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A laboratory study comparing the static navigation technique using a bur with a conventional freehand technique using ultrasonic tips for the removal of fibre posts

Francesc Abella Sans[1] | **Zeena Tariq Alatiya**[1] | **Gonzalo Gómez Val**[1] | **Venkateshbabu Nagendrababu**[2] | **Paul Michael Howell Dummer**[3] | **Fernando Durán-Sindreu Terol**[1] | **Juan Gonzalo Olivieri**[1]

[1]Department of Endodontics, Universitat Internacional de Catalunya, Barcelona, Spain

[2]University of Sharjah, College of Dental Medicine, Department of Preventive and Restorative Dentistry, Sharjah, United Arab Emirates

[3]School of Dentistry, College of Biomedical and Life Sciences, Cardiff University, Cardiff, UK

Correspondence
Francesc Abella Sans, Department of Endodontics, Universitat Internacional de Catalunya, Sant Cugat del Vallès, Barcelona, Spain.
Email: franabella@uic.es

Abstract

Aim: There are currently no high-quality studies comparing the static navigation technique with conventional methods of fibre post removal. The aim of this *ex vivo* study was to compare the effectiveness of fibre post removal between a static navigation technique and a conventional freehand technique using ultrasonics by experienced and inexperienced operators.

Methodology: Forty-eight extracted single-rooted human premolars were root-filled. A fibre post was cemented in all 48 teeth, which were then divided randomly into the following groups: static navigation group using burs; static navigation-ultrasonic group; and non-guided group using ultrasonic tips. The following parameters were evaluated for both experienced operators and inexperienced operators: reaching the gutta-percha root filling successfully, the time required to remove the entire post, the occurrence of lateral root perforations, and the amount of root dentine removed. The Kolmogorov–Smirnov test was used to examine the normality of the data; the ANOVA test was used to compare the significant differences among groups; and Tukey tests were used for all two-by-two comparisons. The significance level was set at 0.05.

Results: In the static navigation group, the gutta-percha was reached significantly more frequently than in the non-guided group ($p < .05$). The static navigation approach required significantly less time than the non-guided approach to reach the gutta-percha ($p < .05$). The total removal of posts was significantly different between groups ($p < .05$), but there was no significant difference between experienced and inexperienced operators in the static navigation group ($p > .05$). More perforations were associated with the non-guided group than with the other two groups. The total mean loss of dentine in the non-guided group in all directions was 0.39 (±0.17) mm, with 0.25 (±0.09) mm for experienced, and 0.42 (±0.16) mm for inexperienced operators.

Conclusion: When compared to a conventional ultrasonic technique for the removal of fibre posts, the static navigation method using burs resulted in less dentine removal, more rapid access to the gutta-percha root filling, less overall time to remove the posts, and fewer complications. When using static navigation, there was no difference in performance between experienced and inexperienced operators.

KEYWORDS

endodontics, fibre post, guided endodontics, post removal, root canal treatment, static navigation technique

INTRODUCTION

Root filled teeth are often restored with posts when the remaining tooth structure does not provide sufficient retention for the restoration (Bhuva et al., 2021). Fibre posts have a modulus of elasticity similar to radicular dentine, allowing them to flex under load and thus reduce the risk of root fracture (Barcellos et al., 2013; Chieruzzi et al., 2012). On the other hand, metal posts are rigid and transfer forces along their long axis, increasing the risk of root fracture (Barcellos et al., 2013; Bhuva et al., 2021; Chieruzzi et al., 2012; Tay & Pashley, 2007). A meta-analysis revealed that fibre posts had higher overall survival rates over the medium term (3 to 7 years) than metal posts (Wang et al., 2019), whilst another meta-analysis concluded that the overall survival rate for fibre posts was 92.8%, and for metal posts, it was 78.1% (Tsintsadze et al., 2022).

When root filled teeth with post-retained restorations and post-treatment periapical disease require root canal retreatment, the post must be removed to regain access to the root canal system (Anderson et al., 2007; Perez et al., 2020). The removal of a metal post and its luting cement is often time-consuming and risks damaging the residual tooth structure (Gesi et al., 2003). However, during removal of metal posts, the operator can easily identify the post and differentiate it from the root dentine. Fibre posts are difficult to distinguish from the root dentine especially deep within the canal space, even with the use of a dental microscope (Cho et al., 2021). In addition, due to their lower modulus of elasticity, fibre posts cannot be predictably removed with ultrasonics (Cho et al., 2021). In order to minimize the loss of dentine, establishing the interface between the root filling and the end of the post is an important component of the procedure (Cho et al., 2021). Care must also be taken to avoid aberrant angulation, root perforations, crack propagation, and root fracture (Altshul et al., 1997; Castrisos & Abbott, 2002; Gesi et al., 2003; Haupt et al., 2018; Schwindling et al., 2020; Scotti et al., 2013). Round burs, ultrasonic tips, and specifically designed removal kits have been proposed as methods for removing fibre posts (Anderson et al., 2007; Gesi et al., 2003, Scotti et al., 2013). Although ultrasonic devices have been reported to be the most commonly used technique (Lindemann et al., 2005), they have disadvantages, such as generating heat and causing dentine cracks, which reduces the fracture resistance of roots (Altshul et al., 1997, Schwindling et al. 2020). Therefore, safer alternative methods are required.

Guided endodontics may be either static or dynamic. Static guided endodontics requires the fabrication of three-dimensional (3D) printed templates using cone beam computed tomography (CBCT) images, scans, and virtual imaging software for access cavity preparation (Krastl et al., 2016) and endodontic surgery (Strbac et al., 2017). This technique has been reported to be an effective approach for obtaining an optimal clinical outcome, with the advantages of being highly accurate and rapid, as well as increasing the conservation of tooth structure and reducing the risk of iatrogenic damage (Anderson et al., 2018; Connert et al., 2018; Krastl et al., 2016; Maia, de Carvalho, et al., 2019; Moreno-Rabié et al., 2020; Zehnder et al., 2016). Dynamic navigation systems (DNS) utilize computer-assisted guided technology, multiple cameras, and motion tracking devices connected to the dental handpiece and patient. The system continuously compares the path created within the tooth or bone with the virtually planned drill path using software which interprets CBCT images of the teeth and jaws (Vasudevan et al., 2022). According to a systematic review, difficult clinical scenarios such as teeth with root canal obliteration, preparing conservative access cavities, root canal retreatment, and microsurgery can be effectively managed by dynamic navigation systems with fewer iatrogenic errors in less time (Vasudevan et al., 2022). However, the evidence in this systematic review is limited because the articles included were either case reports or laboratory-based studies; none were clinical studies.

Three case reports (Cho et al., 2021; Maia, Moreira Júnior, et al., 2019; Schwindling et al., 2020) utilized the static navigation technique to remove fibre posts from maxillary anterior teeth, with one case report (Perez et al., 2020) using the technique to remove fibre posts from maxillary posterior teeth. These four reports concluded that removal of a fibre post using a static navigation technique was a rapid and reliable procedure that caused little damage to the remaining tooth structure and was associated with few post-endodontic management complications. The case reports (Perez et al., 2020; Schwindling et al., 2020) recommended that future studies should be conducted to validate the accuracy and reproducibility of the method in comparison to more conventional methods for fibre post removal (Perez et al., 2020).

