= 0.035)

- **Mesial:**

The highest mean of dentin removal was recorded at the coronal section (0.108±0.002), followed by the middle section (0.093±0.002). The lowest mean of dentin removal was at the apical section (0.086±0.002). There was a significant difference between all sections(*p-value*<0.001).

- **Buccal:**

The highest mean of dentin removal was recorded in the middle section (0.167±0.008), followed by the apical section (0.142±0.005). The lowest mean of dentin removal was at the coronal section (0.140±0.007). There was a significant difference between the middle and the other two sections. There is no significant difference between coronal and apical sections (*p-value*=0.026).

- **Lingual:**

The highest mean of dentin removal was recorded in the middle section (0.156±0.008), followed by the coronal section (0.138±0.007). The lowest mean of dentin removal was at the apical section (0.103±0.007). There was a significant difference between all sections (*p*<0.001). There was a significant difference between the apical and the other two sections. No significant difference was found between the coronal and middle sections (*p-value*<0.001).

**Table (5): Mean values and standard deviation of remaining dentin thickness for drill group (B).**

| Variables | Group B | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distal | | Mesial | | Buccal | | Lingual | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Coronal** | 0.099 [b] | 0.002 | 0.108 [a] | 0.002 | 0.140 [b] | 0.007 | 0.138 [a] | 0.007 |
| **Middle** | 0.108 [ab] | 0.005 | 0.093 [b] | 0.002 | 0.167 [a] | 0.008 | 0.156 [a] | 0.008 |
| **Apical** | 0.113 [a] | 0.002 | 0.086 [c] | 0.002 | 0.142 [b] | 0.005 | 0.103 [b] | 0.007 |
| ***p-value*** | **0.035*** | | **<0.001*** | | **0.026*** | | **<0.001*** | |

Means with different superscripts in the same column indicate significant differences. (Repeated measure ANOVA followed by paired sample t-test)

*; significant (p<0.05)   ns; non-significant (p>0.05)

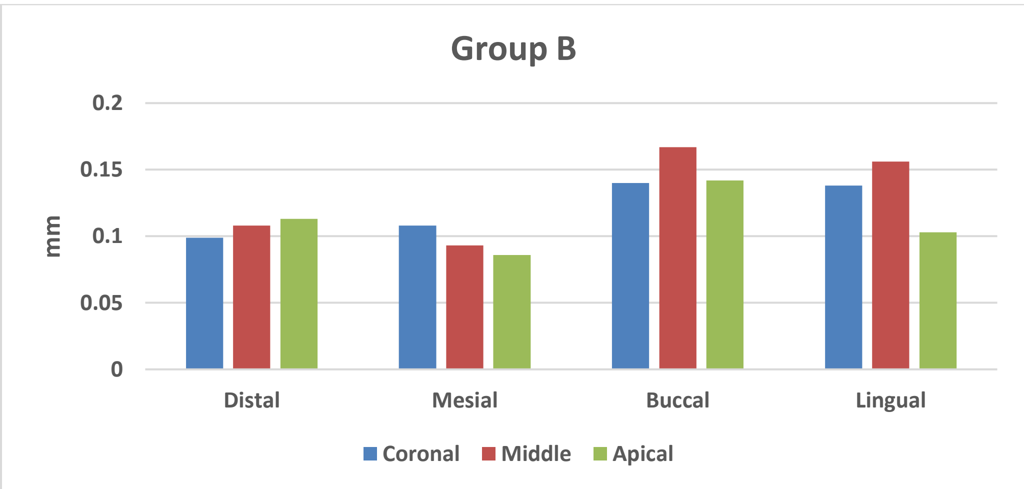



**Figure (15): Bar chart representing the effect of walls on remaining dentin thickness group B**

**C. Using a drill with a guided template removal method.**

- **Distal:**

The highest mean of dentin removal was recorded at the apical section (0.106±0.003), followed by the middle section (0.099±0.002). The lowest mean of dentin removal was at the coronal section (0.093±0.003). There was a significant difference between the coronal and the other two sections. There was no significant difference between the middle and apical sections (*p-value*=0.014).

- **Mesial:**

The highest mean of dentin removal was recorded in the middle section (0.091±0.002), followed by the coronal section (0.086±0.002). The lowest mean of dentin removal was at the apical section (0.071±0.002). There was a significant difference between the apical and the other two sections. No significant difference was found between the coronal and middle sections (*p-value*<0.001).

- **Buccal:**

The highest mean of dentin removal was recorded at the coronal section (0.209±0.012), followed by the middle section (0.202±0.012). The lowest mean of dentin removal was at the apical section (0.076±0.002). There was a significant difference between the apical and the other two sections. No significant difference was found between the coronal and middle sections (*p-value*<0.001).

- **Lingual:**

The highest mean of dentin removal was recorded at the coronal section (0.107±0.003), followed by the middle section (0.101±0.001). The lowest mean of dentin removal was at the apical section (0.100±0.005). There was a significant difference between the coronal and the other two sections. No significant difference was found between the middle and apical sections (*p-value*=0.012).

