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Assessment Of Radicular Dentin Preservation And Procedure Time Following Fiber Post Removal Using Different Treatment Techniques

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ABSTRACT

Objective
This in-vitro study investigated the effect of three fiber post-removal approaches - ultrasonic instrumentation, rotary post drilling, and guided rotary drilling - on radicular dentin preservation, residual fiber post and resin cement, and the time required for post removal. Cone-beam computed tomography (CBCT) was used to assess changes in dentin thickness and the presence of residual material before and after the intervention.
Materials and Methods
Forty-eight freshly extracted human mandibular first molars were selected according to predefined eligibility criteria. The distal roots were endodontically treated, prepared for fiber post placement, and restored with glass fiber posts cemented using a self-adhesive resin cement. The specimens were randomly assigned to three groups (n = 16) according to the post-removal technique. Group A underwent ultrasonic removal, Group B underwent removal with a rotary fiber post drill, and Group C underwent removal with the same rotary drill under a 3D-printed guiding template. CBCT scans were obtained before and after post removal. Changes in dentin thickness were determined at coronal, middle, and apical root levels. Residual fiber post and resin cement were assessed using a binary scoring system, and active post-removal time was recorded.
Results
The three techniques differed significantly in their effects on radicular dentin preservation, residual material, and removal time. The guided rotary technique produced the smallest amount of dentin removal at most evaluated root surfaces and levels. Ultrasonic instrumentation resulted in significantly greater dentin loss than both rotary techniques. Conversely, ultrasonic removal produced the lowest residual fiber post and resin cement scores. The ultrasonic technique required the longest mean removal time (102.38 ± 9.47 s), whereas the unguided and guided rotary techniques required 33.63 ± 3.88 s and 28.94 ± 1.73 s, respectively. The difference between the guided and unguided rotary techniques in removal time was not statistically significant.
Conclusions
Within the limitations of this laboratory study, guided rotary fiber post removal demonstrated the most favorable combination of radicular dentin preservation and procedural efficiency. Ultrasonic instrumentation provided more effective removal of residual post and cement material but was associated with greater dentin removal and a considerably longer procedure time. The choice of removal technique should therefore consider the balance between preservation of root structure and completeness of post-space cleaning.

Keywords: Fiber post removal; Radicular dentin preservation; Procedure time; Post removal techniques.

Introduction

The restoration of endodontically treated teeth plays a critical role in maintaining their structural integrity and long-term function. When a substantial amount of coronal tooth structure has been lost, an intraradicular post may be required to provide retention for the core and support the definitive restoration [1,2]. Fiber-reinforced posts are widely used because of their favorable mechanical and esthetic characteristics and are available in several forms, including glass-, quartz-, and carbon-fiber systems.

Despite their clinical advantages, previously placed fiber posts may need to be removed when endodontic retreatment is indicated, when the post or restoration has failed, or when complications such as post fracture occur [3]. Removal can be challenging because fiber posts are bonded to the surrounding dentin through a resin-based luting material. In addition, their appearance may closely resemble that of dentin, making visual differentiation difficult during instrumentation [4]. Consequently, post removal commonly involves drilling through the post to expose and subsequently regain access to the root canal system.

Several techniques have been proposed for removing intraradicular posts. These include ultrasonic instruments, rotary drills, specialized post-removal systems, and laser-assisted approaches [5]. Each technique has advantages as well as potential disadvantages. Ultrasonic instrumentation, for example, can facilitate disruption of the post–cement complex; however, the prolonged application of ultrasonic energy can generate heat. Temperature elevation at the external root surface may become clinically relevant when ultrasonic activation is maintained for extended periods, potentially placing surrounding periodontal tissues at risk [6,7].

Rotary instrumentation is another commonly used approach for fiber post removal. Although rotary drills can remove the post efficiently, uncontrolled or inaccurate drilling may result in unnecessary removal of sound dentin. Other possible complications include deviation from the original canal trajectory, root perforation, crack formation, and, in severe cases, root fracture [8]. Therefore, maintaining the drill within the original post and canal axis is essential for minimizing iatrogenic damage.