The purpose of this laboratory study was to compare fibre post removal between a conventional freehand technique using ultrasonic tips with a static navigation technique using burs. The key factors investigated were success in reaching the gutta-percha root filling, the time required to remove the entire post, the occurrence of lateral root perforations, and the removal of root dentine. The study also compared experienced operators with inexperienced operators whilst using both techniques.

MATERIALS AND METHODS

The manuscript is reported according to the Preferred Reporting Items for Laboratory studies in Endodontology (PRILE) 2021 guidelines (Nagendrababu et al., 2021). The methodology is presented in Figure 1. The study was approved by the Ethics Committee of the Faculty of Health Sciences at Universitat Internacional de Cataluña in 2021 (END-ECL-2020-09).

Sample size calculation

The sample size was calculated according to the mesiodistal deviation of the bur tip in static navigation access cavity preparations reported by Connert et al. (2017). Twenty-four samples were required in the static navigation group and 24 in the non-guided group to recognize a difference in the minimum apical deviation of 0.15 mm from the tip of the fibre post, assuming the reported standard deviation of 0.18 mm and anticipating no specimen loss during the study (alpha risk of 0.05 and beta risk of 0.2).

Tooth selection and standardization

Forty-eight single-rooted sound human premolar teeth free from caries and existing restoration, extracted for orthodontic purposes from patients aged 18 to 22, were used. Calculus and debris were removed from the teeth using a hand scaler and the teeth polished with a rubber cup and pumice. To minimize anatomical variables between the samples, the selected teeth had uniform occlusal anatomy and similar crown diameter, root diameter, and length. This was achieved by measuring the buccolingual, mesiodistal, and occlusal–gingival dimensions and occlusal–gingival height using a digital calliper and a digital radiographic system (KodakRVG 6100; Carestream Health, Rochester, NY, USA).

Operator groups

Six dentists with a Master's in Endodontics with at least 3 years of experience in specialist practice who were employed as academic staff constituted the experienced group, whilst six postgraduate students in the third year of a Master's degree in Endodontics comprised the inexperienced group. Each operator removed four posts, two using a standardized static navigation technique and two using a standardized non-guided technique. The methods of removing the fibre post using both techniques were explained in detail to each operator before starting the study.

Experimental groups

The teeth were randomly divided into three groups as follows:

Group I—The static navigation group (a drill with a diameter of 0.75 mm and a length of 22 mm (FFDM-Pneumat Tivoly, Bourges, France) was used) ($n=24$):

- *Subgroup inexperienced* ($n=12$): Fibre post removal by postgraduate students registered on a Master's in Endodontics.
- *Subgroup experienced* ($n=12$): Fibre post removal by academic staff (teachers) with a Master's in Endodontics.

Group II—The static navigation–ultrasonic group: After completion of post removal with the static navigation approach, the guide for the bur was removed and an ultrasonic device (Start-X No.3, Dentsply Sirona, Ballaigues, Switzerland) was used to remove remnants of the cement used to lute the posts in a similar way to that used by the non-guided group. Thus, Group II was the continuation of Group I, and the same samples were used.

Group III—Non-guided group (Ultrasonic tips, Start-X No.3, Dentsply Sirona, Ballaigues, Switzerland) was used ($n=24$):

- *Subgroup non-guided—inexperienced* ($n=12$): Fibre post removal by postgraduate students registered on a Master's in Endodontics.
- *Subgroup non-guided—experienced* ($n=12$): Fibre post removal by academic staff (teachers) with a Master's in Endodontics.

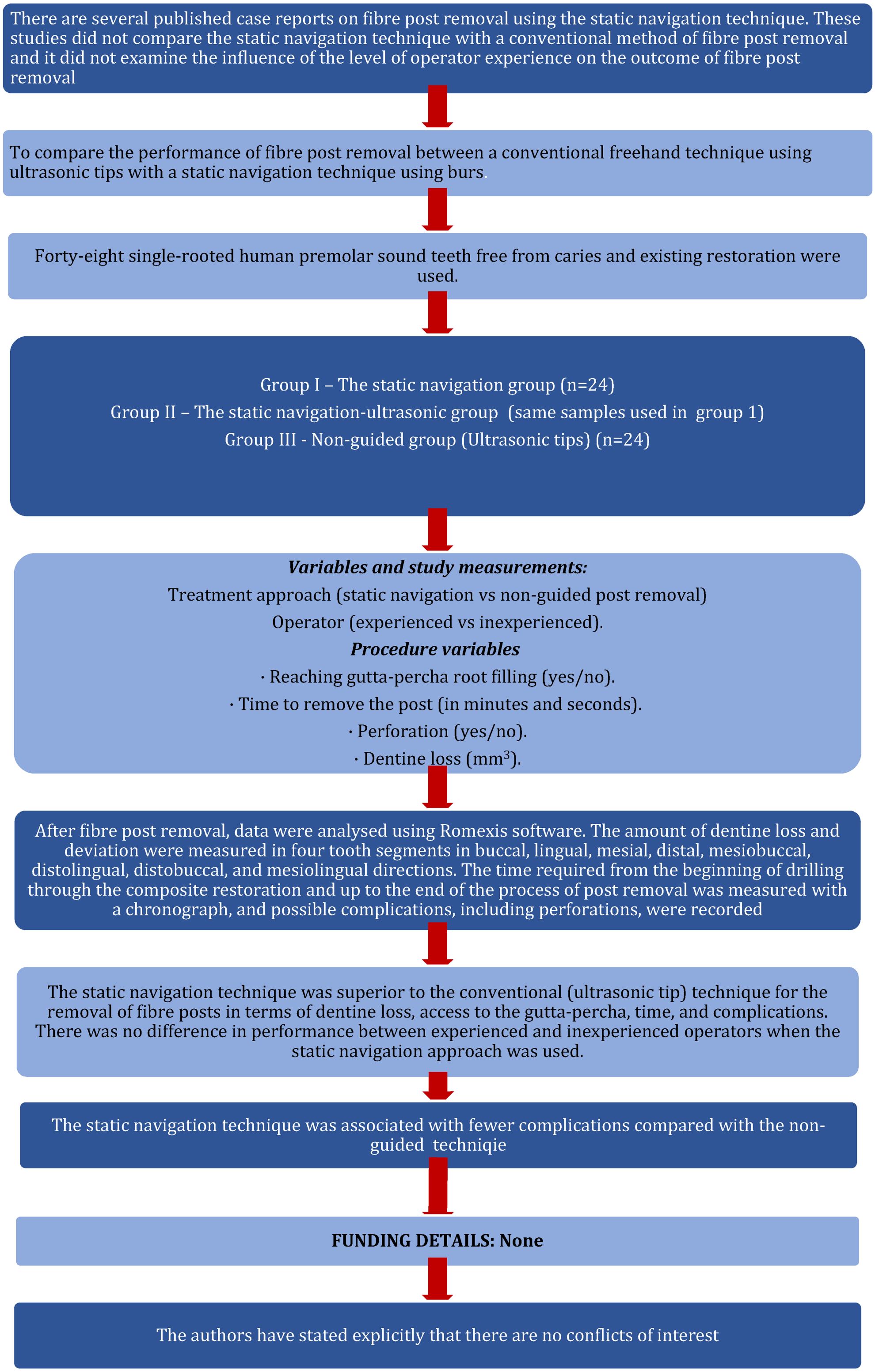

FIGURE 1 PRILE flowchart.