**Table (6): Mean values and standard deviation of remaining dentin thickness for drill with guide group (C).**

| Variables | Group C | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distal | | Mesial | | Buccal | | Lingual | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Coronal** | 0.093 [b] | 0.003 | 0.086 [a] | 0.002 | 0.209 [a] | 0.012 | 0.107 [a] | 0.003 |
| **Middle** | 0.099 [a] | 0.002 | 0.091 [a] | 0.002 | 0.202 [a] | 0.012 | 0.101 [b] | 0.001 |
| **Apical** | 0.106 [a] | 0.003 | 0.071 [b] | 0.002 | 0.076 [b] | 0.002 | 0.100 [b] | 0.005 |
| ***p-value*** | **0.014*** | | **<0.001*** | | **<0.001*** | | **0.012*** | |

Means with different superscripts in the same column indicate significant differences. (Repeated measure ANOVA followed by paired sample t-test)

*; significant (p<0.05)      ns; non-significant (p>0.05)

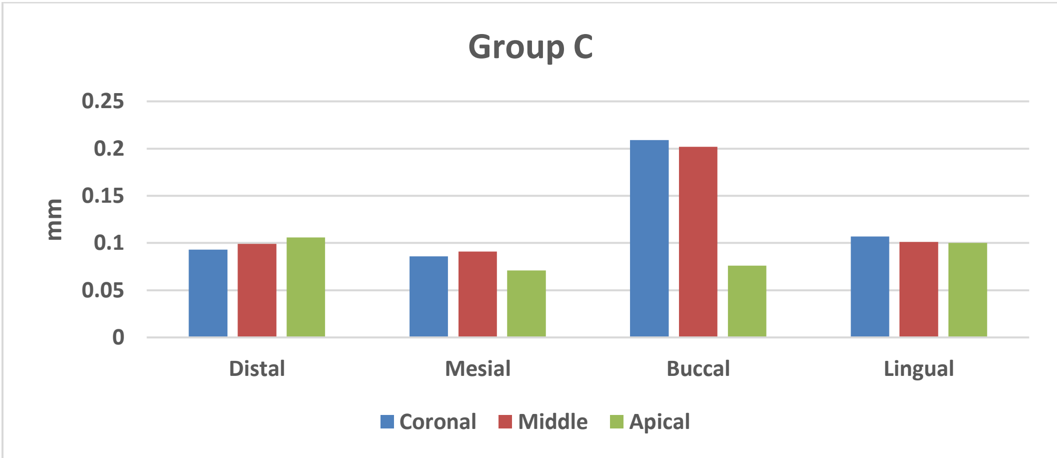



**Figure (16): Bar chart representing the effect of walls on remaining dentin thickness group C**

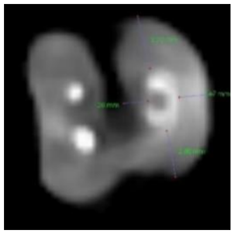
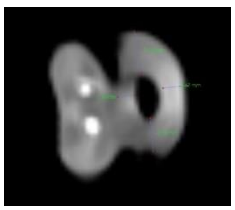
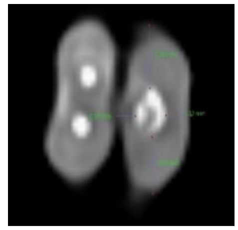
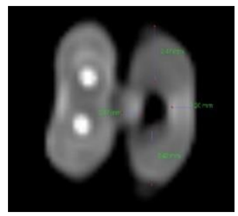
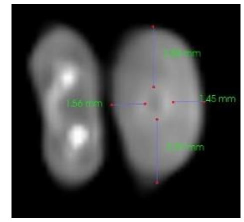
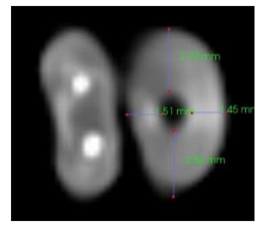
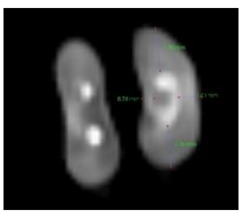
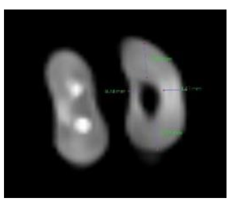
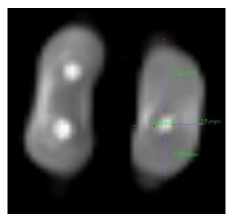
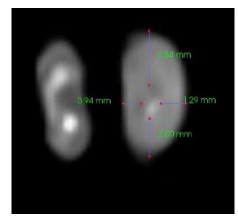
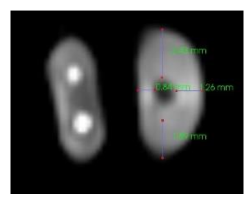
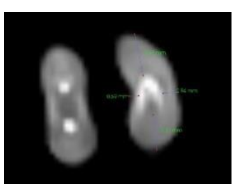
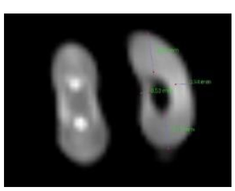
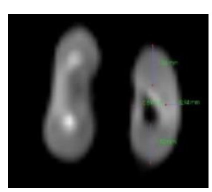
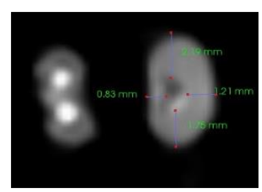
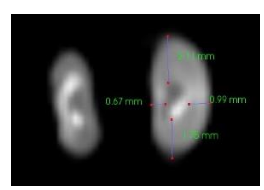
| Dentin thickness | Ultrasonic group | Drill group | Drill with guide group |
|---|---|---|---|
| Coronal | a <br>b  | <br> | <br> |
| Middle | a <br>b  | <br> | <br> |
| Apical | a <br>b  | <br> | <br> |

**Figure (17): CBCTs show the dentin thickness measurement at all tested groups a) pre-operative CBCT b) post-operative CBCT**

## 5.2 Evaluation of residual remnants of fiber post and cement.

Data in this section were statistically analyzed using the Kruskal-Wallis test to compare more than two groups in non-related samples. Friedman test was used to compare more than two groups in related samples. Further, Mann-Whitney and Wilcoxon's tests were used to compare two groups in related samples when there was a significant difference between them.

