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SCHOLARLY REVIEW

Advancements in guided surgical endodontics: A scoping review of case report and case series and research implications

Giusy Rita Maria La Rosa DDS. PhD.[1] | **Matteo Peditto DDS**[2] | **Andrea Venticinque DDS**[1] | **Antonia Marcianò DDS**[3] | **Alberto Bianchi DMD**[1] | **Eugenio Pedullà DDS, MSc, PhD**[1]

[1]Department of General Surgery and Medical-Surgical Specialties, University of Catania, Catania, Italy

[2]Postgraduate School of Oral Surgery, Department of Biomedical, Dental Sciences and Morphofunctional Imaging, University of Messina, Messina, Italy

[3]Department of Clinical and Experimental Medicine, University of Messina, Messina, Italy

Correspondence
Giusy Rita Maria La Rosa, Department of General Surgery and Medical-Surgical Specialties, University of Catania, Catania, Italy.
Email: g_larosa92@live.it

Abstract

This scoping review examined current case series and reports on guided surgical endodontic applications in order to provide a critical platform for future research. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for scoping reviews guidelines were followed. A search on PubMed and Scopus yielded 611 articles, with 17 case reports and 1 series meeting inclusion criteria. Overall, guided surgery addressed anatomical complexities, with 15 articles employing static protocols and 3 dynamic. Results showed minimal iatrogenic errors and reduced chair time, with no postoperative issues reported. Within the cases described, guided endodontic surgery exhibited satisfactory results in management of anatomical complex cases. Cost-effectiveness, the need for adequate follow-up, procedure's reproducibility and accuracy, and objective measurement of the reduction in operative times and iatrogenic errors are some of the limitations in the current reports that need to be considered for planning of future experimental and cohort studies.

KEYWORDS

dynamic endodontic surgery, guided endodontic surgery, scoping review, static endodontic surgery, targeted endodontic microsurgery

INTRODUCTION

The evolution of digital systems and computer-aided design/computer-aided manufacturing (CAD/CAM) technology has improved the treatment planning and management of clinical cases in all medical disciplines, including dentistry [1–3]. CAD/CAM technology and three-dimensional (3D) printing were introduced in the late 1980s and 1990s with a rapid widespread over the years [4–7]. Now, the fabrication of oral cavity models, temporary restorations and surgical templates represent suitable indications for a 3D approach [8–10]. This digital approach has recently incorporated endodontics, particularly surgical endodontics [11–14]. Surgical endodontics consists of a freehand protocol in which an osteotomy and an apical 3-mm resection manoeuvre were used to locate the root apex and eliminate the possible presence of ramifications and lateral canals, respectively [15, 16]. Despite the freehand protocol remaining a valid approach in almost all endodontic surgical cases, its application carries a high risk of removing a significant amount of bone and damaging vital structures [17–20].

To overcome these limitations, a computer-guided approach for surgical endodontics has been proposed, especially for anatomically challenging scenarios [21–23]. The use of guided implantology software, CBCT and 3D digital scanning of the oral cavity represent the key elements of virtual planning for surgical endodontic procedures [24–26]. Two different surgical approaches have been described: static and dynamic [22, 27–30]. The static approach requires the creation of a surgical template, obtained by the combination of a CBCT scan with an optical scan of the oral cavity. Many software programs can be used to design the surgical guide, create the STL file and print it with a 3D printer [14, 31]. This approach seems to ensure not only a precise osteotomy and apical resection but also a reduction in surgical time and postoperative complications [32]. The dynamic approach combines the use of surgical handpieces and radiological images by applying an optical positioning device controlled through a dedicated computer interface [33, 34]. A real-time clinical interface guides the operator to drill in the correct position, avoiding vital structures [34]. Dynamic surgery has been reported to guarantee better access to posterior sectors due to the absence of a surgical template. In each case, a reduction in operative time and risks of iatrogenic errors have been described [24, 35, 36].

The majority of data available in the literature on the applications of endodontic surgery come from case series and case reports [13, 14, 17, 20, 21, 24, 32, 34, 35, 37–46].

The objective of this scoping review is to offer a comprehensive overview of all case series and case reports, synthesising the current applications of guided endodontic surgery, and identifying the primary limitations in management and reporting of the clinical cases that warrant attention in future clinical trials.