Variables and study measurements

Treatment approach (static navigation vs. non-guided post removal).

Operator (experienced vs. inexperienced).

Procedure variables.

- Reaching the gutta-percha root filling successfully (yes/no).
- Time to remove the post (in minutes and seconds).

- Perforation (yes/no).
- Dentine loss (mm^3): the difference in dentine thickness before and after post-removal in four segments of each root in buccal, lingual, mesial, distal, mesiobuccal, distolingual, distobuccal, and mesiolingual directions according to Gambill et al. (1996).

Root canal preparation and filling

A single operator determined the working length (WL) of each root canal by direct vision using a size 15 K-file (Mani, Tochigi, Japan), 0.5 mm short of the apical foramen. Root canals were prepared by the same operator using size 25, .07 taper and size 45, .05 taper WaveOne Gold instruments (Dentsply Sirona, Ballaigues, Switzerland) in a reciprocating motion. Root canals were irrigated using 10 mL of a 2.5% NaOCl solution. After preparation, the root canals were dried with paper points (Dentsply Sirona, Ballaigues, Switzerland). A standard-size gutta-percha cone (Dentsply Sirona, Ballaigues, Switzerland), coated with AH Plus sealer (Dentsply Sirona, Ballaigues, Switzerland), was gently seated at the working length of each tooth. The canals were filled using a warm hybrid technique with size 45–60 gutta-condensers (Dentsply Sirona, Ballaigues, Switzerland) powered with a low-speed handpiece up to 4–5 mm short of the WL. A periapical radiograph was taken to verify the quality of the root filling. Teeth were then stored in water for 7 days at 37°C without placing a final restoration to facilitate the subsequent post space preparation.

Post space preparation

After 1 week, the same operator used pre-measured post preparation drills to remove the coronal gutta-percha and widen the root canal (Largo Peeso Reamer; Dentsply Sirona, Ballaigues, Switzerland). In order to ensure the same post length in all samples, the length of the preparation was standardized in all the samples by leaving 5 mm of gutta-percha in the apical root canal. The canals were rinsed with 10 mL of distilled water and dried with paper points. Visual and radiographic evaluation was performed to ensure there was no residual gutta-percha on the walls of the canal in the anticipated post space. A medium-volume CBCT scan of each tooth was taken with a Promax 3D device (Planmeca OY, Helsinki, Finland) with an 8 × 8-cm field of view (FOV) operating at 0.8 mA and 84 kV, at a 12-s exposure time. The images obtained from these preoperative CBCT scans were used to calculate the dentine thickness and to later compare them with those obtained by the postoperative CBCT scans following fibre post removal. The preoperative CBCT scans were performed without the cemented fibre posts to avoid beam hardening artefacts that could impair the measurements of the remaining dentine.

Fibre post cementation

The length of the fibre posts cemented into the canal was standardized in all the samples. The root canal walls were etched with 37% phosphoric acid (Dentsply Sirona, Ballaigues, Switzerland) for 10 s, rinsed with water, and then gently dried with paper points. Following the manufacturers' instructions, the Prime & Bond XP (Dentsply Sirona, Ballaigues, Switzerland) and self-cure activator (Dentsply Sirona, Ballaigues, Switzerland) was applied to the root canal space using a micro-brush tip (Dentsply Sirona, Ballaigues, Switzerland). A dual-cure cement (Core-X flow, Dentsply Sirona, Ballaigues, Switzerland) was applied to the surface of each fibre post (Number 2 Radix Fibre post, Dentsply Sirona, Ballaigues, Switzerland) and inserted into the root canal. The excess cement was removed, and the post cement was light-cured for three cycles of 20 s each over a 3-min period. The protruding posts were then removed to 2 mm below the occlusal surface and the teeth restored with the composite. The samples were then stored at a relative humidity of 100% for 1 week to ensure the setting of the materials. To simulate clinical conditions, the prepared teeth were positioned within a typodont (Nissin dental model, Kyota, Japan) with the maxillary left second premolar removed (Figure 2). Each typodont was mounted on a dental phantom head during the post removal procedure.

Static guide fabrication

For the virtual planning of the fibre post removal, a post-operative CBCT scan (Promax 3D; Planmeca OY, Helsinki, Finland) with the same exposure parameters as the initial scan was made. Following the manufacturers' recommendations, a single experienced operator obtained digital impressions of each typodont using CEREC Primescan software (ver. 5.1.1, Dentsply Sirona, Ballaigues, Switzerland). The scan data were exported as standard tessellation language (STL) files for 3D analysis. Datasets obtained from this digital workflow (STL and DICOM files) were uploaded to 3D implant planning software (NemoScan®, Madrid, Spain) to plan the fibre post removal. After matching the 3D surface scan and CBCT data, the true-to-scale virtual image of the bur (FFDM-Pneumat Tivoly, Bourges, France) was placed so that the tip reached the visible surface of the gutta-percha. The orientation of

FIGURE 2 The natural teeth (specimens) were placed in the position of the maxillary left second premolar in the typodont.

