

Post Removal Using Guided Endodontics: A Systematic Review of the Literature

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ABSTRACT

Introduction: The aim of this review was to gather and assess all available evidence regarding the efficacy and complications of guided endodontics in the removal of dental posts.

Methods: A systematic review was carried out by three reviewers in PubMed/MEDLINE, Scopus, and Web of Science databases. All clinical trials, observational studies, in vitro and ex vivo studies, case reports, and case series that reported the use of CBCT to create guides for dental post removal up to July 2023 were eligible for inclusion. The quality of the included studies was assessed by the reviewers using the CARE guidelines and the QUIN tool. A predetermined template was used to extract data regarding the participant characteristics, printer, materials, software, and clinical parameters of the procedure.

Results: A total of nine studies were included. Of those, seven were case reports and two were in vitro studies. All the included publications showed that the use of guided endodontics was effective in the removal of the post. Complications were observed in only two cases. Studies showed variability among the techniques used, but all were successful. Accuracy was reported in only two studies.

Conclusion: Within the limitations of this review, guided endodontics was shown to be an effective technique for the removal of dental posts with a low risk of iatrogenic errors. The quality and amount of available evidence is still low. Future well-designed studies are essential to establish these findings.

Keywords: guided endodontics, guided technique, post removal, systematic review.

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I. INTRODUCTION

Endodontically treated teeth often come with a considerable loss of structure, resulting in inadequate support and retention necessary for their restoration [1], [2]. In addition, the absence of ferrule has a negative effect on their survival [3]. On the other hand, crown coverage has been shown to positively affect the survival rate of endodontically treated teeth [4]. Among other options, clinicians may choose the use of intraradicular posts to rehabilitate this lost support for the restorative material. As with every dental treatment, their use comes with complications such as fractures, and unwanted dentin loss [4]. Moreover, the outcome of endodontic treatment varies depending on a plethora of factors where sometimes re-treatment is the only option [5]. Therefore, the removal of the post may be in several cases necessary.

A correlation between the loss of dentin and fracture susceptibility has been previously reported in the literature [6]–[8]. It is important to remove the post with as little dentin loss as possible using a technique that produces a low risk of iatrogenic errors. Several techniques, such as the use of ultrasonics or the use of a drill, have been suggested in the

past, but all of them resulted in dentin removal and the formation of microcracks [9]. In addition, among the studies that examine the efficacy and risks of post removal techniques, a heterogeneity of methodology can be noted [10]–[12]. Several studies have also reported an increased risk of root perforation during the removal, something that highlights the need for an alternative with lower risk of iatrogenic errors [13].

In recent years, guided endodontics has emerged as a novel approach in the field of clinical dentistry [14]. This technique consists of the use of cone-beam computed tomography (CBCT) to create digitally designed guides for the access cavity preparation and endodontic surgery. It produces safe and predictable results, may reduce the unwanted removal of dental issue, and assists with difficulties in endodontic procedures such locating calcified canals [14]–[16]. Several studies have argued the efficacy of guided endodontics in the removal of dental posts. These included case reports, technique reviews or in-vitro studies, but so far, no systematic review of all the studies has been performed. The purpose of this systematic review is to assess all available evidence in the literature regarding the use of the guided technique for the removal of dental posts.

II. MATERIALS AND METHODS

A. Protocol and Registration

The present systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. The protocol was registered beforehand in Open Science Framework with the following ID 10.17605/OSF.IO/Q5YRA.

B. PICO Question

The present study aimed to answer the question “Is guided endodontics an effective technique for the removal of dental posts?” The reviewers formulated the following PIO question to determine the inclusion and exclusion criteria. The Comparator (C) of the PICO question was not applicable for this review. Situation [15]–[18].

Population: human teeth with dental post.

Intervention: guided endodontics with the use of CBCT to create a guide.

Outcome: removal of dental post, complications.

C. Eligibility Criteria

All clinical trials, observational studies, in vitro and ex vivo studies, case reports, and cases series up to June 2023 that reported the use of CBCT to create guides for dental post removal were eligible for inclusion. Poster presentations, abstracts, literature reviews, letters to the editor, technique discussions, expert opinions, were excluded.