MATERIALS AND METHODS

This scoping review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for scoping reviews [47] and focused on the synthesis and critical evaluation of case series and case reports so far available on the applications of guided endodontic surgery. There is no consensus on the minimum number of cases to define the distinction between case report and case series. Thus, based on a previous literature analysis [48], we assumed to classify case series as studies that reported a minimum of five cases.

Search strategy

A literature search was conducted in PubMed and Scopus databases on 10 October 2023 to identify all relevant studies. The following strategy was adopted for each database: 'Static Endodontic Surgery' OR 'Dynamic Endodontic Surgery' OR '3D Endodontic Surgery' OR 'Guided Endodontic Surgery' OR 'Targeted Endodontic Surgery'. No language or time restriction was used. Reference lists of selected studies were further screened for other relevant studies. Leading peer-reviewed scientific journals in endodontics and miscellaneous (*Journal of Endodontics, International Endodontic Journal, Australian Endodontic Journal, Clinical Oral Investigations, Odontology*) were also hand searched. Two authors independently reviewed and decided which studies had to be included. Disagreement was solved through discussion or by the decision of a third expert reviewer.

Eligibility criteria

All case reports and case series evaluating the application of guided techniques for managing surgical endodontic cases were included.

Exclusion criteria

Laboratory studies, cases not peer-reviewed, conference proceedings and studies without an English abstract were excluded. Additionally, studies that used guided techniques for non-surgical purposes, such as guided endodontics for orthograde treatments, were also excluded.

Data extraction and qualitative synthesis

For each study, the following items were tabulated: author; year; country; study design, patients; tooth type; aim; surgery; follow-up; radiological healing verification; main findings; limits identified by the authors. This calibrated form was tested by the team before its use. Data were extracted independently by two reviewers. No intervention of a third reviewer was required to solve disagreements. Qualitative synthesis focused on the main applications of guided endodontic surgery, as well as the benefits and limitations associated with its use.

RESULTS

Search findings

The initial search returned 619 articles (Pubmed = 610, Scopus = 9); after duplicate removal (n = 8), 611 articles

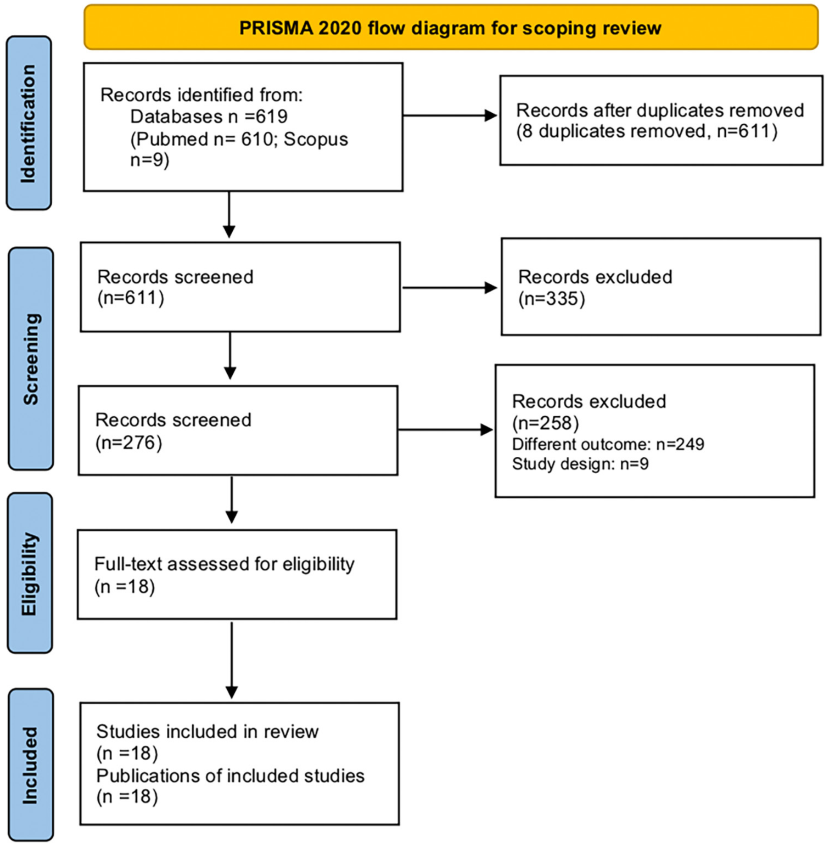

FIGURE 1 Flow chart of review process.

were screened. Of these, 17 case reports and 1 case series were selected according to the inclusion criteria (Figure 1). The main characteristics of the included studies are provided in Table 1.