### 5.2.1 Comparison between removal methods.

- **Coronal section:**

The highest mean of residual remnants of fiber post and cement was recorded in group C (0.56±0.13), followed by group B (0.50±0.13). The lowest mean of residual remnants of fiber post and cement was in group A (0.13±0.09). There was a significant difference between group A and the two other groups. There was no significant difference between groups B and C (*p-value*=0.026).

- **Middle section:**

The highest mean of residual remnants of fiber post and cement was recorded in group C (0.69±0.12), followed by group B (0.56±0.13). The lowest mean of residual remnants of fiber post and cement was in group A (0.19±0.10). There was a significant difference between group A and the two other groups. There was no significant difference between groups B and C (*p-value*=0.014).

- **Apical section:**

The highest mean of residual remnants of fiber post and cement was recorded in group C (0.75±0.11), followed by group B (0.63±0.13). The lowest mean of residual remnants of fiber post and cement was in group A (0.25±0.11). There was a significant difference between group A and the two other groups. There was no significant difference between groups B and C (*p-value*=0.014).

### 5.2.2 Comparison between root sections.

- **Group A (ultrasonic):**

  The highest mean of residual remnants of fiber post and cement was recorded at the apical section (0.25±0.11), followed by the middle section (0.19±0.10). The lowest mean of residual remnants of fiber post and cement was at coronal section (0.13±0.09). There was a significant difference between all sections(*p-value*=0.549).

- **Group B (drill):**

  The highest mean of residual remnants of fiber post and cement was recorded at the apical section (0.63±0.13), followed by the middle section (0.56±0.13). The lowest mean of residual remnants of fiber post and cement was at the coronal section (0.50±0.13). There was a significant difference between all sections (*p-value*=0.717).

- **Group C (drill with guided template):**

  The highest mean of residual remnants of fiber post and cement was recorded at the apical section (0.75±0.11), followed by the middle section (0.69±0.12). The lowest mean of residual remnants of fiber post and cement was at the coronal section (0.56±0.13). There was a significant difference between all sections (*p-value*=0.459).

**Table (7): Mean values and standard deviation of residual remnants of different groups and sections.**

| Variables | Residual remnants of fiber and cement | | | | | | |
|---|---|---|---|---|---|---|---|
| | Group A | | Group B | | Group C | | p-value |
| | Mean | SD | Mean | SD | Mean | SD | |
| Coronal | 0.13 $^{aB}$ | 0.09 | 0.50 $^{aA}$ | 0.13 | 0.56 $^{aA}$ | 0.13 | **0.026*** |
| Middle | 0.19 $^{aB}$ | 0.10 | 0.56 $^{aA}$ | 0.13 | 0.69 $^{aA}$ | 0.12 | **0.014*** |
| Apical | 0.25 $^{aB}$ | 0.11 | 0.63 $^{aA}$ | 0.13 | 0.75 $^{aA}$ | 0.11 | **0.014*`** |
| *p-value* | **0.549ns** | | **0.717ns** | | **0.459ns** | | |

Means with different lower-case superscripts in the same column indicate significant difference. Means with different upper-case superscripts in the same row indicate significant difference. Friedman test was used to compare between all three thirds followed by Wilcoxon test to compare two thirds. The Kruskal Walis test was used to compare between all three groups followed by Mann Whitney test to compare two groups.

*; significant (p<0.05) ns; non-significant (p>0.05)