D. Search Strategy

Systematic literature searches were conducted by three reviewers independently (S.P., M.A., A.N.) in PubMed/MEDLINE, Scopus, and Web of Science for articles up to June 2023. No language restrictions were applied. In addition, a manual literature search was performed in Journal of Endodontics, International Endodontic Journal, Australian Endodontic Journal, and ENDO-Endodontic Practice Today. The snowball technique was utilized to identify potentially eligible studies from the references of the included publications. Grey literature was searched using GreyNet International (<http://www.greynet.org>). A follow-up search was conducted in July 2023.

The keywords Guided endodontics OR guided technique OR guided access OR computer guided OR computer aided OR printed template AND dental post removal were used.

E. Study Selection

The three reviewers (S.P., M.A., A.N.) independently removed duplicates and assessed the articles based on their title and abstract in the first round and based on their full text on the second round. Articles providing limited information from their title and abstract were included in the second round for a full-text analysis to avoid excluding any publications. Any disagreement was resolved with discussion.

F. Data Extraction

The three reviewers independently extracted the data from the studies using a pre-decided template. The extracted data were as follows: name of the first author, country, subject characteristics, teeth, CBCT type, voxel size, field of view (FOV), impression material, scanner type, software used for planning, printer used for guide, bur diameter, bur speed, bur type, guide material, guide sleeve, post type, efficacy, complications, and type of complication.

G. Quality Assessment

To assess the quality of the included studies the CARE guidelines (for Case Reports) were used for case reports and the QUIN tool was used for the in vitro studies [19], [20]. The three reviewers independently assessed the included studies. Any disagreement was resolved with discussion. After using the CARE checklist, the average compliance was calculated. For the QUIN tool 12 domains were assessed for each study, each domain receiving 0, 1, or 2 points depending on if it fulfills the criteria. Using this score, they were categorized as low risk (>70%), medium risk (50-70%), or high risk (<50%).

III. RESULTS

A. Study Selection

The PRISMA flow chart of the review and selection process is shown in Fig. 1 [21]. The initial electronic search returned 201 publications. After removing duplicates, 154 articles were screened based on their title and abstract.

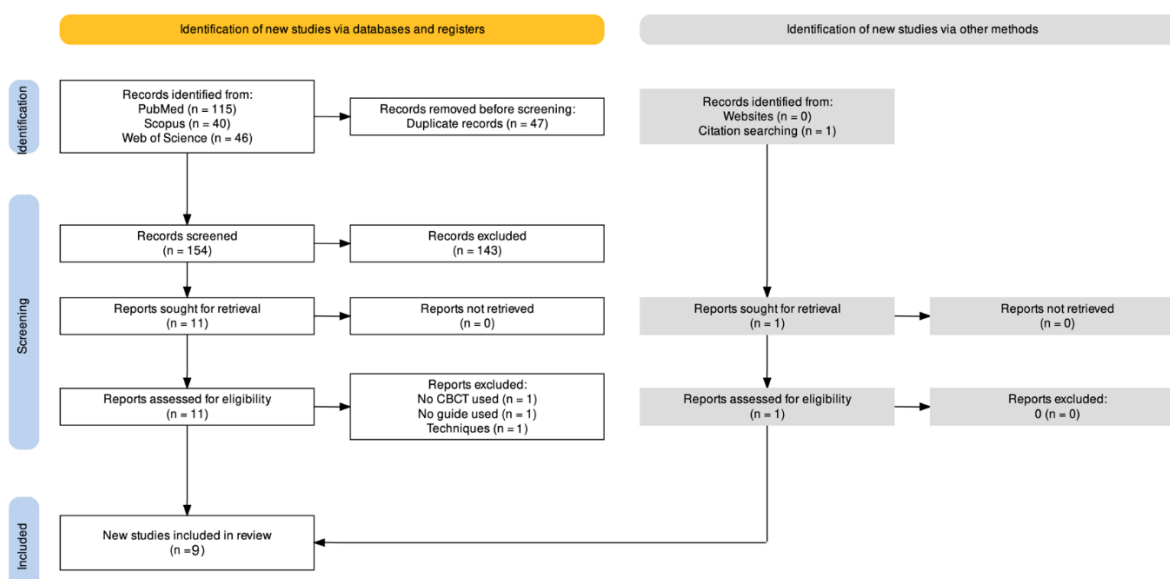


Figure 1. Flowchart of the selection process.