General characteristics of the included studies

Four articles were performed in America [21, 24, 32, 42], six in Europe [13, 14, 34, 38, 44], six in Asia [17, 40, 41, 43, 45, 46] and one in Oceania [39]. In addition, two articles were multi-centre [20, 37].

A total of 36 patients were included with a higher prevalence of women (64%). The age ranged from a minimum of 21 [40] to a maximum of 66 years [21]. The most frequent type of tooth underwent guided endodontic surgery was the first upper [13, 21, 32, 44–46] and lower molar [32, 37, 38, 42, 45, 46], followed by the upper central [17, 40, 43, 45] and lateral incisor [14, 34, 41, 45] and the upper second premolar [13, 20, 24, 43]. Follow-up periods varied from a minimum of 1 week [21, 24, 32, 37, 43] to a maximum of 21-months [44]. No postoperative problems were found in all cases described. The most frequent method to verify the bone healing progression was a periapical radiograph [14, 17, 20, 24, 32, 34, 37, 39, 41, 43–46]; only three used periapical radiographs and CBCT at the end of the follow-up period [13, 40, 42]. Two articles did not report any verification method [21, 32].

Main applications

Seven case reports employed digital pre-design, fabrication, and use of a surgical template during the osteotomy and apical resection stages to improve precision and accuracy [13, 17, 24, 37, 39, 40, 42]. Eight articles proposed a different approach. More specifically, they employed a technique involving using trephine burs to perform osteotomy and apical resection in a single step [14, 20, 21, 32, 38, 41, 43, 44]. Furthermore, three reports described the use of dynamic surgery to ensure the exact apex localization [34, 45, 46].

Eleven cases reported that static and dynamic surgery allowed for reduced chair time, precise apical localization, and conservative osteotomy [13, 17, 21, 32, 34, 38, 40, 41, 43, 45, 46]. Two case reports showed few iatrogenic errors in managing complex cases [24, 37]. Furthermore, Gambarini et al. demonstrated that dynamic surgery permitted an undergraduate student to perform accurate apex localization and apicoectomy [34]. In addition, Chaves et al. proposed a novel simplified workflow for guided endodontic surgery, which minimised operative time and cost [42]. Popowicz et al.'s study reported that using

TABLE 1 Main features of the included studies.

Author	Year	Country	Study design	Patients	Tooth type	Aim
Ahn et al. [37]	2018	Korea, USA	Case report	$N=1$ 57-year-old woman	Lower first molar	To assess a surgical template for guided osteotomy.
Antal et al. [14]	2020	Hungary	Case report	$N=1$ 43-year-old male	Upper lateral incisor	To use a custom bone trephine for root-end resection.
Benjamin et al. [32]	2021	USA, Brazil	Case report	$N=3$ 63- and 38-year-old females; 53-year-old male	Upper and lower first molar	To assess the use of the guided technique in challenging scenarios (proximity of the neuro-vascular bundle).
Chen et al. [45]	2023	China	Case series	$N=9$ Teeth = 11 with 12 roots F = 7, M = 2 Mean age = 29.6 Follow-up at 12-months $N=8$ Teeth = 10 with 11 roots	Upper central and lateral incisors; lower central incisor; upper canine; upper and lower first molar.	To determine the accuracy of a DNS for guided osteotomy and root-end resection during EMS and evaluate its prognosis.
Chaves et al. [42]	2022	Brazil	Case report	$N=1$ 32-year-old woman	Lower first molar	To present a new method for the surgical treatment of a mandibular molar with a thick buccal cortical, with the help of CBCT only, excluding the use of 3D oral scanning.
Fu et al. [46]	2022	China	Case report	$N=3$ F = 1, M = 2 Mean age = 26.6	Upper first molar; lower first and second molar.	To report a novel approach to DNS-assisted EMS and its application in posterior teeth.
Gambarini et al. [34]	2019	Italy	Case report	$N=1$ 34-year-old male	Upper lateral incisor	To assess the simple use of dynamic surgery by an undergraduate student.
George et al. [39]	2020	Australia	Case report	$N=1$ 27-year-old female	Lower second premolar	To introduce an easy method for fabricating a surgical guide.
Giacomino et al. [21]	2018	USA	Case report	$N=3$ 66- and 39-year-old females; 23-year-old man.	Upper first and second molar; lower second premolar.	To illustrate using 3D printed guides and trephine burs to achieve single-step osteotomy and root-end resection.
Kim et al. [17]	2019	Korea	Case report	$N=1$ 25-year-old man	Upper central incisor	To use a template for targeting the apex position.
Mahendran et al. [43]	2023	India	Case report	$N=3$ 32- and 33-year-old females; 42-year-old male.	Upper central incisor and second premolar	To apply a new surgical endodontic technique by using a 3D printed template for guided osteotomy and root resection.
Popowicz et al. [20]	2019	Poland, USA	Case report	$N=2$ 37- and 52-year-old females	Upper second premolar	To surgically describe guided endodontics using implant planning software, 3D printed surgical guides and a modified soft tissue access.