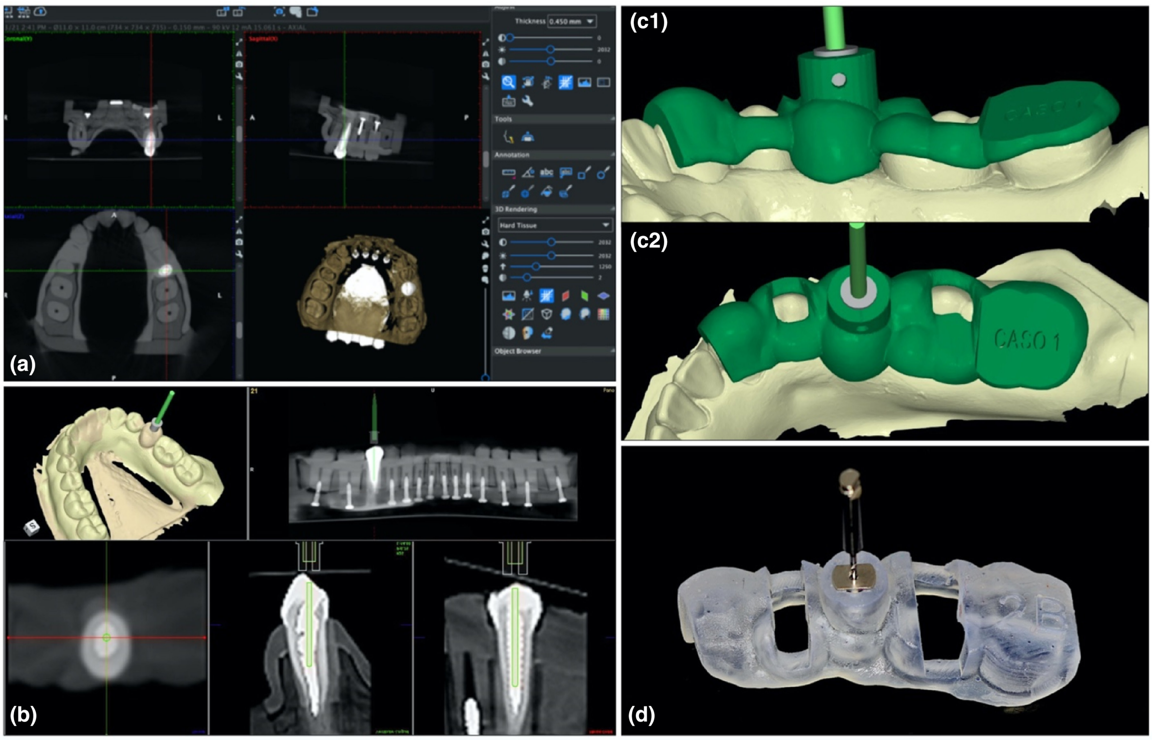

FIGURE 3 Static navigation process: (a) Preoperative CBCT scan (Planmeca Promax 3D; Planmeca OY, Helsinki, Finland). (b) CBCT and intraoral scanner data were exported in standard tessellation language (STL) file format, and the two models were aligned and registered in the 3D implant planning software (NemoScan®, Madrid, Spain). (c.1, c.2) Designing the guide, with a space provided to insert a metal sleeve (FFDM-Pneumat®, Bourges, France), the support surfaces of the guide were extended over two teeth on either side of the treated tooth to guarantee sufficient stability of the guide during the procedure. (d) The guide with the bur diameter of 0.75 mm and a length of 22 mm (FFDM-Pneumat Tivoly, Bourges, France) and a metal sleeve with a height of 6 mm, an internal diameter of 0.75 mm, and an external diameter of 3.5 mm (FFDM-Pneumat®, Bourges, France).

the path for the virtual drilling was designed to avoid aesthetic and mechanical anatomical features of the tooth (buccal surface and marginal crests). When designing the guide, space was provided to insert a metal sleeve with a height of 6 mm, an internal diameter of 0.75 mm, and an external diameter of 3.5 mm (FFDM-Pneumat®, Bourges, France). The sleeve was necessary to guide the drill. The support surfaces of the guide were extended over two teeth on either side of the treated tooth to guarantee sufficient stability of the guide during the procedure. The guide was designed to be supported on the tooth surfaces just above the middle third of the crown of the teeth. The various virtual guides were exported as STL files and sent to a stereolithography 3D printer (Form 2, Formlabs, Somerville, Massachusetts, US). Three-dimensional impressions were made to manufacture the guides using Dental SG Resin (Formlabs) (Figure 3).

Fibre post removal

Each typodont with the relevant tooth was then fixed into a dental phantom head in the same position, and samples were divided randomly into subgroups as follows:

Non-guided subgroups (experienced and inexperienced subgroups)

Using a dental operative microscope (ZEISS OPMI pico; Carl Zeiss Meditec AG, Oberkochen, Germany), and under rubber dam isolation in which the clamp was seated on the molar tooth (Figure 4c), fibre posts were removed using stainless-steel Start-X No.3 ultrasonic tips (Dentsply, Ballaigues, Switzerland) powered by an ultrasonic generator (Acteon, Merignac, France) without water cooling but with continuous irrigation using normal saline and periodic drying with paper points. The operators were free to use whatever power setting they considered necessary. When the operator reached the gutta percha successfully by visualizing it with the microscope, a periapical radiograph was taken to confirm the result. However, when post remnants were visible on the radiograph, they continued with the ultrasonic device until they were removed and took a further radiograph. Then, a first postoperative CBCT scan was acquired using the same parameters as before.

Static navigation procedure subgroups (experienced and inexperienced subgroups)

The guide was adapted and stabilized on the premolar tooth and adjacent artificial teeth in the dental arch of the typodont, with the fit and placement confirmed through several viewing windows (Figure 4a,b). A bur with a diameter of 0.75 mm and a length of 22 mm (FFDM-Pneumat Tivoly, Bourges, France) and a metal sleeve with a height of 6 mm, an internal diameter of 0.75 mm, and an external diameter of 3.5 mm (FFDM-Pneumat®, Bourges, France) were used. A flowable composite was used to place and retain the sleeve. The drill was then inserted through the metal sleeve and moved along the precise path in two to three steps until it reached the gutta-percha root filling. Each phase involved removing the guide, irrigating the root canal with normal saline, and cleaning the drill. The guide was then removed, and a new periapical radiograph was taken to confirm that the gutta-percha had been reached. After reaching the gutta-percha, a second CBCT scan was performed on each sample. Subsequently, after the static navigation phase, the guide was removed and ultrasonic tips (Start-X No. 3, Dentsply Sirona, Ballaigues, Switzerland) were used to remove remnants of the luting cement (as was done for the non-guided technique), and then a third CBCT scan was performed on each sample (static navigation-ultrasonic group).

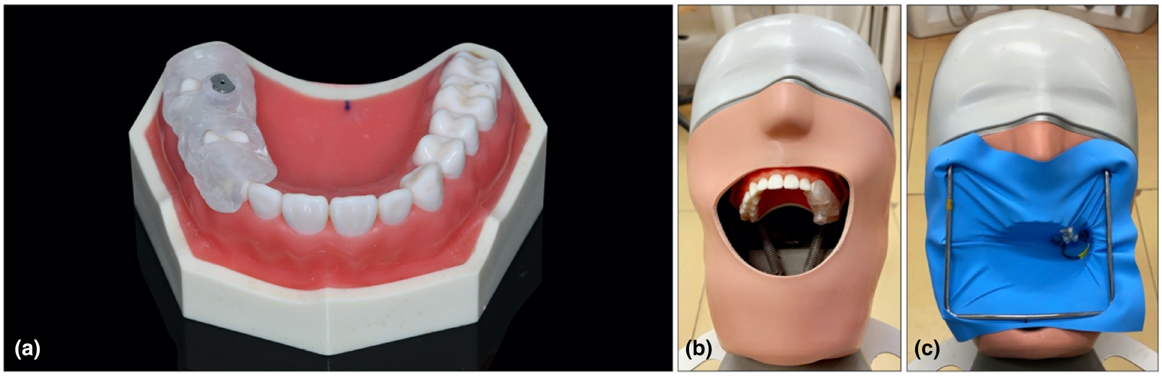

FIGURE 4 (a) The guide was adapted and stabilized on the artificial teeth in the dental arch of the dental phantom. (b) Each typodont with the relevant tooth was fixed into a dental phantom head in the same position. (c) Under the rubber dam isolation, the clamp was placed on the first molar tooth, and fibre posts were removed.