Recent developments in digital dentistry have introduced guided approaches for endodontic procedures. Guided endodontics combines three-dimensional imaging, digital planning, and computer-aided manufacturing to control the trajectory of an instrument during treatment [9,10]. In fiber post removal, CBCT data can be combined with surface-scanning information to determine the position of the post and surrounding root anatomy. A customized 3D-printed guide can subsequently be fabricated to direct the removal drill along a predetermined path [11]. The use of a customized guide may improve the positional accuracy of rotary instrumentation and reduce inadvertent removal of radicular dentin [12]. By restricting the direction of the drill, guided post removal may also decrease the possibility of deviation, perforation, or excessive enlargement of the post space. Nevertheless, evidence comparing guided rotary removal with conventional rotary and ultrasonic techniques remains limited, particularly when dentin preservation, residual post and cement, and procedure time are evaluated simultaneously.

Accordingly, the present study was designed to compare three fiber post-removal techniques—ultrasonic instrumentation, rotary drilling, and guided rotary drilling - with respect to the amount of radicular dentin removed, residual fiber post and resin cement, and the time required to complete post removal. CBCT imaging was used to quantify changes in dentin thickness and identify residual material following the intervention. The null hypothesis was that no significant differences would exist among the three post-removal techniques regarding radicular dentin removal, residual fiber post and resin cement, or the time required for post removal.

Materials and Methods:

This is an in vitro experimental, randomized, controlled, interventional prospective study. 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 [5].

Selection and Preparation of the Teeth

A total of 65 freshly extracted human mandibular molars were collected from the outpatient clinic of the Oral Surgery Department, Faculty of Dental Medicine, Al-Azhar University. The collected teeth were initially cleaned of hard deposits using an ultrasonic scaler (Guilin Woodpecker Medical Instrument Company, Guangxi, China). Subsequently, the teeth were disinfected by immersion in 2.5% sodium hypochlorite (NaOCl) solution (Clorox, Egyptian Company for Household Bleach, Cairo, Egypt) for 30 minutes. Any remaining soft tissue debris on the root surfaces was removed using a periodontal curette (Gracey curette, LM-Dental™, Finland). All teeth were examined under a dental operating microscope (DOM) (OMS2350 Dental Microscope, Zumax Medical Company, Jiangsu, China) at 8× magnification to identify any external root abnormalities, including root resorption, fractures, cracks, or root caries. Radiographic examination was subsequently performed in both buccolingual and mesiodistal projections using a size 2 digital intraoral sensor (IDA, Dabi Atlante, Brazil) to determine the number and configuration of the distal root canals. The teeth were selected according to predetermined inclusion and exclusion criteria. The inclusion criteria were: teeth extracted from patients aged 18–40 years; fully developed roots with mature apices; relatively straight roots with a curvature of 0–10°; distal roots exhibiting a Type I canal configuration according to Vertucci's classification [13]; and an overall tooth length ranging from 18 to 20 mm. Teeth were excluded if they exhibited root caries, root resorption, root fractures or cracks, immature apices, calcified root canals or pulp stones, more than one distal root canal, or a tooth length greater than 20 mm or less than 18 mm.

Following the screening process, 48 mandibular first molars from the 65 collected teeth met the eligibility criteria and were included in the study. The selected teeth were stored in 0.9% normal saline solution (Egypt Otsuka Pharmaceutical Co., S.A.E., 10th of Ramadan City, A.R.E.) until they were required for experimental procedures.