Surgery	Follow-up	Radiological healing verification	Main findings	Limits identified by the authors
Static	1 week	Periapical radiograph	The use of a template facilitated osteotomy in complex cases.	The 3D fabrication of surgical templates was a time-consuming process; scattering.
Static	6 months	Periapical radiograph	The trephine removed the resected apex in one step.	The piece of tissue removed often stuck into the burs.
Static	3 and 10 days; 1 week.	NR	Using a 3D printed guide allowed conservative osteotomy and accurate root resection.	Time spent preoperatively designing and fabricating the template.
Dynamic	3, 6 and 12 months	CBCT at 1-week, periapical radiograph at the other follow-ups.	The results showed high accuracy of DNS in EMS. Moreover, DNS-guided EMS exhibited a success rate similar to that of freehand EMS over a short-term follow-up.	The need for lips retraction specially to facilitate the access in posterior regions; the surgical trephine used is designed for the implants' removal and thus created excessive dentinal tubules exposition; the trephine is unstable at the beginning phases; good hand-eye clinician coordination.
Static	7 months and 1 year	Periapical radiograph, CBCT at 1 year.	The new workflow could reduce chair time, costs and allow minor distortions.	The presence of high-density materials, such as implants or metal restorations, could have produced artefacts.
Dynamic	3 and 9 months	Periapical radiography	The DNS demonstrated its viability, predictability, and time-efficiency for cases involving treatment in anatomically complex regions, such as posterior teeth.	Economic costs; the need for hand-eye clinician coordination; learning curve.
Dynamic	1, 3, and 6 months	Periapical radiograph	The system allowed the precise localization of the root and precise apicoectomy.	The initial cost of the device.
Static	1 and 2 weeks; 3 months.	Periapical radiograph	The use of the template allowed the safe management of complex cases.	Fabrication of surgical stents was a complex and long-drawn-out process.
Static	12 weeks; 1 week and 1 month.	NR	The guided surgery produced an osteotomy site with predictable angulation, diameter, and depth.	Costs of equipment (i.e. CBCT, CAD-CAM software and 3D printer).
Static	1 month	Periapical radiograph	The new technique demonstrated improved accuracy compared with a free-hand procedure.	Scattering; surgical access disturbed by lips and cheeks.
Static	1 week and 1 month	Periapical radiograph	3D printing has proven to be advantageous in the field of surgical endodontics, offering promising opportunities over conventional methods.	NR
Static	7- and 8-months	Periapical radiograph	TEM with one single vertical incision allowed minimally invasive access.	Limited view of the resected root and difficulty in using ultrasonic tips.