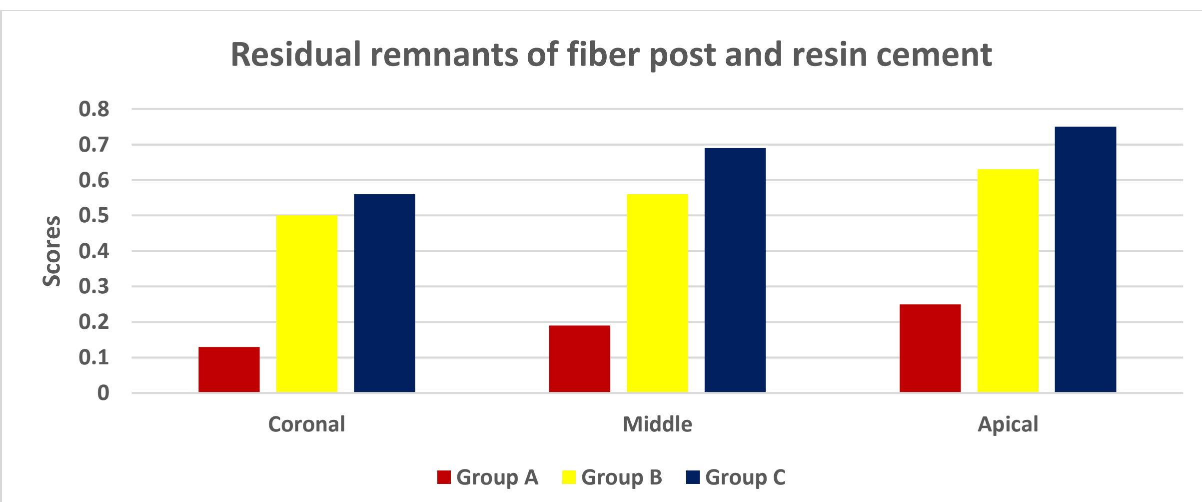



**Figure (18): Bar chart representing residual remnants of different groups**

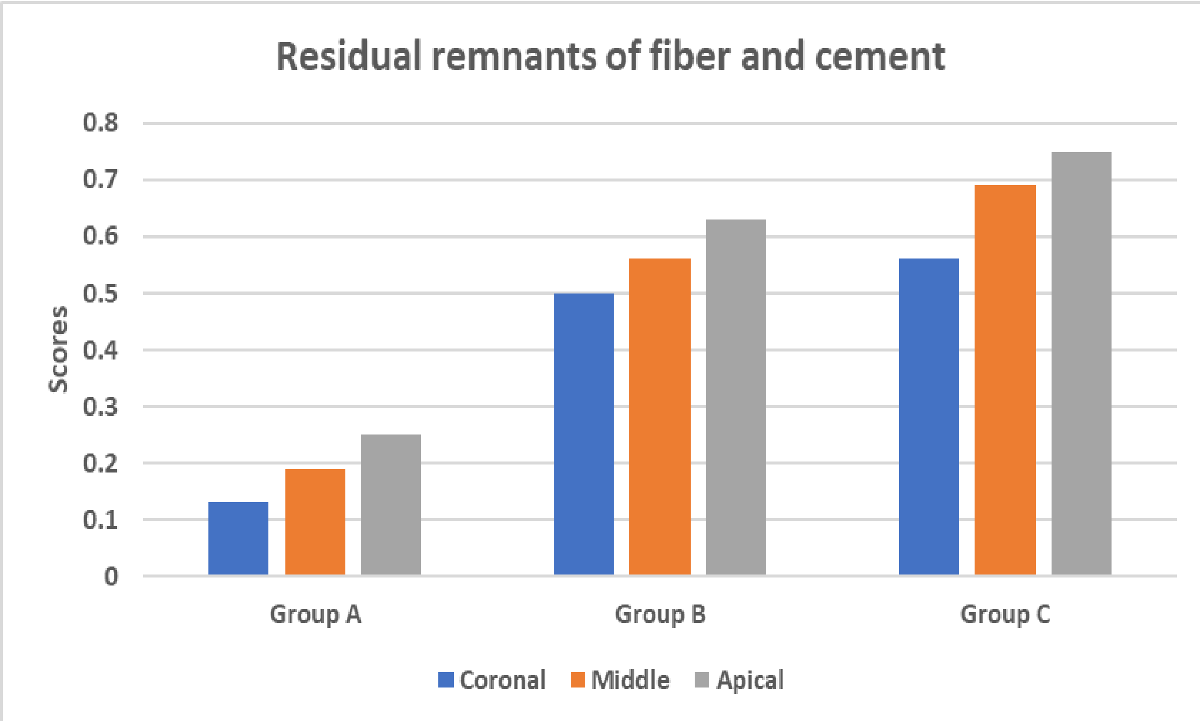



**Figure (19): Bar chart representing residual remnants of different sections**

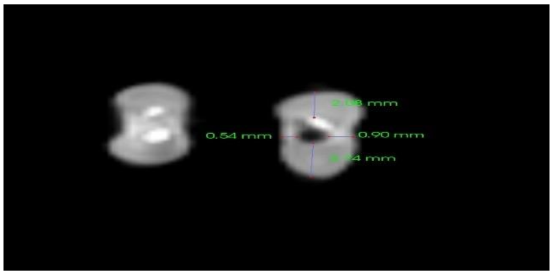
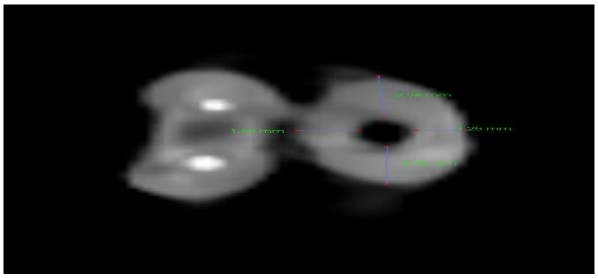
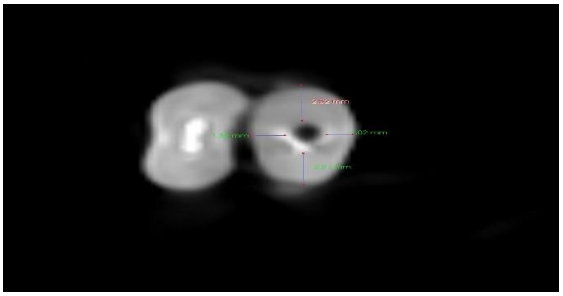
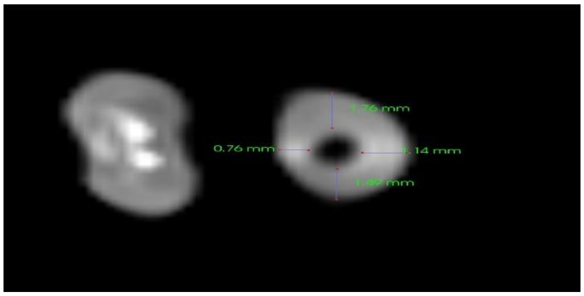
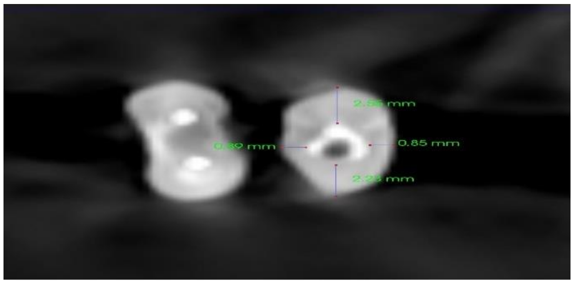
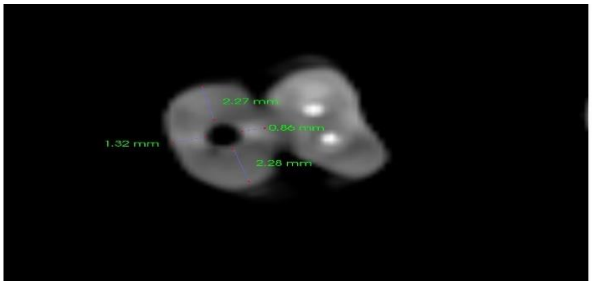
| Residual remnants of fiber post and cement | Score (1) | Score (0) |
|---|---|---|
| **Ultrasonic group** |  |  |
| **Drill group** |  |  |
| **Drill with guide group** |  |  |