Data measurements

The time required from the beginning of drilling through the composite restoration and up to the end of the process of post removal was measured with a chronograph, and possible complications, including perforations, were recorded. Using Romexis software (Planmeca X, Helsinki, Finland), pre- and first, second, and third postoperative CBCT scans were compared for each specimen (Figure 5). The amount of dentine loss and deviation were measured in four tooth segments, the first position (coronal) was at the cementoenamel junction and the fourth position (apical) was near the gutta-percha; the two other positions were spaced equally between the coronal and apical positions (Figure 5b1,c1) in buccal, lingual, mesial, distal, mesiobuccal, distolingual, distobuccal, and mesiolingual directions (Figure 5b2,c2). Using the Gambill formula (Gambill et al., 1996), the extent and direction of canal deviation and dentine loss was determined by measuring the distance from the edge of the canal to the outer surface of the tooth before post removal in each segment and in all directions as previously described. These measurements were then compared with the same measurements taken from the images after post removal. The following formula was used for the deviation calculation: (X1–X2)–(Yl–Y2). X1 represented the distance from the outside of the root to the periphery of the canal before post-removal; Y1 represented the distance from the inside of the root to the periphery of the canal before post-removal; X2 represented the distance from the outside of the root to the periphery of the canal after post-removal; and Y2 represented the distance from the inside of the root to the periphery of the canal after post-removal (Figure 5a1). A result of 0 from the canal transportation formula indicated no deviation. The measurements of CBCT images were performed by one operator and were repeated by a second operator not related to this study to ensure the consistency between the two measurements. The perforated teeth were not included in these measurements.

Statistical analysis

Statistical analysis was performed using R software (R project for Statistical Computing, version 4.0.2). Means, standard deviations, and confidence interval values were calculated. The Kolmogorov–Smirnov test was used to check data normality, an ANOVA test was used to make comparisons between the groups, and Tukey tests were used to make all two-by-two comparisons. The level of significance was set at $p < .05$.

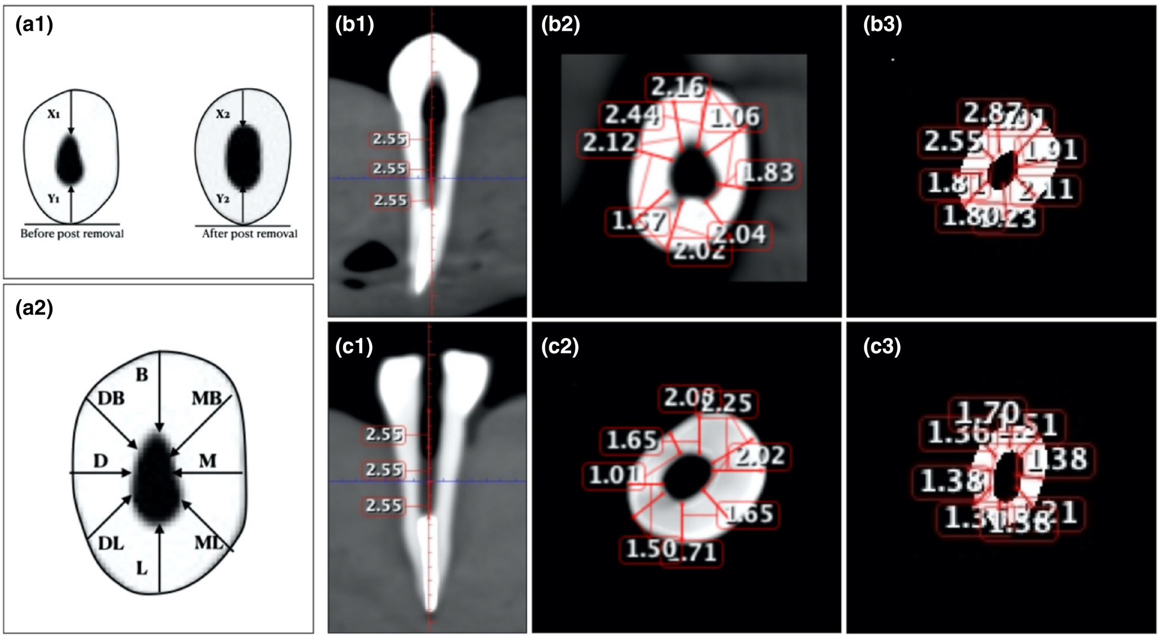

FIGURE 5 (a.1) Axial view of a tooth before and after post removal to measure dentine loss and canal deviation. Image before post removal (left): original canal space represented by dark shaded area. Image after post removal (right): dark shaded area represents canal shape after post removal. (a.2) The measurements taken in all eight directions of the tooth. (b.1) The measurement was taken in four segments of the tooth before post removal using Romexis software (Planmeca X, Helsinki, Finland). (b.2, b.3) Pre CBCT measurement in eight directions before post removal. (c.1) The measurement in four segments of the tooth after post removal. (c.2, c.3) Post CBCT measurements after post removal.

RESULTS

Reaching gutta-percha

The gutta-percha was successfully reached significantly more frequently in the static navigation group compared with the non-guided group ($p < .05$). In the static navigation group, the gutta-percha was successfully reached in 23 out of 24 teeth (96%), with no significant differences between experienced and inexperienced operators ($p > .05$). In contrast, in the non-guided group, the gutta-percha was successfully reached in 11 of the 24 teeth (46%), with a significant difference between experienced and inexperienced operator subgroups ($p < .05$), with gutta-percha in two teeth (17%) being reached successfully in the experienced group and in nine teeth (75%) in the inexperienced group.

Time

The mean time spent for post removal and reaching the gutta-percha in the non-guided group was 26 min 18 s (±13 min 23 s). In the static navigation group, an average of 5 min 14 s (±3 min 36 s) was necessary to remove the post and reach the gutta-percha within the root canal. In the static navigation–ultrasonic group, the time spent to remove the cement remnants with ultrasonics was 14 min 41 s (±8 min 19 s) (Table 1). The time needed to reach the gutta-percha and remove the post remnants and cement was 9 min. 58 s (±7 min 57 s). The static navigation–ultrasonic approach required significantly less time to reach the gutta-percha compared with the non-guided approach ($p < .05$). A significant difference was found for the total time required for removal of posts between the techniques ($p < .05$), but no significant difference was found between the experienced and inexperienced operators. ($p > .05$).

Root perforation

There was a significant difference in the number of perforations between the static navigation group and non-guided group and a significance difference between the static navigation-ultrasonic group and non-guided group during post removal ($p < .05$). The non-guided group was associated with more perforations than the other two groups, in which 13 teeth were perforated (54%) (10 teeth in the experienced subgroup and three teeth in the inexperienced subgroup) (Figure S1). In contrast, there were no perforations in the static navigation group (group 1), and only one perforation occurred when removing cement remnants with ultrasonics in the inexperienced static navigation–ultrasonic group (group 2).

Dentine loss and deviation

The total mean of dentine loss in the non-guided group in all directions was 0.39 (±0.17) mm, 0.26 (±0.09) mm for experienced, and 0.42 (±0.16) mm for inexperienced operators. In the static navigation group (both experienced and inexperienced operator subgroups), there was no dentine loss in any direction following the initial post removal. However, after subsequent ultrasonic removal of post remnants in the static navigation–ultrasonic group, the mean dentine loss in all the directions was 0.398 (±0.18) mm, 0.398 (±0.16) mm for experienced, and 0.391 (±0.18) mm for inexperienced operators (Table 2). No significant differences were found between the non-guided group and the static navigation–ultrasonic group after the removal of post remnants with ultrasonics ($p > .05$). The mean deviation in all directions in the non-guided group was −0.03 (±0.17) mm, −0.027 (±0.16) mm for experienced, and 0.027 (±0.17) mm for inexperienced operators. No deviation was observed in the static navigation group. After the ultrasonic removal of post remnants in the static navigation–ultrasonic group, the mean deviation in all the directions was −0.00075 (±0.22) mm, 0.019 (±0.24) mm for experienced operators, and −0.019 (±0.21) mm for inexperienced operators (Table 3). No significant differences occurred between the non-guided group and the static navigation–ultrasonic group after the ultrasonic removal of post remnants ($p > .05$).