(Continues)

TABLE 1 (Continued)

Author	Year	Country	Study design	Patients	Tooth type	Aim
Reddy et al. [40]	2022	India	Case report	$N=2$ 23- and 21-year-old males	Upper central incisor	To present the use of 3D-printed surgical guides for performing endodontic surgery.
Schmid et al. [44]	2022	Germany	Case report	$N=1$ 38-year-old woman	Upper first molar	To describe a novel approach for minimally invasive fully guided apicoectomy using a custom-made 3D-printed template.
Strbac et al. [13]	2017	Austria	Case report	$N=1$ 38-year-old female	Upper first molar and second premolar	To evaluate a surgical template for osteotomy and root resection.
Sutter et al. [38]	2019	Switzerland	Case report	$N=1$ 56-year-old male	Lower first molar	To introduce a novel method with CAD/CAM for a guided apicoectomy.
Tavares et al. [24]	2020	Brazil	Case report	$N=1$ 33-year-old female	Upper second premolar	To present a new method for performing guided surgical endodontics.
Ye et al. [41]	2018	China	Case report	$N=1$ 37-year-old female	Upper lateral incisor	To describe the use of a 3D printed template for performing periapical surgery.

Abbreviations: AP, Apical periodontitis; CAD/CAM, Computer-Aided Design/Computer-Aided Manufacturing; CBCT, Cone Beam Computed Tomography; DNS, dynamic navigation system; EMS, endodontic microsurgery; F, Female; M, Male; NR, Not Reported; TEM, Targeted Endodontic Surgery.

trephine burs with a single vertical incision ensured minimally invasive access [20]. Similarly, five studies reported that trephine burs resulted in precise one-step osteotomy and apical resection [14, 21, 38, 43, 44]. Interestingly, Chen et al. was the only study assessed the accuracy of dynamic endodontic surgery based on deviations in the platform, apex, and angle of the osteotomy, as well as in the length and angle of the root-end resection [45].

DISCUSSION

Orthograde endodontic treatment cannot be performed in some cases, such as in obliterated canals and anatomically challenging cases; consequently, surgical endodontics is required [17, 49].

Surgical endodontics was classically performed using a freehand protocol with the aid of a microscope, micro instruments and ultrasonic tips [18, 50–53]. Recently, guided surgical endodontics has been proposed to improve the procedure and assist clinicians in the management of the most complex cases [21, 24, 32, 38].

In recent years, different guided endodontic surgical techniques have been introduced that follow a static or dynamic approach. In the static approach, microsurgery is conducted using surgical templates to perform guided osteotomy and apical resection [13, 20, 24]. In the dynamic approach, specific equipment consisting of a navigator with an infrared system [34, 35] is used. However, to date, there is no protocol that allows the standardised management of guided endodontic surgery.

Study designs in guided endodontic surgery literature

The case series and case reports are study designs with limited clinical evidence that do not establish causation and prevent generalizability of the results [18]. On the contrary, the case reports/series have the advantage of collecting clinical observations, proposing new ideas and functioning as a teaching document to facilitate the identification of similar cases [54–56]. A preliminary investigation has revealed that the majority of clinical data on the applications

Surgery	Follow-up	Radiological healing verification	Main findings	Limits identified by the authors
Static	6 months	Periapical radiograph; CBCT.	Targeted EMS allows conservative and minimally invasive osteotomy.	NR
Static	21 months	Periapical radiograph; CBCT at 1 week.	No postoperative complication and a total symptoms' remission was achieved after 2 weeks. The 21 months' follow-up showed clinically and radiologically satisfying conditions This technique could represent a minimally invasive approach for preserving infected maxillary molars.	The needed equipment diminished the practicability, increased the costs for the patient and the surgeon, and it was time consuming.
Static	6 and 12 months	Periapical radiograph; CBCT at 12 months.	The proposed method ensured a precise and safe approach to osteotomy.	The production was costly and time-consuming.
Static	6 months	Periapical radiograph	Guided apicoectomy allowed precise root resection.	CBCT, intraoral scanner, software for guided surgery, and 3D printing capability are necessary.
Static	1 week; 1 and 6 months	Periapical radiograph	This technique showed a reduction in iatrogenic errors.	High cost of the device.
Static	6 months	Periapical radiograph	This method simplified the surgical procedure and improved the treatment efficiency.	Time-consuming pre-operative procedure; difficulties in using the trephine burs in the posterior regions; cost of 3D device.

of endodontic surgery originate from case series and case reports. For this reason, a scoping review of only case series and case reports has been conducted to synthesise the current applications and identify the main limitations in clinical cases' management and reporting, with the aim of providing valuable data for the design of future high-quality experimental and observational studies.