Of those, 11 were sought for retrieval. After full-text analysis 3 studies were excluded for the following reasons: study did not use CBCT, study did not use a guide, publication was a narrative review of a technique. Using the snowball technique one more publication was identified. Finally, 9 studies were included in this review [22]–[30]. Inter-reviewer reliability was calculated using Cohen's kappa (0.92 for the first round, 1 for the second round).

B. Study Characteristics

The extracted data from the included studies are shown in Table I. Included studies consisted of 7 case reports, and 2 in vitro studies, published between 2019 and 2023. No clinical trials or cross-sectional studies were identified. A total of 3 males and 5 females ranging from 13 to 63-years-old were included in the case reports [22]–[28]. The following teeth were used in the included studies: Maxillary incisors, maxillary bicuspid, maxillary molars, mandibular bicuspid, mandibular molars. Only 8 studies reported the model of the CBCT used to receive the image, and of those 3 reported the voxel size and only 1 the field of view [22], [24]–[30]. Three studies used a non-digital impression to create a model and all the studies used an intraoral scanner, digital planning software, as well as various printers for their guides in their methodology. Of the reported bur characteristics, the bur diameter used to access the post ranged from 0.75 mm to 2.2 mm and the speed ranged from 350 rpm to 40,000 rpm. Various types of burs were used, including an implant drill. Only two studies reported the guide material being polymer resin [22], [30]. Five studies reported the dimensions of the guide sleeve [22], [23], [26], [29], [30]. All 9 studies included the removal of a fiber post.

C. Effectiveness and Complications

Data showed a high success rate of the fiber post removal. A percentage was calculated dividing the number of cases in which the post was successfully removed without causing complications to the total number of cases included in the review and was shown as a percentage on Table I. In the same table any complications mentioned in the examined studies were reported along with the respective percentage. Likewise, in every study, the reviewers divided the number of cases in which a complication had occurred to the total number of cases included.

The effectiveness was measured by the reviewers as the ability to remove the dental post without causing severe complications such as a fracture or a perforation of the root. In all case reports the post was successfully removed with no complications (100% success rate) [22]–[28]. In one in vitro study the post was removed from all but one tooth (97.5% success rate) where perforation occurred [29]. In the other in vitro study, the post was removed in 87.5% of the teeth, in one case it was unsuccessful because the drill bit hit the canal wall [30].

D. Quality Assessment

A detailed overview of the risk of bias assessment using the CARE guidelines checklist and the QUIN tool can be found in Table II, and Table III, respectively. Regarding the case reports, the lowest score was 63% and the maximum 83%. The following parameters were not fulfilled in any of the included case reports: prognosis, intervention adherence

and tolerability, patient's perspective, patient's consent. On the other hand, 18 parameters were fulfilled by all case reports. Regarding the in vitro studies, one was assessed as a high risk of bias study, while the other one as a low risk of bias [29], [30]. Neither of the studies included a control group, and neither of the studies reported any blinding of the two operators. Both of the in vitro studies reported clear aims, a detailed explanation of the sampling technique, and blinding of the presentation of the results. None of the included studies reported any conflict of interest.

IV. DISCUSSION

Currently, clinicians remove posts using a variety of techniques including the use of drills or ultrasonic, which may take a considerable amount of time [10], [31], [32]. Findings from this review showed that the use of guided endodontics is effective in the removal of dental posts with a low risk of iatrogenic errors. Complications were reported only in the two in vitro studies [29], [30]. Of those, the first one showed an 87.5% success rate and the second one 97.5%.

Even though it is not in the scope of this review, the two studies reported statistically significant deviations between the virtual planning and the drill path. However, the mean deviations were in accordance with previous studies, and were considered low in the literature, thus promoting the fact that guided endodontics leads to minimum deviations [33], [34]. All studies except for one used a guide with a sleeve to establish minimum deviations of the drill [22]–[27], [29]. One case report introduced a novel sleeveless guide approach which showed to be effective without complications, but its accuracy was not measured [28]. The reviewers suggest that future studies examine the substance loss and accuracy of this technique. Apart from the efficacy, it is also important to investigate if this technique can be used as a better alternative for post removal regarding the amount of dentin loss.