**Figure (20): pre-and post-operative CBCTs show the residual remnants of fiber post and cement that have score (1) and score (0)**

## 5.3 Time needs to remove the fiber post.

Data in this section were statistically analyzed using the ANOVA test to compare more than two groups in related samples. A paired sample t-test was used to compare two groups in related samples. Further, the Tukey Post Hoc and one-way ANOVA tests were used to compare more than two groups in non-related samples when there was a significant difference.

### 5.3.1 Comparison between removal methods.

The highest mean of time needed for fiber post removal was recorded in group A (102.38±9.47), followed by group B (33.63±3.88). The lowest mean of time needed for fiber post removal was in group C (28.94±1.73). There was a significant difference between group A and the two other groups. No significant difference exists between groups B and C (*p-value*<0.001).

**Table (8): Mean values and standard deviation of time to remove the fiber post of different groups.**

| Variables | The time needed to remove the fiber post. | |
|---|---|---|
| | Mean | SD |
| **Group A** | 102.38 [a] | 9.47 |
| **Group B** | 33.63 [b] | 3.88 |
| **Group C** | 28.94 [b] | 1.73 |
| ***p-value*** | **<0.001*** | |

Means with different superscripts in the same column indicate significant differences. (One-Way ANOVA followed by Tukey post hoc test)

*; significant (p<0.05)      ns; non-significant (p>0.05)

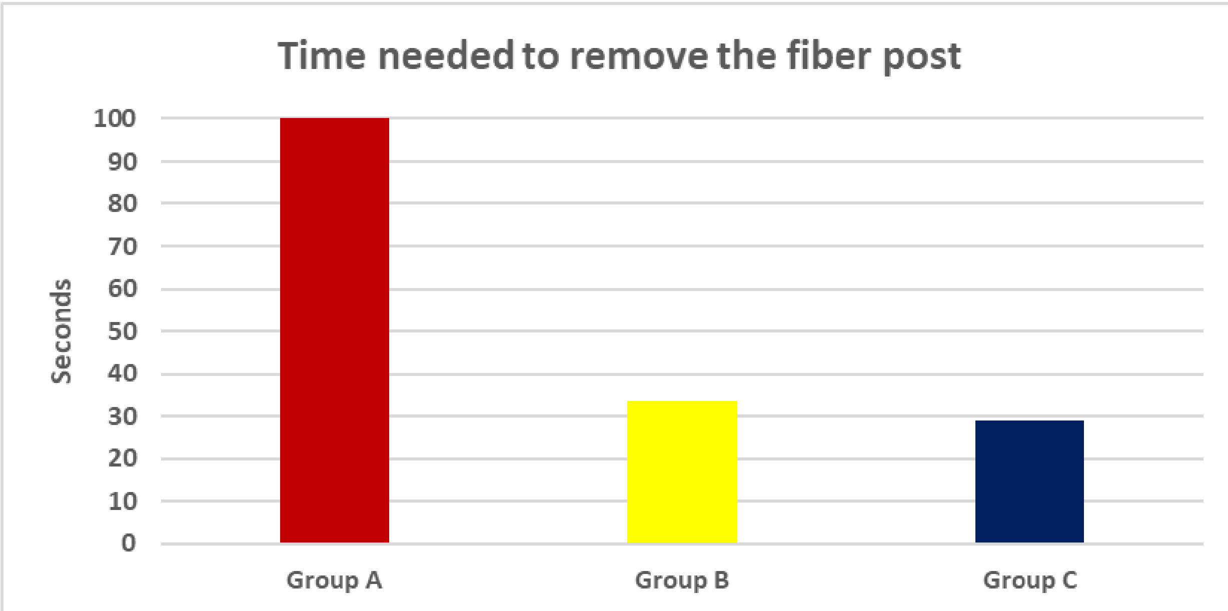



**Figure (21): Bar chart representing the time to remove the fiber post of different groups**

## 6. Discussion

Restoration of endodontically treated teeth is of paramount importance, the same as proper root canal treatment [56,59]. Loss of coronal tooth structure by more than 50% would determine using posts to retain a core and distribute stresses. In endodontic retreatment situations, removal of posts is mandatory to regain access to the root canals[75,76]. This experimental, randomized, controlled, interventional prospective in-vitro study aimed to evaluate the remaining dentin thickness, fiber post and resin cement residuals, and time needed to remove fiber posts using different methods.