Fabrication of the Molds

Twelve rectangular plastic molds measuring 85 × 35 mm in diameter and 12 mm in thickness were fabricated. Each mold contained four cylindrical cavities, each measuring 12 mm in diameter and 12 mm in height. The external surfaces of the molds were labeled according to the corresponding root surfaces as buccal, lingual, mesial, distal, cervical, and apical. Two box-shaped cavities were prepared on the mesial and buccal aspects of each mold and subsequently filled with amalgam to facilitate proper orientation and repositioning of the specimens. The roots of all specimens were coated with two consecutive layers of colored nail polish (Yolo Cosmetics, Cairo, Egypt). Each mold was then positioned on a glass slab measuring 10 × 10 cm, and the individual cavities were filled with softened pink wax (El-Kods Wax Company, El-Mansoura, Egypt). The wax was softened using a laboratory wax heater (Wax Heater Pot 4; DENSHINE) at 58°C for 5 minutes until a sufficiently flowable consistency was achieved. Each tooth specimen was subsequently embedded in the softened wax up to the level of the cementoenamel junction (CEJ). During embedding, the teeth were carefully oriented so that the buccal, lingual, mesial, and distal surfaces corresponded with the respective markings on the mold. The root apices were maintained exposed and clearly visible.

Access Cavity Preparation

A conventional access cavity was prepared in all specimens. Initial penetration and deroofing were performed using a #3 round carbide bur (Mani Inc., Tochigi, Japan) mounted on a high-speed handpiece (T3 turbine, T3 mini, Dentsply Sirona, Bensheim, Germany) under water cooling. The canal orifices were initially located using a DG16 endodontic explorer (Kerr, USA). The access cavity walls were refined with an Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland), followed by ultrasonic refinement using an E3D tip (Guilin Woodpecker Medical Instrument Co., Guangxi, China). The pulp chamber was irrigated with 2 mL of 5.25% sodium hypochlorite using a 30-gauge double-side-vented needle (NaviTip, Ultradent Products Inc., South Jordan, UT, USA) attached to a 3-mL Luer-lock syringe. The canal orifices were then explored and negotiated with a #8 stainless-steel K-file (Mani Inc., Tochigi, Japan). The final access cavity had a triangular outline, with its base directed mesially and apex directed distally.

Root Canal Chemo-mechanical Preparation

Canal patency was established using a #10 K-file, and the working length was set 1 mm short of the apical foramen. Root canals were prepared using AF Blue rotary files (Fanta Dental Co., Ltd., Shanghai, China) at 350 rpm and 2 Ncm torque with an electric endodontic motor (C-Smart-7, Coxo, China). An #17/0.12 file was used for orifice enlargement, followed sequentially by #20/0.04, #25/0.04, and #30/0.04 files to the established working length. During preparation, canals were irrigated with 3 mL of NaOCl alternated with 17% EDTA after each instrument. Irrigation was performed using a 30-gauge double-side-vented needle positioned 2 mm short of the working length at a flow rate of 1 mL/min. Following completion of instrumentation, a final rinse with 3 mL normal saline was performed to neutralize the EDTA.

Obturation of the Samples

Following canal preparation, the canals were dried with #30/0.04 taper paper points and obturated using the lateral compaction technique. A #30/0.04 taper master gutta-percha cone (Meta Biomed, Korea) was fitted to the working length and radiographically verified. Adseal resin-based sealer (Meta Biomed, Korea) was applied before placement of the master cone. Lateral compaction was performed using a #30 finger spreader (Mani Inc., Tochigi, Japan), followed by insertion of #30/0.02, #25/0.02, and #20/0.02 accessory gutta-percha cones until adequate compaction was achieved. Excess gutta-percha was removed to the canal orifice, and the pulp chambers were cleaned with alcohol-moistened cotton pellets. Buccolingual and mesiodistal radiographs were obtained to verify the quality of obturation. The specimens were stored at room temperature in a sealed container on moistened gauze for one week to allow complete setting of the sealer.