A variability among the protocols used in the studies was prominent. The vast majority of studies used CBCT imaging, and an intraoral impression of the patient's teeth obtained with an intraoral scanner to digitally plan the guide. Then, using a 3D printer the guide was printed. On the other hand, some of the studies used an intraoral alginate impression to create a cast which was later scanned using an intraoral scanner to digitally plan the guide. Different types of burs and different speeds also did not alter the effectiveness of the procedure. Regardless of the technique, no difference in effectiveness or the prevalence of complications was noted.

Regarding the time needed to complete the procedure, none of the studies measured it. An average planning time of 9.4 minutes has been reported in the literature [35]–[38]. However, one must consider that may vary depending on the type of printer, printing, and the software being used.

Guided endodontics seems to be a reliable alternative for various endodontic uses such as access opening, producing a low risk of iatrogenic errors. It is also not influenced by the experience of the operator [39]. In one in vitro study examined in our review the experienced and inexperienced operator exhibited a difference in the mean deviation angle. Therefore, a learning curve as in many dental procedures is expected. The other studies included did not account for a difference in experience between these two groups.

TABLE I: EXTRACTED DATA FROM THE INCLUDED STUDIES

| Author | Alfada <i>et al.</i> [22] Saudi Arabia | Cho <i>et al.</i> [23] Korea | Liu <i>et al.</i> [24] China | Maia <i>et al.</i> [25] Brazil | Perez <i>et al.</i> [26] France | Schwindling <i>et al.</i> [27] Germany | Xue <i>et al.</i> [28] China | Fachin <i>et al.</i> [29] Brazil | Perez <i>et al.</i> [30] France |
|-------------------------|--|---|---|---|--|---|---|--|--|
| Study design | Case report | Case report | Case report | Case report | Case report | Case report | Case report | In vitro | In vitro |
| Subject characteristics | 40-year-old male | 19-year-old female, 13-year-old female | 34-year-old female | 38-year-old female | 36-year-old male | 62-year-old male | 30-year-old female | Not applicable | Not applicable |
| Teeth | 23 | 11, 11, 21, 22 | 13 | 21 | 16 | 21 | 11 | 36,46 (extracted teeth) | 10 maxillary molars, 10 mandibular molars, 10 maxillary bicuspid, 10 mandibular bicuspid |
| CBCT | Planmeca Pro-Max 3D S (Planmeca OY, Helsinki, Finland) | Undisclosed | Sirona Galileos comfort plus; Dentsply Sirona | i-Cat Classic; Imaging Sciences International | Promax3D, Planmeca®, Helsinki, Finland | Sirona Galileos comfort plus, Dentsply Sirona | 3D Accuitomo; J. Morita Mfg. Corp, Fushimi-ku, Kyoto, Japan | Prexion, San Mateo, CA, USA | NewTom Srl VGi; Verona, Italy |
| Voxel Size | 0.15 mm | Undisclosed | Undisclosed | Undisclosed | Undisclosed | 0.25x0.25x0.25 | Undisclosed | Undisclosed | 120x80 mm |
| FOV | Undisclosed | Undisclosed | Undisclosed | Undisclosed | Undisclosed | Sphere with a diameter of 15.4 cm, 12 bit, scan time: 14 s, 357 images | Undisclosed | Undisclosed | Undisclosed |
| Impression | Polyvinyl siloxane material (Imprint 4, 3 M, Saint Paul, Minnesota, USA) | Alginate (Aroma fine plus normal set, GC Corporation, Tokyo, Japan) | Not applicable | Not applicable | Not applicable | Alginate Impression | Not applicable | Not applicable | Not applicable |
| Scanner | Desktop laser scanner R700 Desk- top (3Shape, Copenhagen, Denmark). | CS3600, Carestream Dental, Atlanta, GA, USA | TRIOS 3; 3Shape A/S | TRIOS Color Pod; 3Shape A/S | Omnicam, Sirona®, York, Pennsylvania, USA | D800 laboratory scanner; 3shape, Copenhagen, Denmark | TRIOS 3; 3Shape, Copenhagen, Denmark | iTero (Align Technology, San Jose, CA, USA) | Trios; 3shape; Copenhagen |
| Software | ProDigiDent, Implastation for Windows x6464 Bit Beta Version | DDS-Pro, Digital Dental Service, Czeszochowa, Poland | Blue Sky Plan 4; Blue Sky Bio | SimPlant Pro 15; Materialise Dental | Blue Sky Plan (Blue Sky Bio®) | CoDiag- nostiX; Dental Wings, Montréal, Canada | Implant Studio; 3Shape | coDiagnostiX™ (Version 9.14, Dental Wings GmbH, Chemnitz, Germany) | BlueSkyPlan (BlueskyBio; LLC; Grayslake, IL, USA) |
| Printer | MiiCraft 125; MiiCraft, Jena, Germany | BIO3D, Bio3D Ltd., Seoul, Korea | Projet MJP 3600; 3D Systems | Objet Eden260V, MED610; Stratasys Ltd | FormLabs® printer (Som- erville, Massachusetts, USA) | Freeform PRO2; Asiga, Alexandria, Australia | M2; Concept Laser GmbH, Lichtenfels, Germany | Straumann® CARES® P series, Straumann, Basel, Switzerland | Soflex version 350 (VOCO GmbH, Cuxhaven, Germany) |
| Bur Diameter | 1.4 mm | 1 mm | 0.8 to 1.6 mm | 1.3 mm | 0.75 mm | Undisclosed, 2.2mm | Undisclosed | 1 mm | 0.75 mm |
| Bur Speed | Undisclosed | 10,000 rpm | 4,000 rpm | 350 rpm | 40,000 rpm | 5,000 rpm, 6,000 rpm | Undisclosed | 40,000 rpm | 10,000 rpm |
| Bur Type | Size 4 long-shank round bur (Thomas, Bourges, France) | Steco System Technik | Customized drill | Neodent Drill for Temp implants; Neodent | FFDM-Pneumat®, Bourges, France | Diamond bur, implant-drill Pilot drill, #044.210, Straumann, Basel, Switzerland | TF11; Mani, Utsunomiya, Tochigi, Japan | Spherical Diamond Tip | Undisclosed |
| Guide Material | Photo-polymerized biocom- patible polymer resin | Undisclosed | Undisclosed | Undisclosed | Undisclosed | Undisclosed | Titanium for Medicals, Optimal Material | Undisclosed | V-print SG resin (VOCO GmbH) |