Anatomical considerations in guided endodontic surgery

A direct comparison of the selected cases was not possible due to the great variety in purpose, methodology and surgical protocol.

The majority of described cases involved molars. The anatomy and type of tooth can significantly impact guided surgery, particularly in the case of multi-rooted teeth like molars. Their intricate root canal structures, thicker vestibular bone walls, and proximity to sensitive anatomical features such as sinuses and mandibular canals pose considerable challenges for apicoectomy procedures [57–59]. Moreover, ensuring precise trephine positioning and angulation often necessitates extreme lip retraction, particularly when working in posterior regions [38].

Case selection for guided endodontic surgery in the included studies

The clinical cases selected for guided endodontic surgery varied among the studies. A guided surgical approach was preferred for the management of persistent and recurrent apical periodontitis in previously root canal treated teeth [13, 14, 20, 34, 37, 43–45] especially when the orthograde retreatment could not be recommended for the presence of a metal post [14]. In addition, the authors used a guided surgical approach in the presence of significant root canal calcifications that prevented orthograde root canal treatment [17], history of trauma [40], large periapical lesion suspected to be a cyst [41] as well as for the management of cases with anatomical difficulties [21, 24, 32, 38, 39, 42, 46]. The anatomical challenge included a thick buccal cortical bone plate [42], the proximity of vital anatomical structures such as the greater palatine artery [21, 32], maxillary sinus [21, 24, 46], inferior alveolar nerve [38], accessory mental neurovascular bundle, posterior superior alveolar artery [32] and mental foramen [39].

Static versus dynamic guided surgery: Benefits and limitations

Among the included cases, only three applied a dynamic guided endodontic approach [34, 45, 46]. Both static and dynamic surgery follow a guided surgical protocol, with the aim to allow the clinician to achieve accurate osteotomy and apical resection [27]. The included cases exhibited advantages and disadvantages for both systems. Static surgery applies bony-, mucosal- or dental-supported surgical guides [27] which should permit the performance of surgical endodontics with a high level of accuracy in terms of osteotomy and apical resection [39]. Moreover, if designed correctly, it should prevent injury to vital anatomical structures [21, 24, 32, 38, 39], reducing iatrogenic errors [24]. However, designing a surgical guide is not simple. It is often a time-consuming process [13, 24, 34, 37, 39, 41] requiring the knowledge of different digital design programs [21, 38]. In addition, the use of technology such as CBCT and intra-oral scanners increases the total costs [13, 24, 34, 38]. To overcome these limitations, current research is focusing on the use of affordable benchtop 3D printers that can also be used in private practices and are easier to manage [37]. Alternatively, 3D printing labs with experience in the fabrication of implant surgical guides could produce templates for endodontic use [60–62]. The use of CBCT has another notable limitation linked with the scattering generated by metal prosthetic restorations [25, 63, 64]. Scattering is determined by photons diffracted from their original path after interaction with an object, represented in this case by the prosthetic restoration [65, 66]. This phenomenon is of clinical interest because it could create radiographic artefacts that modify the appearance of the digitally designed surgical template, thereby preventing the achievement of the best possible accuracy [67].

Dynamic surgery does not include the fabrication of a surgical template. Instead, this system integrates surgical instrumentation and radiological images via an optical positioning device through a dedicated software interface [34]. The included studies used a dynamic approach to root apex location [34] for facilitating the osteotomy and apex resection manoeuvres [27, 34]. Overall, dynamic surgery should permit a substantial reduction in surgical time [27, 34, 35] with the additional advantage of assisting the operator to make corrections during the surgical phase by changing the inclination of the handpiece [27]. Interestingly, one study assessed the accuracy of guided procedure by determining deviations in the platform, apex, and angle of the osteotomy, as well as in the length and angle of the root-end resection [45]. According to their results no notable disparities between arch types (maxilla versus mandible), sides (left versus right), and surgical depth (greater than versus less than 5 mm) emerged. This suggests that the usage of dynamic guided endodontics can be especially advantageous in anatomically demanding scenarios, thereby lowering the occurrence of iatrogenic mistakes.