Post-Space Preparation, Insertion and Cementation

A standardized 14-mm post space was prepared from a fixed reference point at the tip of the distobuccal cusp, leaving 4–5 mm of apical gutta-percha for apical sealing. Post-space preparation was performed using the Olipost Light fiber post drill (1.2 mm diameter; Olident, Cologne, Germany) mounted on a low-speed handpiece (NSK Pana Air, Japan) driven by an electric motor (Surgic AP, NSK, Tochigi, Japan) at 10,000 rpm and 5 Ncm torque. The canal was irrigated with 2 mL normal saline after each 5-mm penetration, using a 30-gauge double-side-vented needle, while the drill flutes were cleaned with moistened gauze. Radiographs were obtained to confirm complete removal of gutta-percha from the prepared post space. The canals were then rinsed with 5 mL distilled water and dried with paper points. The glass fiber post was finally inserted to the full 14-mm prepared depth, with its rubber stopper adjusted to ensure proper seating. Self-adhesive resin cement Pentron Breeze (Pentron clinical, USA; BR) was injected into the post spaces then 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.

Grouping of the Samples

The 48 specimens were randomly allocated into three groups (n = 16) according to fiber post-removal technique:

- **Group A:** Ultrasonic tip removal.
- **Group B:** Fiber post drill removal.
- **Group C:** Fiber post drill removal using a 3D-printed guide.

Pre-intervention CBCT Scanning

CBCT scans were obtained for all specimens after fiber post cementation using a Vatech Green X™ system (Vatech, Seoul, Korea) at a voxel size of 0.150 mm, 94 kV, 13.3 mA, and 2.9-second exposure time. Image brightness and contrast were standardized using the manufacturer's software.

Design and Fabrication of the Guided Template

The CBCT datasets were exported in DICOM format, while surface scans of the specimens were obtained using a Medit i500 intraoral scanner (Medit Corp., Seoul, Korea) and saved as STL files. Both datasets were imported into Blue Sky Plan software (V4.1.0; Blue Sky Bio, Grayslake, IL, USA) and superimposed by matching the tooth surfaces. The fiber post position was incorporated into the digital planning to design the guides.Two guide designs were fabricated using a Phrozen Sonic 4K 3D printer (Phrozen, Taiwan) with photosensitive ABS-like resin. The first guide controlled the drill during the initial 3 mm of post removal, whereas the second guided the drill along the entire length of the fiber post.

Fiber post removal

Group A: ultrasonic technique

Fiber posts were removed using a diamond-coated ultrasonic tip (RT2, EMS, Switzerland) operated with an ultrasonic unit (DTE D5, Woodpecker, China) at maximum Endo-mode power with water cooling. The tip was maintained parallel to the long axis of the post and root and applied to the center of the post until the underlying gutta-percha became visible. Instrumentation was interrupted every 15 seconds to limit heat generation and prevent tip fracture. Periodic periapical radiographs were obtained to monitor the removal process.

Group B: Rotary drill technique

Fiber posts were removed using a 1.4-mm Hi-Rem fiber post drill (Overfibers, Bologna, Italy) operated at 10,000 rpm and 5 Ncm torque. The drill path was irrigated with 2 mL normal saline after each 5-mm progression, and the drill flutes were cleaned with moistened gauze. Removal was periodically assessed radiographically until complete post removal was achieved.

Group C: Guided Rotary drill technique

Fiber posts were removed using the same 1.4-mm fiber post drill under the fabricated 3D-printed guides. The drill was operated at 10,000 rpm and 5 Ncm torque. The guide was repositioned as required during each 5-mm progression, followed by irrigation with 2 mL normal saline and cleaning of the drill flutes. Periodic periapical radiographs were used to verify the progress and completion of post removal.

Post-intervention CBCT Scanning

Post-removal CBCT scans were obtained using the same equipment, exposure parameters, and imaging protocol used for the pre-intervention scans.

Evaluation Methods

a. **Remaining Dentin Thickness**

Pre- and post-intervention CBCT scans were superimposed using InVivo 5 software (Anatomage, San Jose, CA, USA) to ensure measurements were performed at identical levels. Three reference levels were established at 2, 4, and 6 mm apical to the distal canal orifice, representing the coronal, middle, and apical regions, respectively. At each level, dentin thickness was measured simultaneously on the buccal, lingual, mesial, and distal aspects of the canal before and after post removal.

b. Fiber Post and Resin Cement Residuals

Post-removal CBCT scans were evaluated for residual fiber post and resin cement using a binary scoring system adapted from Vasconcelos et al. [14]. A score of **0** indicated complete absence of residual material, whereas **1** indicated the presence of fiber post and/or resin cement remnants [15].

c. Fiber Post Removal Time

Removal time was recorded using a stopwatch, starting when the instrument engaged the fiber post and ending when the entire post was removed. Any interruption in instrumentation was excluded from the active removal time.