| Author | Alfada <i>et al.</i> [22] Saudi Arabia | Cho <i>et al.</i> [23] Korea | Liu <i>et al.</i> [24] China | Maia <i>et al.</i> [25] Brazil | Perez <i>et al.</i> [26] France | Schwindling <i>et al.</i> [27] Germany | Xue <i>et al.</i> [28] China | Fachin <i>et al.</i> [29] Brazil | Perez <i>et al.</i> [30] France |
|----------------------------|--|--|---------------------------------|------------------------------------|--|---|---------------------------------|---|--|
| | (Freeprint Temp; DETAX GmbH & Co., Ettlingen, Germany) | | | | | | Technology, Chengdu, China | | |
| Guide Sleeve | 3.0 mm external diameter, 1.7 mm internal diameter, and 5 mm length | 1.0-mm inner diameter, a 3.5-mm outer diameter, and a 5.0-mm height | Undisclosed | Undisclosed | 6 mm in height, 3.5 mm in external diameter and 0.75 mm in internal diameter (FFDM- Pneu- mat®, Bourges, France) | Undisclosed | Sleeveless | 1 mm internal diameter, 5 mm length (steco- system-technik GmbH & Co. KG, Hamburg, Germany) | 0.75 mm inner diameter, 3.50 mm outer diameter, 5 mm lenght |
| Post type | Fiber post | Fiber-reinforced composite post | Fiber post | Fiber-reinforced composite post | Fiber-reinforced post | Glass fiber-reinforced composite post | Fiber post | Fiberglass post | Glass fiber post |
| Success in post removal | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 97.50% | 87.50% |
| Complications | No (0%) | No (0%) | No (0%) | No (0%) | No (0%) | No (0%) | No (0%) | Yes (2.5%) | Yes (12.5%) |
| Type of complication | - | - | - | - | - | - | - | Perforation | Drill bit hit the canal wall |