Out of 65 recently extracted mandibular first molars, 48 teeth were used in the study. Seventeen teeth were excluded for the following reasons: teeth with roots caries (n=4), teeth with immature apices (n=1), teeth with root lengths more than 20 mm (n=4), teeth with more than one distal root canals (n=6), and teeth with root fractures or cracks (n=2).

Mandibular first molars were used as they are the most common teeth that undergo root canal treatment due to their early eruption in addition to their straight distal root, which facilitates fiber post-preparation and removal[71,77,78,79]. Teeth were collected from patients between 20 and 40 years old to minimize variations in dentin nature due to secondary and sclerotic dentin deposition and to standardize the length of the roots[79].

Twelve rectangular plastic molds were constructed containing four rounded holes. The sides of the mold were marked according to the root surfaces as buccal, lingual, mesial, distal, cervical, and apical sides. A two-box-shaped cavity was made on the mesial and buccal sides of the mold and was filled with amalgam to quickly identify the surfaces on the exposed CBCT[80].

Traditional access cavity was carried out for all samples to make the cavity wide enough for fiber post preparation and guide fabrication and insertion[81]. Wall refining of the pulp chamber was done using an ultrasonic wall refining tip to make the wall smooth for guide insertion[83,84]. Root canal preparation was carried out with AF Blue rotary files due to its superior flexibility and availability. The preparation proceeds till file size #30/0.04 as larger apical sizes will remove unnecessary dentin from the root canal walls[85,86].

During post-space preparation, a standardized post space, 14 mm deep from the tip distobuccal cusp, is a fixed reference point to standardize fiber post length for all samples[85]. Post spaces were prepared using a drill of Olipost Light fiber posts with a 1.2 mm diameter and leaving 4-5 mm of gutta-percha apically for apical seal[86]. The drill flutes were cleaned with moistened gauze after each penetration depth till they reached the complete post-space preparation to achieve maximum cutting efficiency of the drill[24]. Olipost Light fiber posts were made in the "Zircon-CLEAR" technology, which means that the content of nano zirconium particles does not affect the transparency of the posts, keeping them completely translucent. The transparency of the posts ensures the possibility of using dual-cure resin cement in the canal. Olipost Light is pre-coated with primer based on silicone (silane) So, it could create a chemical adhesion to resin cement[87].

A self-adhesive resin cement, Pentron Breeze was chosen due to its dual-cure properties, which provide the advantages of both light and chemically-activated resins, reach the adequate degree of polymerization, and provide an extended working time due to the easily controlled light-curing mechanism[88]. The resin cement was injected into the post spaces to ensure the flow of all cement into the root canal[89,70,90]. The post was seated in a pumping motion, allowing full seating without voids[41,91].

A Pre- and post-intervention CBCT was obtained for all molds. Pre-intervention CBCT was used to guide fabrication and measure the remaining dentin thickness before fiber post-removal(17,92). Post-intervention CBCT To analyze the remaining dentin thickness and the residual remnants after fiber post-removal (10,3).

Two guides were fabricated from the molds' pre-intervention CBCT and STL files. The first template design guides the drill for only the first 3 ml of the fiber post; the second template design guides the drill for the whole length of the fiber post. This procedure is done to make sure the drill is fully guided and stabilized from the first drop in the fiber post till finishing its removal(15).

The methods used in this study for fiber post removal were ultrasonic, fiber post drill, and fiber post drill with a guided template. Removal of fiber post in ultrasonic method done with a diamond-coated ultrasonic tip with water coolant to prevent heat generation decimated to the root canal walls and to prevent fracture of the tips(70,5). In the fiber post drill method, the fiber post was removed using a fiber post drill with a 1.4 mm diameter(92). The diameter of the drill was more than the drill used for fiber post preparation (1.2 mm) to ensure the removal of the whole fiber post and the luting cement. In the fiber post drill with guides method, the fiber post was removed through the fabricated endodontic guides to minimize the amount of removed dentin. During the fiber post-removal process, periapical radiographs were taken at intervals to prevent any deviation from the axis of the fiber post and root canal(69).

When evaluating the remaining dentin thickness after fiber post-removal at all root sections using the tested post-removal methods, the drill with guide achieved the lowest removed dentin than other tested groups. This may be attributed to the digital design of the guides providing the reliable and predictable location of root anatomy and fiber existing location(2,22). The precise fit between the guide tube and drill shank helped to maintain the drilling axis precisely to the target point(93,94).

This result is in agreement with **Maia et al.** in 2019, who reported that the endodontic guide is a promising option that is straightforward to execute and offers a safe procedure, avoiding radicular structure reduction crack propagation, root axis deviation, and perforation during fiber post removal[2]. In the same way, **Alfadda et al.** in 2022 confirm the usefulness of a guide for removing a fiber post[50]. Another study performed by **S. Mo et al.** in 2023 revealed that the accuracy of drilling with the novel 3D printed assembled guide system used for fiber post removal is superior to that of the freehand method[95]. Additionally, **Perez et al.** in 2020 conducted a case study aimed to illustrate the benefits of endodontic guides for the removal of fiber posts; it also concluded that the endodontic guide effectively spares the dental tissues and offers more excellent safety compared with other traditional means of post-removal[91].