DISCUSSION

The present study is the first to compare the removal of fibre posts using a conventional freehand ultrasonic technique

TABLE 1 The mean (standard deviation) time spent in each group for fibre post removal in minutes and seconds.

Procedure time	Non-guided group		Static navigation group		Static navigation + US	
Total	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	24:09 (16:01)	28:27 (10:24)	5:39 (4:10)	4:49 (3:00)	16:35 (7:27)	12:46 (9:02)
	26:18 (13:23)[a]		5:14 (3:36)[b]		14:41 (8:19)[c]	

Note: [abc]Variables that share the same superscript letter are not statistically significant.

TABLE 2 The mean (standard deviation) total dentine loss in all directions for all groups.

Dentinal loss	Non-guided group		Static navigation group		Static navigation + US	
Total	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.4219 (0.164)	0.26 (0.0965)	0.0003 (0.0016)	0.000 (0.000)	0.3915 (0.1819)	0.398 (0.162)
	0.3925 (0.172875)[a]		0.0002 (0.0011)[b]		0.3988 (0.1821)[a]	
B	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.452 (0.206)	0.264 (0.136)	0.000 (0.000)	0.000 (0.000)	0.415 (0.189)	0.371 (0.185)
	0.418 (0.204)[a]		0.000 (0.000)[b]		0.394 (0.185)[a]	
L	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.495 (0.166)	0.390 (0.131)	0.000 (0.000)	0.000 (0.000)	0.422 (0.161)	0.369 (0.173)
	0.476 (0.160)[a]		0.000 (0.000)[b]		0.397 (0.165)[a]	
M	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.365 (0.132)	0.228 (0.057)	0.000 (0.000)	0.000 (0.000)	0.294 (0.121)	0.324 (0.193)
	0.340 (0.180)[a]		0.000 (0.000)[b]		0.308 (0.156)[a]	
D	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.426 (0.140)	0.109 (0.058)	0.000 (0.000)	0.000 (0.000)	0.306 (0.199)	0.381 (0.171)
	0.368 (0.180)[a]		0.000 (0.000)[b]		0.342 (0.186)[a]	
MB	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.407 (0.112)	0.249 (0.058)	0.000 (0.000)	0.000 (0.000)	0.347 (0.137)	0.475 (0.122)
	0.378 (0.120)[a]		0.000 (0.000)[b]		0.408 (0.208)[a]	
ML	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.344 (0.164)	0.308 (0.127)	0.003 (0.012)	0.000 (0.000)	0.424 (0.267)	0.384 (0.149)
	0.338 (0.153)[a]		0.002 (0.008)[b]		0.405 (0.215)[a]	
DB	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.409 (0.197)	0.243 (0.042)	0.000 (0.000)	0.000 (0.000)	0.471 (0.209)	0.496 (0.187)
	0.379 (0.189)[a]		0.000 (0.000)[b]		0.483 (0.195)[a]	
DL	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.477 (0.195)	0.288 (0.163)	0.000 (0.000)	0.000 (0.000)	0.453 (0.172)	0.453 (0.122)
	0.443 (0.197)[a]		0.000 (0.000)[b]		0.453 (0.147)[a]	

Note: [abc]Variables that share the same superscript letter are not statistically significant.

with a static navigation strategy using burs followed by ultrasonic removal of cement remnants. The results revealed that the static navigation technique was quicker as well as being associated with reduced dentine loss in order to reach the gutta-percha root filling without perforation. These positive results occurred with both inexperienced as well as more experienced operators. In summary, in this laboratory setting, fibre post removal using a static navigation technique was effective and resulted in the maximum preservation of the coronal and radicular tooth structure as well as a reduced risk of complications. However, use of ultrasonics after the static navigation phase to ensure all post and cement remnants were removed did result in more loss of dentine and more complications. Clinicians must therefore use care when employing ultrasonic devices to remove residual post material and cements.

The results of this study revealed that the conventional non-guided ultrasonic technique was associated with more dentine removal and more complications compared to the static navigation technique. These results are similar to those of other studies, which also found the static navigation technique to be safe and conservative of tooth tissue, even when performed by inexperienced operators (Casadei et al., 2020; Fonseca Tavares et al., 2022; Maia, de Carvalho, et al., 2019). In fact, conventional techniques are associated with an excessive amount of tooth structure loss (Kim et al., 2017), reduce the fracture resistance of the root (Aydemir et al., 2018), and result in a higher prevalence of deviations and/or perforations (Aydemir et al., 2018; Maia, Moreira Júnior, et al., 2019).

Unlike other studies, in this study, a smaller 0.75 mm diameter bur was used, with the result that the mean deviation and dentine loss were 0 in all directions since the drill diameter was smaller than the diameter of the post to be removed (the tip diameter of the post was 0.8 mm and the head diameter 1.4 mm). In essence, the

TABLE 3 The mean deviation (standard deviation) in all the directions for all groups.

Deviation	Non-guided group		Static navigation group		Static navigation + US	
Total	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	−0.027 (0.178)	−0.0277 (0.165)	0.000 (0.012)	0.000 (0.000)	−0.01925 (0.21425)	0.01975 (0.24)
	−0.0345 (0.17825)		0.000 (0.00225)		−0.00075 (0.225)	
B-L deviation	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	−0.043 (0.139)	−0.126 (0.267)	0.000 (0.001)	0.000 (0.000)	−0.008 (0.205)	0.002 (0.253)
	−0.058 (0.154)		0.000 (0.001)		−0.033 (0.224)	
M-D deviation	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	−0.060 (0.150)	0.119 (0.002)	0.000 (0.000)	0.000 (0.000)	−0.011 (0.202)	−0.057 (0.260)
	−0.058 (0.154)		0.000 (0.000)		−0.033 (0.227)	
MB – DL deviation	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	−0.070 (0.243)	−0.039 (0.221)	0.000 (0.000)	0.000 (0.000)	−0.106 (0.218)	0.022 (0.211)
	−0.064 (0.228)		0.000 (0.000)		−0.045 (0.220)	
DB – ML deviation	Inexperienced	Experienced	Inexperienced	Experienced	Inexperienced	Experienced
	0.065 (0.180)	−0.065 (0.170)	−0.003 (0.012)	0.000 (0.000)	0.048 (0.232)	0.112 (0.236)
	0.042 (0.177)		−0.002 (0.008)		0.078 (0.231)	

drill only contacted the post and not the root dentine. This was similar to other studies, although larger drills with a diameter of 2.2, 1.5, 1.3, or 0.85 mm were used (Connert et al., 2018; Krastl et al., 2016; Maia, Moreira Júnior, et al., 2019; Schwindling et al. 2020). Moreover, Hussey et al. (1997) reported a greater increase in temperature when drills with a large diameter were used. Thus, reducing the diameter of the drill from 1.5 mm to 0.75 mm appears to have a positive effect in terms of less heat generation on the root surface, less crack formation, and a decrease in the loss of root dentine (Connert et al., 2018; Perez et al., 2020).