TABLE II: RISK OF BIAS ASSESSMENT USING THE CARE GUIDELINES

| Author | 1 | 2 | 3a | 3b | 3c | 3d | 4 | 5a | 5b | 5c | 5d | 6 | 7 | 8a | 8b | 8c | 8d | 9a | 9b | 9c | 10a | 10b | 10c | 10d | 11a | 11b | 11c | 11d | 12 | 13 | % |
|--------------------------------|---|---|----|----|----|----|---|----|----|----|----|---|---|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|
| Alfada <i>et al.</i> [22] | N | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | N | N | Y | Y | Y | Y | Y | N | N | 76 |
| Cho <i>et al.</i> [23] | Y | Y | Y | N | N | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | N | Y | Y | Y | N | N | 73 |
| Liu <i>et al.</i> [24] | Y | Y | Y | N | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | N | 80 |
| Maia <i>et al.</i> [25] | N | Y | Y | N | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | N | 76 |
| Perez <i>et al.</i> [26] | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | N | 80 |
| Schwindling <i>et al.</i> [27] | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | N | 83 |
| Xue <i>et al.</i> [28] | N | Y | Y | N | N | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | N | 63 |

Thirteen domains along with their subcategories were examined with a “Y(es) or N(o)” answer including: title, keywords, abstract, introduction, patient information, clinical findings, timeline, diagnostic assessment, therapeutic intervention, follow-up and outcomes, discussion, patient perspective, informed consent

TABLE III: RISK OF BIAS ASSESSMENT USING THE QUIN TOOL

| Author | Clearly stated aims/objectives | Detailed explanation of sample size calculation | Detailed explanation of sampling technique | Details of comparison group | Detailed explanation of methodology | Operator details | Randomization | Method of measurement of outcome | Outcome assessor details | Blinding | Statistical analysis | Presentation of results | Risk of bias |
|---------------------------|-----------------------------------|---|---|-----------------------------------|---|---------------------|---------------|--|--------------------------------|----------|-------------------------|----------------------------|--------------------|
| Fachin <i>et al.</i> [29] | 2 | 2 | 2 | 0 | 2 | 2 | 1 | 1 | 2 | 0 | 2 | 2 | Low |
| Perez <i>et al.</i> [30] | 2 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | High |

Even though effective, this technique comes with limitations. It does not allow immediate intervention because it requires planning. The technique used is also prone to distortion during the intraoral scanning and/or the printing process [40]. In addition, the use of CBCT comes with more ionizing radiation than normal radiographs, meaning that the clinician should evaluate if benefits outweigh the cost [41]. Lastly, all techniques require that the clinician is familiar with digital planning software, it usually being computer-aided design (CAD) software. The learning curve may vary depending on the software used [42].

Regarding the strengths of this review, this review managed to systematically gather, summarize, and assess the available evidence on the topic.

One of the limitations of this review is that only the removal of fiber posts was reported. Another and more important limitation are the number and quality of evidence included. The studies of this review consist of just 6 case reports and 2 in vitro studies which are generally considered low level evidence in the hierarchy of evidence-based medicine [43]. Additionally, case reports are susceptible to potential publication bias [44]. Furthermore, the risk of bias in one in vitro study was high and did not provide satisfactory reporting regarding the sample size calculation, control group, outcome assessor details, and blinding. A control group is important to establish a baseline and should be considered in future studies [45]. A meta-analysis was not performed due to the low amount and heterogeneity of the available evidence [46], [47].

Another limitation is that the reporting of data in case reports was not uniform, and the parameters used in each study were heterogeneous. Five of the studies did not report the voxel size or field of view used in the CBCT [23]–[26], [28], [29]. The reviewers observed a big variability among the studies regarding the CBCT machine, scanner, and printer used. In addition, 6 of the studies did not report the guide material [23]–[27], [29]. Since this is a technique based on the CBCT data, it would make more sense to have methodologically similar data reported [48]. This also highlights the need for uniform reporting to improve the quality of studies [49], [50].

In conclusion, as mentioned above, it is essential that the results of this review are treated with caution. Current evidence does show that the use of guided endodontics is effective and a safe procedure to remove dental posts, but this is based mostly on low quality evidence. Future high-quality and well-designed studies are of paramount importance to assess the technique, its limitations, usage, accuracy, and safety.

V. CONCLUSION

Current evidence supports that the use of guided endodontics is an effective and promising technique in the removal of fiber posts with a low risk of complications. However, extrapolation of the results should be treated with caution due to the low quality of evidence available. Future well-designed clinical studies are required to establish these findings.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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