Alternatively, the ultrasonic group achieved the highest removed dentin, which may be due to the malleability of the ultrasonic tip than the rigid drill, which makes it more challenging to direct the active ultrasonic vibrating tip to the area of application, which can remove more dentin during fiber post-removal[95,10]. In addition, the large diameter of the ultrasonic tip, in addition to its tip angle, allows the removal of more dentin than that removed by the drill, especially in the absence of magnification [10,95]. In contrast, using the drill removal method without a guide achieved a lower amount of removed dentin than the ultrasonic, which may be due to its smaller diameter compared to the ultrasonic tip diameter. On the other side, using the drill for post removal without guidance may increase the possibilities of drill deviation from the long axis of the fiber post removing more dentin than when using a drill with a guide[96,97,65,8]. The results of this study are in agreement with **Haupt et al.** in 2022, who confirmed the higher efficiency of the DT Post Removal Kit (drill) than the Sonic Flex Endo group with the preservation of sound dentin[64]. Also, **Schwindling et al.** in 2019 supported this finding[20]. On the contrary, the results of this study disagree with **Lindemann et al.** in 2005, who compared the efficiencies of a fiber post-removal system recommended by the manufacturer and ultrasonic tips. He noted that ultrasonic tips' removal efficiency was better than the kits. This may be attributed to the use of metal posts in the study group[63].

The only exception was detected at the buccal wall of the coronal section, revealing achieving the highest amount of removed dentin when using a drill with a guide. This may be due to the free hand insertion of the drill during the transient moving from the first guide to the second guide, which made the direction of the drill more buccally[58,17]. This result is in agreement with **M. Farronato et al.** in 2023, who concluded that there was a deviation at the coronal entrance point when using an endodontic guide in the access cavity[17].

Regarding the evaluation of the remaining dentin thickness at different root sections using the ultrasonic removal method, the coronal section achieved the highest amount of removed dentin in most circumstances. This may be attributed to the aggressive tapered design of the ultrasonic tip (taper 8%), allowing for increasing the amount of removed dentin at the coronal section than the middle and apical sections[10]. This result is in accordance with the results of **Cho et al.** in 2021, who confirmed that the ultrasonic removal method removed more dentin at the coronal section when compared with the Er,Cr:YSGG laser removal method[39].

When using the post-removal method with a drill without a guide, the highest amount of removed dentin at the middle third is at the buccal and lingual walls, while the apical section has the highest amount of removed dentin at the distal wall concomitantly with the coronal section that has the highest amount at the mesial wall. A possible explanation is the direction of the drill that cut more mesially at the coronal section and more distally at the apical section by the effect of the free hand technique. Furthermore, cutting more dentin at the middle section buccally and lingually may be directly related to the post drill designed to prepare the canal for a double conical-shaped fiber post, so the drill has a large diameter at its middle section compared to that used for post space preparation[20,98,99]. In agreement with the result, **Marchionatti et al.** in 2017, in a systematic review, compared conical posts to cylindrical posts [100].

Using a post-drill method with a guide achieved the highest amount of removed dentin at the coronal section towards the buccal and lingual walls, while the apical section has the highest amount of removed dentin distally that may be allowed by using the guide that makes the drilling procedures seem to be centralized with the long axis of the post with respecting the possible anatomical cross-sectional variations of the distal root canals used in the study[70,76,91].

When evaluating the residual remnants after fiber post-removal using the tested methods, although the aggressive removal of root dentin with ultrasonic is a big disadvantage of this tool, it represents the best method to remove remnants of fiber post and resin cement residuals over the others tested groups. This may be attributed to the vibration action of the ultrasonic that allows for breaking the cement dentin-resin interface by the effect of thermos-mechanical disassembly[39,102]. This is in agreement with **Haupt et al**. in 2018, who reported that removal kits left more residue on the root canals than sonic tips, regardless of fiber post type[8]. On the contrary, a previous systematic review in 2021 showed greater agility in removing fiber posts with manufactured removal kits, and the ultrasonic inserts seem to work better in removing fiber remnants and luting agents[75].

When evaluating the time needed for fiber post-removal using the tested methods, the drill with or without guide group achieved the faster method of fiber post-removal than the ultrasonic group. This may be attributed to the straightforward of the drill, and the excellent fitting of the guides makes the removal more accessible and faster[103,97]. Although there is no significance between drill with and without guide, the time required to remove fiber post and resin cement residuals is shorter in the case of drill with guide than without guide. This may be attributed to the feasibility and accuracy of guided fiber post-removal have been confirmed in vivo and in vitro(104,21). This technique reduces chairside time and the difficulty of a clinical operation and completes the repair treatment in a single visit. In addition, this technique increases accuracy and provides a predictable effect using two guides because the quantitative and the fiber post can be completely quantified and visualized using the preoperative virtual design(104). In agreement with this study, **Aydemir et al.** in 2018 compared the time required for two different fiber post-removal systems and found that the fiber post-removal time for the ultrasonic group was significantly longer than that for the removal kit(1). In addition, **Haupt et al.** in 2022 agreed with this study and stated that removal with the round bur and the sonic tip required significantly more time compared to the post-removal kit that has drilled for all types of posts(64). For further confirmation of this study, **Arukaslan and Aydemir** in 2019 **and Aydemir et al**. in 2018 determined the fiber post-removal times for all groups, and significant differences among the groups were found(70,1). In another way, a previous study by **Scotti et al.** in 2013 concluded that removal time was affected significantly by operator experience and post type(3). Also, **Liu et al.** in 2023 confirmed that guided fiber post-removal is practical and reduces difficulties, treatment duration, and appointment times while providing increased accuracy(104).