Statistical Analysis

Data were analyzed using IBM® SPSS® Statistics Version 20 for Windows. Means and standard deviations were calculated for each group. Data normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Remaining dentin thickness and removal-time data showed normal distributions and were analyzed parametrically, whereas residual-material scores were non-parametric. Statistical significance was set at $P \leq 0.05$.

Results

1. Evaluation of Remaining Dentin Thickness

Remaining dentin thickness was analyzed using repeated-measures ANOVA, paired-sample t-tests, one-way ANOVA, and Tukey post-hoc tests, as appropriate.

➢ **Comparison Between Removal Methods**

A. Coronal Section

Group A showed the greatest dentin removal on the distal (0.174 ± 0.002 mm), mesial (0.246 ± 0.006 mm), and lingual (0.236 ± 0.011 mm) surfaces, whereas Group C showed the lowest values on the distal (0.093 ± 0.003 mm), mesial (0.086 ± 0.002 mm), and lingual (0.107 ± 0.003 mm) surfaces. On the buccal surface, Group C showed the highest value (0.209 ± 0.012 mm), while Group B showed the lowest (0.140 ± 0.007 mm). Significant differences were detected among the groups for all surfaces ($p < 0.001$).

B. Middle Section

Group A demonstrated the greatest dentin removal on the distal (0.181 ± 0.002 mm), mesial (0.155 ± 0.006 mm), buccal (0.307 ± 0.008 mm), and lingual (0.242 ± 0.005 mm) surfaces. Group C showed the lowest values on the distal (0.099 ± 0.002 mm), mesial (0.091 ± 0.002 mm), and lingual (0.101 ± 0.001 mm) surfaces, while Group B showed the lowest buccal value (0.167 ± 0.008 mm). Significant differences were observed among the groups for all surfaces ($p < 0.001$).

C. Apical Section

Group A exhibited the greatest dentin removal on all surfaces: distal (0.173 ± 0.004 mm), mesial (0.114 ± 0.002 mm), buccal (0.249 ± 0.009 mm), and lingual (0.268 ± 0.016 mm). Group C showed the lowest values on the distal (0.106 ± 0.003 mm), mesial (0.071 ± 0.002 mm), and buccal (0.076 ± 0.002 mm) surfaces, while Group B showed the lowest lingual value (0.103 ± 0.007 mm). Significant differences were observed among the groups for all surfaces ($p < 0.001$).

➢ **Comparison Between Root Sections**

A. Ultrasonic Removal (Group A)

Dentin removal varied significantly among root sections on the distal ($p = 0.040$), mesial, and buccal surfaces ($p < 0.001$), but not on the lingual surface ($p = 0.097$). The greatest distal removal occurred in the middle section (0.181 ± 0.002 mm), while mesial and buccal removal was greatest coronally (0.246 ± 0.006 and 0.330 ± 0.016 mm, respectively). The greatest lingual removal was observed apically (0.268 ± 0.016 mm).

B. Drill Removal (Group B)

Significant differences among root sections were found on the distal ($p = 0.035$), mesial ($p < 0.001$), buccal ($p = 0.026$), and lingual ($p < 0.001$) surfaces. The greatest removal occurred apically on the distal surface (0.113 ± 0.002 mm), coronally on the mesial surface (0.108 ± 0.002 mm), and in the middle section on the buccal (0.167 ± 0.008 mm) and lingual (0.156 ± 0.008 mm) surfaces.