A consequence of using a smaller drill is that some of the post material remained in situ; however, once the initial drilling had been completed, a second stage using ultrasonic tips to eliminate any remaining post and cement was undertaken. The remnants of the post and cement were easily distinguishable from the root dentine. Yet, even with this additional step, the static navigation–ultrasonic approach was more rapid and more conservative with fewer complications (perforation) than the non-guided technique.

In the present study, no root perforations were detected when using the static navigation approach because the metal sleeve maintained the axis of the bur precisely within the body of the post (Ishak et al., 2020; Perez et al., 2020). This is in accordance with other studies that reported no perforations occurred when using the static approach unless there was an error during planning or a lack of stability in the guide (Campello et al., 2019; Connert et al., 2018; Moreno-Rabié et al., 2020).

It has been suggested that endodontic guides should be stabilized on at least eight teeth and sometimes with pins (Connert et al., 2018; Maia, Moreira Júnior, et al., 2019; Schwindling et al., 2020). The guide in this study was limited to four teeth, similar to other studies (Bordone & Cauvrechel, 2020; Perez et al., 2020), so the operative field was reduced to only five teeth, and the stability of the guide remained sufficient, thus decreasing the risk of interference between the guide and the operative field. In this study, to ensure adequate stability of the guide, the limits of the guide were extended buccally and lingually with a verification window to ensure that the guide sat correctly on the adjacent teeth.

There was no significant difference between the experienced and inexperienced operators in the static navigation group, and both groups were able to reach the gutta-percha with no complications and no dentine loss. This indicates that when adopting the static navigation approach, experience had no effect on the outcome, and the technique can be used successfully by all dentists. Other studies have also reported that this technique is viable and safe even when performed by inexperienced clinicians (Casadei et al., 2020; Maia, de Carvalho, et al., 2019). In the non-guided group, the inexperienced operators (postgraduate students) created fewer complications than the experienced operators (teachers). The difference in time between them was not significant, which means that essentially, they completed the work within the same time. One possible explanation why the students had fewer complications is perhaps because they were informally "competing" with each other and hoping to impress the staff, which made them highly motivated to succeed. It is possible that the experienced teacher group members were over-confident. In the present study, third-year postgraduate students made-up the "inexperienced" group. It is expected that the clinical skills of third-year postgraduate students would be superior to those of general dentists. However, previously, only three fibre posts had been removed by postgraduate students involved in the current study. Future research could compare the performance of general dental practitioners and postgraduate students when utilizing the static navigation technique for post removal.

Ultraviolet (UV) light has been used to aid in the removal of composite materials, and studies have demonstrated that this method is both rapid and non-invasive (Bush et al., 2010; Leontiev et al., 2021). In the present investigation, the composite was limited to the occlusal access cavity; as a consequence, it was detectable with a microscope. On the other hand, it was not essential to completely remove the composite restoration in order to use the static navigation technique as long as the access through the composite sufficient to allow the bur to pass through. Therefore, UV light was not used during removal of the composite restorations.

This laboratory-based study has several limitations. Although the study was performed on sound teeth to reduce the variables, in real clinical situations, the teeth would be restored with a composite restoration or crown. Moreover, when using the static navigation approach, the ability to irrigate and remove debris during drilling is limited. For this reason, in this study, post removal was performed in three steps, and the guide was withdrawn between each step to allow the canal to be irrigated and debris removed. Another limitation is that tooth isolation with dental dam was difficult when using the static navigation technique because the guide was extended to the last tooth in the arch and the margins of the guide were extended buccally and lingually. To overcome this limitation, it is better not to extend the margins of the splint buccally and lingually or not include the last tooth in the arch to ensure the guide does not interfere with the dental dam clamp. Another limitation is the experience of the operators in terms of fibre post removal was not extensive. Future studies must be conducted to investigate the long-term effect of the static navigation techniques on temperature increase and crack formation in the root as well as investigate the use of other methods to remove post remnants after using the static navigation approach, particularly as the supplementary ultrasonic phase in this study (Group 2) resulted in dentine loss and complications. New sleeve designs and resin guides are needed to allow an internal irrigation spray to be inserted during drilling. Also, studies are needed to compare the impact of a range of bur diameters.

CONCLUSION

Within the limitations of this *ex vivo* laboratory study on extracted teeth, the static navigation technique was superior to the conventional (ultrasonic tip) technique for the removal of fibre posts in terms of dentine loss, access to the apical gutta-percha root filling, operating time, and complications. There was no difference in performance between experienced and inexperienced operators when the static navigation approach was used.

AUTHOR CONTRIBUTIONS

All the authors made substantial contributions to the manuscript. All the authors have read and approved the final version of the manuscript.

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None.

CONFLICT OF INTEREST STATEMENT

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

No.

ORCID

Francesc Abella Sans https://orcid.org/0000-0002-3500-3039
Zeena Tariq Alatiya https://orcid.org/0009-0000-9235-6714
Gonzalo Gómez Val https://orcid.org/0000-0003-4935-7046
Venkateshbabu Nagendrababu https://orcid.org/0000-0003-3783-3156
Paul Michael Howell Dummer https://orcid.org/0000-0002-0726-7467
Fernando Durán-Sindreu Terol https://orcid.org/0000-0003-3041-5787
Juan Gonzalo Olivieri https://orcid.org/0000-0002-9780-7884

REFERENCES

Altshul, J.H., Marshall, G., Morgan, L.A. & Baumgartner, J.C. (1997) Comparison of dentinal crack incidence and of post removal time resulting from post removal by ultrasonic or mechanical force. *Journal of Endodontics*, 23, 683–686.

Anderson, G.C., Perdigão, J., Hodges, J.S. & Bowles, W.R. (2007) Efficiency and effectiveness of fiber post removal using 3 techniques. *Quintessence International*, 38, 663–670.

Anderson, J., Wealleans, J. & Ray, J. (2018) Endodontic applications of 3D printing. *International Endodontic Journal*, 51, 1005–1018.

Aydemir, S., Arukaslan, G., Sarıdağ, S., Kaya-Büyükbayram, I. & Ylıdıran, Y. (2018) Comparing fracture resistance and the time required for two different fiber post removal systems. *Journal of Prosthodontics*, 27, 771–774.

Barcellos, R.R., Correia, D.P., Farina, A.P., Mesquita, M.F., Ferraz, C.C. & Cecchin, D. (2013) Fracture resistance of endodontically treated teeth restored with intra-radicular post: the effects of post system and dentine thickness. *Journal of Biomechanics*, 46, 2572–2577.

Bhuva, B., Giovarruscio, M., Rahim, N., Bitter, K. & Mannocci, F. (2021) The restoration of root filled teeth: a review of the clinical literature. *International Endodontic Journal*, 54, 509–535.

Bordone, A. & Cauvrechel, C. (2020) Treatment of obliterated root canals using various guided endodontic techniques: a case series. *Giornale Italiano di Endodonzia*, 4, 34.

Bush, M.A., Hermanson, A.S., Yetto, R.J. & Wieczkowski, G., Jr. (2010) The use of ultraviolet LED illumination for composite resin removal: an in vitro study. *General Dentistry*, 58, e214–e218.