Based on the results of this study, the null hypothesis is rejected as the drill with guide group achieved the lowest dentin thickness removal and the fastest method for fiber post removal, while the ultrasonic group achieved the highest fiber post and resin cement residual remnants removal but with longer time needed.

# 7. Conclusions

Within the limitation of this in vitro study, the following conclusions are drawn:

1- Removal of fiber posts using a post drill with a guide is the safest method than using ultrasonics to preserve root dentin or even using the same drill without guidance.

2- Removal of fiber posts using a post drill with a guide needs the least required time than using ultrasonic or even using the same drill without guidance.

3- Although the ultrasonic removal method is effective in the removal of fiber posts and residual cement, it is a more destructive method than the post drill with or without guidance.

4- It is not necessary that the most efficient removal method has the shortest time removal period.

5- Using the post-removal guide has the prevailing of preserving the root dentin.

## 8. Recommendations

1- More research should be done to create a new innovative tool that is less invasive than the present methods.

2- More research should be done using the dynamic navigation guide for fiber post-removal to minimize the use of two guides in fiber post-removal in this study.

3- After removing the fiber post, more evaluation methods must be used to evaluate the remaining dentin thickness and the fiber post and resin cement residual remnants using Micro C.T.

4- Further studies should be done to modify drill kits for fiber post-removal.

5- Further clinical trials are required to evaluate this novel guide system under in vivo conditions.

6- The advancement of technology and devices requires more collaboration toward providing accessible, rapid, and cheap equipment.

7- Magnification should be one of the devices to manage the removal of fiber posts.

# 9. Summary

Glass fiber posts are the gold standard for treating endodontically treated teeth with insufficient coronal structure. Although it offers better retention and stress distribution when used, fiber post-fracture and endodontic retreatment is still the most common failure mode for glass fiber posts.

This study was directed to evaluate the effect of the fiber post removal on the remaining dentin thickness, the time needed to remove the fiber post, and the fiber post and resin cement residual remnants using different removal methods. This study chose 48 mandibular first molars following inspection and criteria evaluation. The samples were prepared, obturated, and distal root prepared for fiber post insertion and cementation. CBCT was done after fiber post-cementation and another scan after fiber post-removal. The teeth were grouped into three groups according to fiber post-removal methods. For group A, ultrasonic was used for fiber post removal; for group B, a drill was used for fiber post removal; and for group C, a drill with guide was used for fiber post removal.

The result showed that the ultrasonic group achieved the highest means of removing fiber posts and resin cement residual remnants from the other groups. The drill with guide group achieved the lowest mean of dentin thickness removal and the fastest group of fiber post removal than the other groups.

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## ١١. الملخص العربي


تُعَتَّبُر دعامات الالياف الزجاجية معيارًا ذهبيًا لعلاج الأسنان التي تعاني من هيكل سني تاجي غير كافٍ. على الرغم من أنها توفر قابلية تثبيت أفضل وتوزيع للضغط عند الاستخدام، إلا أن كسر الدعامات الليفية وإعادة العلاج الجذري لا تزال هي الأسباب الأكثر شيوعًا لفشل الدعامات الليفية.

تهدف هذه الدراسة إلى تقييم تأثير إزالة الدعامات الليفية على سمك العاج المتبقي، والوقت المطلوب لإزالة دعامة ليفية، وبقايا الدعامات الليفية والمواد اللاصقة الراتنجية باستخدام طرق إزالة مختلفة. تم اختيار إجمالي ٤٨ ضرس اول سفلي تم فحصها وتقييمها وفقًا للمعايير. تم تحضير العينات وإحضارها وتحضير الجذر البعيد لإدخال الدعامة الليفية وتثبيته. تم إجراء التصوير المقطعي لحساب الشعاع المخروط بعد تثبيت الدعامة الليفية ومسح آخر بعد إزالة الدعامة الليفية. تم تقسيم الأسنان إلى ثلاث مجموعات وفقًا لطرق إزالة الدعامات الليفية. تم استخدام الموجات فوق الصوتية لإزالة الدعامة الليفية في المجموعة أ، وتم استخدام اداة الحفر لإزالة الدعامة الليفية في المجموعة ب، وتم استخدام الحفر مع الدليل الموجه لإزالة الدعامة الليفية في المجموعة ج .

أظهرت النتائج أن المجموعة التي استخدمت الموجات فوق الصوتية حققت أعلى متوسط لإزالة الدعامة الليفية وبقايا المواد اللاصقة الراتنجية من المجموعات الأخرى. أما المجموعة التي استخدمت الحفر مع الدليل الموجه فقد حققت أدنى متوسط لإزالة سمك العاج وكانت أسرع مجموعة في إزالة العمود الليفي من المجموعات الأخرى.

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# تقييم غير جائر لسمك العاج المتبقي والوقت اللازم لإزالة دعامة ليفية باستخدام قالب موجه

رسالة مقدمة كجزء من مقومات الحصول على درجة الماجستير في علاج الجذور


**من**

**الطبيب / أحمد محمد أحمد مصلحي**

بكالوريوس طب وجراحة الفم والأسنان -٢٠١٠م،

كلية طب الأسنان - جامعة ٦ اكتوبر

طبيب أسنان بمستشفى كفر شكر التخصصي


٢٠٢٣م – ١٤٤٥هـ