C. Guided Drill Removal (Group C)

Significant differences among root sections were observed on all surfaces: distal ($p = 0.014$), mesial, buccal ($p < 0.001$), and lingual ($p = 0.012$). The greatest removal occurred apically on the distal (0.106 ± 0.003 mm) and mesial (0.091 ± 0.002 mm) surfaces, whereas buccal and lingual removal was greatest coronally (0.209 ± 0.012 and 0.107 ± 0.003 mm, respectively).

2. Evaluation of Fiber Post and Resin Cement Residuals

Residual fiber post and resin cement were evaluated using Kruskal–Wallis and Friedman tests, followed by Mann–Whitney and Wilcoxon tests when appropriate.

a) Comparison Between Removal Methods

Group A demonstrated significantly fewer residual materials than Groups B and C in all root sections. In the coronal section, residual scores were 0.13 ± 0.09, 0.50 ± 0.13, and 0.56 ± 0.13 for Groups A, B, and C, respectively ($p = 0.026$). In the middle section, the corresponding values were 0.19 ± 0.10, 0.56 ± 0.13, and 0.69 ± 0.12 ($p = 0.014$). In the apical section, values were 0.25 ± 0.11, 0.63 ± 0.13, and 0.75 ± 0.11, respectively ($p = 0.014$). No significant differences were detected between Groups B and C.

b) Comparison Between Root Sections

No significant differences in residual material were observed among the coronal, middle, and apical sections within any group. The corresponding p-values were 0.549 for Group A, 0.717 for Group B, and 0.459 for Group C.

3. Evaluation of time Required for Fiber Post Removal

A significant difference was observed among the three removal techniques ($p < 0.001$). Group A required the longest removal time (102.38 ± 9.47 seconds), followed by Group B (33.63 ± 3.88 seconds), whereas Group C required the shortest time (28.94 ± 1.73 seconds). Group A differed significantly from both Groups B and C, while no significant difference was found between Groups B and C.

Discussion

The removal of an intraradicular fiber post is a technically demanding procedure because adequate access to the underlying root canal must be obtained while preserving as much sound radicular structure as possible. Excessive dentin removal may compromise the mechanical resistance of the root and increase the risk of subsequent complications. The present in-vitro investigation compared ultrasonic instrumentation, conventional rotary drilling, and guided rotary drilling using three principal outcomes: radicular dentin preservation, residual post and resin cement, and post-removal time. Forty-eight mandibular first molars were selected from an initial sample of 65 extracted teeth after application of standardized inclusion and exclusion criteria. The distal roots of mandibular first molars were selected because their relatively straight anatomy facilitates standardized post-space preparation and provides a suitable model for comparing different removal procedures [16]. Restricting the age of the donors was intended to reduce variations in dentin characteristics associated with age-related changes and increased deposition of secondary or sclerotic dentin [17]. A standardized experimental setup was used to maintain the orientation of the specimens throughout CBCT acquisition and the subsequent post-removal procedures. The reference markings incorporated into the molds facilitated identification of the buccal, lingual, mesial, and distal root surfaces during image analysis [18]. Conventional access cavities were prepared to provide sufficient access for post-space preparation and instrumentation. Ultrasonic refinement of the chamber walls was subsequently performed to obtain a smoother surface and facilitate accurate adaptation of the guiding templates [19]. The root canals were prepared to a final size of #30/0.04. This preparation size was selected to provide a standardized canal configuration while avoiding unnecessary enlargement of the root canal walls [20]. A 14-mm post space was then created while maintaining approximately 4–5 mm of apical gutta-percha to preserve the apical seal. A 1.2-mm drill was used for post-space preparation, with periodic cleaning of the drill flutes to maintain cutting efficiency [21].The use of pre- and post-removal CBCT scans allowed changes in radicular dentin thickness to be assessed at corresponding anatomical levels. The digital workflow used for the guided group incorporated both CBCT and surface-scan data. This enabled the position of the fiber post to be incorporated into the guide design and allowed the drill trajectory to be predetermined before the removal procedure.