Campello, A.F., Marceliano-Alves, M.F., Siqueira, J.F., Jr., Marques, F.V., Guedes, F.R., Lopes, R.T. et al. (2019) Determination of the initial apical canal diameter by the first file to bind or cone-beam computed tomographic measurements using micro-computed tomography as the gold standard: an ex vivo study in human cadavers. *Journal of Endodontics*, 45, 619–622.

Casadei, B.A., Lara-Mendes, S.T.O., Barbosa, C.F.M., Araújo, C.V., de Freitas, C.A., Machado, V.C. et al. (2020) Access to original canal trajectory after deviation and perforation with guided endodontic assistance. *Australian Endodontic Journal*, 46, 101–106.

Castrisos, T. & Abbott, P.V. (2002) A survey of methods used for post removal in specialist endodontic practice. *International Endodontic Journal*, 35, 172–180.

Chieruzzi, M., Pagano, S., Pennacchi, M., Lombardo, G., D'Errico, P. & Kenny, J.M. (2012) Compressive and flexural behaviour of fibre reinforced endodontic posts. *Journal of Dentistry*, 40, 968–978.

Cho, C., Jo, H.J. & Ha, J.H. (2021) Fiber-reinforced composite post removal using guided endodontics: a case report. *Restorative Dentistry & Endodontics*, 46, e50.

Connert, T., Zehnder, M.S., Amato, M., Weiger, R., Kühl, S. & Krastl, G. (2018) Microguided endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. *International Endodontic Journal*, 51, 247–255.

Connert, T., Zehnder, M.S., Weiger, R., Kühl, S. & Krastl, G. (2017) Microguided endodontics: accuracy of a miniaturized technique for apically extended access cavity preparation in anterior teeth. *Journal of Endodontics*, 43, 787–790.

Fonseca Tavares, W.L., de Oliveira Murta Pedrosa, N., Moreira, R.A., Braga, T., de Carvalho Machado, V., Ribeiro Sobrinho, A.P. et al. (2022) Limitations and management of static-guided endodontics failure. *Journal of Endodontics*, 48, 273–279.

Gambill, J.M., Alder, M. & del Rio, C.E. (1996) Comparison of nickel-titanium and stainless steel hand-file instrumentation using computed tomography. *Journal of Endodontics*, 22, 369–375.

Gesi, A., Magnolfi, S., Goracci, C. & Ferrari, M. (2003) Comparison of two techniques for removing fiber posts. *Journal of Endodontics*, 29, 580–582.

Haupt, F., Pfitzner, J. & Hülsmann, M. (2018) A comparative in vitro study of different techniques for removal of fibre posts from root canals. *Australian Endodontic Journal*, 44, 245–250.

Hussey, D.L., Biagioni, P.A., McCullagh, J.J. & Lamey, P.J. (1997) Thermographic assessment of heat generated on the root surface during post space preparation. *International Endodontic Journal*, 30, 187–190.

Ishak, G., Habib, M., Tohme, H., Patel, S., Bordone, A., Perez, C. et al. (2020) Guided endodontic treatment of calcified lower incisors: a case report. *Dentistry Journal*, 8, 74.

Kim, J.J., Alapati, S., Knoernschild, K.L., Jeong, Y.H., Kim, D.G. & Lee, D.J. (2017) Micro-computed tomography of tooth volume changes following post removal. *Journal of Prosthodontics*, 26, 522–528.

Krastl, G., Zehnder, M.S., Connert, T., Weiger, R. & Kühl, S. (2016) Guided endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. *Dental Traumatology*, 32, 240–246.

Leontiev, W., Magni, E., Dettwiler, C., Meller, C., Weiger, R. & Connert, T. (2021) Accuracy of the fluorescence-aided identification technique (FIT) for detecting tooth-colored restorations utilizing different fluorescence-inducing devices: an ex vivo comparative study. *Clinical Oral Investigations*, 25, 5189–5196.

Lindemann, M., Yaman, P., Dennison, J.B. & Herrero, A.A. (2005) Comparison of the efficiency and effectiveness of various techniques for removal of fiber posts. *Journal of Endodontics*, 31, 520–522.

Maia, L.M., de Carvalho, M.V., da Silva, N.R.F.A., Brito Júnior, M., da Silveira, R.R., Moreira Júnior, G. et al. (2019) Case reports in maxillary posterior teeth by guided endodontic access. *Journal of Endodontics*, 45, 214–218.

Maia, L.M., Moreira Júnior, G., Albuquerque, R.C., de Carvalho, M.V., da Silva, N.R.F.A., Hauss, D.D. et al. (2019) Three-dimensional endodontic guide for adhesive fiber post removal: a dental technique. *The Journal of Prosthetic Dentistry*, 121, 387–390.

Moreno-Rabié, C., Torres, A., Lambrechts, P. & Jacobs, R. (2020) Clinical applications, accuracy and limitations of guided endodontics: a systematic review. *International Endodontic Journal*, 53, 214–231.

Nagendrababu, V., Murray, P.E., Ordinola-Zapata, R., Peters, O.A., Rôças, I.N., Siqueira, J.F., Jr. et al. (2021) PRILE 2021 guidelines for reporting laboratory studies in endodontology: a consensus-based development. *International Endodontic Journal*, 54, 1482–1490.

Perez, C., Finelle, G. & Couvrechel, C. (2020) Optimisation of a guided endodontics protocol for removal of fibre-reinforced posts. *Australian Endodontic Journal*, 46, 107–114.

Schwindling, F.S., Tasaka, A., Hilgenfeld, T., Rammelsberg, P. & Zenthöfer, A. (2020) Three-dimensional-guided removal and preparation of dental root posts-concept and feasibility. *Journal of Prosthodontic Research*, 64, 104–108.

Scotti, N., Bergantin, E., Alovisi, M., Pasqualini, D. & Berutti, E. (2013) Evaluation of a simplified fiber post removal system. *Journal of Endodontics*, 39(11), 1431–1434.

Strbac, G.D., Schnappauf, A., Giannis, K., Moritz, A. & Ulm, C. (2017) Guided modern endodontic surgery: a novel approach for guided osteotomy and root resection. *Journal of Endodontics*, 43, 496–501.

Tay, F.R. & Pashley, D.H. (2007) Monoblocks in root canals: a hypothetical or a tangible goal. *Journal of Endodontics*, 33, 391–398.

Tsintsadze, N., Margvelashvili-Malament, M., Natto, Z.S. & Ferrari, M. (2022) Comparing survival rates of endodontically treated teeth restored either with glass-fiber-reinforced or metal posts: a systematic review and meta-analyses. *The Journal of Prosthetic Dentistry*. S0022-3913(22)00047-6. Available from: https://doi.org/10.1016/j.prosdent.2022.01.003

Vasudevan, A., Santosh, S.S., Selvakumar, R.J., Sampath, D.T. & Natanasabapathy, V. (2022) Dynamic navigation in guided endodontics–A systematic review. *European Endodontic Journal*, 7, 81–91.

Wang, X., Shu, X., Zhang, Y., Yang, B., Jian, Y. & Zhao, K. (2019) Evaluation of fiber posts vs metal posts for restoring severely damaged endodontically treated teeth: a systematic review and meta-analysis. *Quintessence International*, 50, 8–20.

Zehnder, M.S., Connert, T., Weiger, R., Krastl, G. & Kühl, S. (2016) Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. *International Endodontic Journal*, 49, 966–972.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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