Radicular dentin preservation

The principal finding concerning dentin preservation was that the guided rotary technique resulted in the smallest overall amount of radicular dentin removal. The improvement observed with the guided technique can reasonably be related to the controlled trajectory provided by the customized guide. Rather than relying entirely on operator visualization and manual control, the drill was constrained to a digitally planned pathway corresponding to the location of the fiber post. This may have limited lateral displacement of the instrument and consequently reduced unnecessary enlargement of the post space. Previous investigations have similarly suggested that guided approaches can improve the accuracy of fiber post removal and reduce the risk of damaging surrounding root structure [22,23]. Maia et al. [24], described a digitally planned guide specifically for adhesive fiber post removal and emphasized its potential to provide a controlled and conservative procedure. Comparable advantages have subsequently been reported by Alfadda et al. [25] and Mo et al. [26], who demonstrated improved drilling accuracy with guided systems.

The ultrasonic group exhibited the greatest amount of dentin removal at most evaluated surfaces. Several factors may explain this observation. Unlike a rotary drill operating within a relatively constrained path, an ultrasonic tip produces multidirectional vibration and may be more difficult to maintain precisely within the center of the post. Furthermore, the geometry and relatively large working dimensions of the ultrasonic tip may allow it to contact the surrounding dentin during post removal [27]. These characteristics could explain the greater loss of radicular structure observed in the present study. The conventional rotary group showed less dentin removal than the ultrasonic group. Nevertheless, the absence of a mechanical guide means that the direction of the drill remains dependent on operator control. Even a small deviation from the original post axis can result in asymmetric removal of dentin. Therefore, although the rotary drill is capable of efficiently cutting the fiber post and surrounding cement, its freehand use may not provide the same level of positional control achieved with a guided system [28]. The present findings are generally consistent with studies reporting greater preservation of sound dentin when dedicated rotary systems are used compared with ultrasonic instrumentation [11]. However, they differ from the findings of Lindemann et al. [29], who reported greater efficiency for ultrasonic instruments than for a post-removal kit. Differences in the type and design of the posts investigated may account for this discrepancy. Fiber posts and metallic posts behave differently during removal, and the cutting and vibrational characteristics of the instruments may therefore produce different outcomes depending on post composition. An interesting finding in the current study was observed at the buccal surface of the coronal root section. In this specific location, the guided group demonstrated greater dentin removal than the other groups. This result does not necessarily indicate failure of the guide throughout the procedure. Instead, it may be associated with the transition between the two guiding templates. During this stage, the drill was temporarily introduced without complete guidance, potentially allowing a slight buccal displacement at the coronal entry point. The distribution of dentin removal within the root also differed according to the instrumentation method. In the ultrasonic group, the coronal region generally exhibited greater dentin loss. The tapered geometry of the ultrasonic tip may contribute to this pattern because a greater portion of the active tip engages the coronal region during instrumentation [30]. Comparable findings have been reported by Cho et al. [31] who observed greater coronal alteration following ultrasonic fiber post removal. With conventional rotary instrumentation, the pattern was less uniform. Increased dentin removal on the buccal and lingual surfaces of the middle root section may be related to the geometry of the post-removal drill. The drill used in the present investigation was designed for removal of a fiber post with a double-conical configuration and consequently has a relatively larger diameter in its middle region. This geometry may result in greater contact with the buccal and lingual walls during freehand drilling. Variations in drill direction may additionally explain the greater mesial removal coronally and distal removal apically. The guided rotary technique produced a more centralized removal pattern overall. Because the guide restricts the drill trajectory, variations in the amount of dentin removed are more likely to reflect differences in the natural cross-sectional anatomy of the distal root rather than substantial operator-induced deviation. The distal roots of mandibular first molars may exhibit variations in their buccolingual and mesiodistal dimensions, which could influence the amount of dentin surrounding the post at different levels [32,33].

Residual fiber post and resin cement

Although the guided rotary technique was the most conservative with respect to radicular dentin, ultrasonic instrumentation produced the lowest residual scores for fiber post and resin cement. Thus, the technique that best preserved the root structure was not necessarily the technique that produced the cleanest post space. The superior removal of residual material observed with ultrasonic instrumentation may be related to the mechanical vibration produced by the active tip. Ultrasonic energy can disrupt the interface between the post, resin cement, and dentin, facilitating detachment of residual material that may remain after rotary drilling [34]. The ability of the ultrasonic tip to contact irregular areas within the post space may also contribute to the more complete removal of small remnants. These findings are clinically relevant because residual fiber and luting material may interfere with subsequent cleaning and shaping during endodontic retreatment. However, the improved cleanliness obtained with ultrasonic instrumentation must be considered alongside its greater dentin-removal effect. Therefore, the most appropriate technique may depend on the clinical priority. When preservation of the root is the primary concern, guided rotary removal may be preferable; when residual post or cement remains after the principal removal procedure, ultrasonic instrumentation may be useful as a supplementary technique.

Post-removal time

A marked difference in procedure time was observed among the three techniques. Ultrasonic instrumentation required considerably more time than either rotary method. The shorter duration associated with rotary instrumentation may be explained by the direct cutting action of the drill. Once the drill is positioned within the fiber post, material can be removed progressively along the predetermined path. Ultrasonic removal, in contrast, involves repeated application of the vibrating tip and intermittent pauses, which may increase the overall procedure time. In the present study, interruptions were incorporated into the ultrasonic protocol to limit heat generation and reduce the possibility of instrument fracture. Although the guided group demonstrated the shortest mean removal time, the difference between the two rotary groups was not statistically significant. Nevertheless, the numerical reduction in time observed with the guided technique suggests that improved instrument control may facilitate the procedure. The guide can stabilize the drill and reduce the need for repeated visual corrections, potentially making the removal process more straightforward.

The present findings are consistent with previous investigations reporting longer removal times for ultrasonic techniques compared with dedicated rotary post-removal systems [35]. Aydemir et al. [1] reported significant differences in removal time between fiber post-removal systems, while Haupt et al. [36] similarly demonstrated longer working times with techniques that relied on sonic or rotary burs compared with dedicated post-removal systems. Other investigations have also suggested that guided post removal can reduce procedural difficulty and treatment duration while improving the predictability of the drilling trajectory [37].

Clinical implications

The findings of this study indicate that the choice of a fiber post-removal technique involves a compromise between structural preservation, completeness of material removal, and treatment time. Ultrasonic instrumentation was the most effective approach for eliminating residual fiber post and resin cement, but this benefit was accompanied by greater radicular dentin removal and a substantially longer procedure. Conventional rotary drilling provided a faster alternative with less dentin loss than ultrasonic instrumentation, although the absence of guidance leaves greater potential for deviation from the intended pathway. The guided rotary technique demonstrated the most favorable overall balance among the evaluated parameters. Its principal advantage was preservation of radicular dentin, while it also produced the shortest numerical removal time. The guide therefore appears particularly useful when maintaining the original root anatomy is considered a priority. A combined strategy involving guided rotary removal followed by selective ultrasonic cleaning may warrant investigation in future studies. These findings indicate that efficiency should not be defined solely by the completeness of post removal; preservation of the remaining root structure is equally important when selecting a retreatment technique.

Limitations

Several limitations should be considered when interpreting the present findings. First, the investigation was conducted under in-vitro conditions using extracted mandibular first molars with relatively standardized root anatomy. Clinical conditions may differ because of variations in patient anatomy, access, moisture control, operator experience, and periodontal support. Second, the study evaluated dentin changes using CBCT, whose spatial resolution is lower than that of micro-computed tomography. Third, the study used a specific fiber post, resin cement, ultrasonic tip, and rotary drill system; therefore, the findings may not be directly applicable to all commercially available materials and instruments. Finally, the effect of operator experience was not independently evaluated. Future investigations should consider micro-CT analysis, different post and cement systems, a wider range of root anatomies, and clinical studies to determine whether the advantages observed with guided rotary removal can be reproduced under clinical conditions.

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