The main disadvantage are that the whole procedure is computer-dependent, and a lag at any point during the procedure could lead to iatrogenic errors [27] as well as the expensive cost of the equipment, including devices, CBCT and navigator [34]. In addition, achieving proper access and angulation with the trephine can be challenging, often requiring extreme lip retraction, especially in posterior areas [45]. The surgical trephine, originally designed for implant and bone graft removal, creates a resected apex that lacks the necessary concave shape [68], potentially harbouring intra-radicular infections due to exposed dentinal tubules [45]. Finally, dynamic guided surgery demands exceptional hand-eye coordination and expertise, as clinicians must simultaneously manage the screen and manipulate the handpiece during the procedure [45].

Methodological diversity in surgical approaches

Surgical approach exhibited notable variety among the cases described. Multi-step static surgery was a commonly employed method, involving the use of a surgical template for osteotomy [13, 17, 37, 39, 42] with rotating instruments of different dimensions [24, 37, 39]. Ultrasonic surgical tips for osteotomy [42] and piezoelectric saws for apical resection [13] were also proposed. Standardised burs in osteotomy ensured conservative tissue removal, preserving vital anatomical structures [13, 17, 37, 39, 40]. Additionally, one study used a special surgical template for precise soft tissue management during flap creation [24]. Another approach, one-step static surgery, employed chirurgical templates but introduced the use of trephine burs for simultaneous osteotomy and apical resection [14, 20, 21, 32, 38, 41, 43, 44]. However, the non-uniform diameter of classic trephine burs posed a risk of over-penetration [21, 32, 38]. To address this, Antal et al. [14] described a custom-made trephine bur system for predictable osteotomy dimensions. This technique is experimental and lacks commercial availability, limiting the number of cases for scientific conclusions.

Follow-up and evaluation of treatment efficacy

Among the included articles, the most common method to verify the bone healing process was the periapical radiograph with three studies also used CBCT [13, 40, 42] at the end of the follow-up. Both the methods described have been reported to be suitable for this purpose [69]. The included studies followed up the clinical case for different periods ranging from a minimum of 1 week [21, 24, 32, 37, 43] to a maximum of 21-months [44]. In general, no postoperative complications were observed in any of the described cases [13, 14, 17, 20, 21, 24, 32, 34, 37–46]. However, some of the included reports had a follow-up period insufficient for detecting any bone healing [17, 21, 32, 37, 39, 43].

Two case reports evaluated iatrogenic errors associated with guided surgery technique, yet neither described the methodology applied to verify the occurrence of iatrogenic errors [24, 37].

Purpose and impact of the scoping review

The exclusive selection of case series and case reports could potentially affect the validity of this review. However, as previously mentioned, this scoping review was conceived to explore the main limitations in the management and reporting of clinical cases, with the purpose of providing valuable insights for the design of future high-quality clinical trials and cohort studies [70, 71]. Thus, within the limit mentioned, the results obtained can be equally informative and adequate for our purpose.

Our scoping review provides a unique contribution to the literature by employing a methodologically rigorous approach to comprehensively compile and analyse case reports and series on guided endodontic surgery. This stands in contrast to the more generalised [72, 73] or technique-specific focus of the previous reviews [74], and includes the most up-to-date research in this rapidly evolving field.

Future perspectives in guided endodontic surgery

The use of guided surgical endodontics techniques might be useful in selected cases (e.g. obliterated canals, challenging anatomical scenarios and prosthetic restorations), justifying the high initial cost of operative equipment; however, cases included in this review have shown some pivotal limitations that warrant special consideration in future clinical experimental and cohort studies. Among these limitations, the need for adequate follow-up and radiological bone healing verification, procedure's reproducibility and accuracy, objective measurement of the reduction in operative times and iatrogenic errors, and cost-effectiveness need to be addressed in the future studies.

Final considerations for future research

Ensuring sufficient and consistent follow-up, coupled with rigorous radiological assessment, is paramount. In many cases, case series and reports often lack comprehensive data on the long-term post-operative outcomes and radiological evidence of bone healing [17, 21, 32, 37, 39, 43].

Furthermore, the issue of reproducibility is a prominent concern in guided endodontic surgery. Variations in surgical techniques, operator experience, and patient-specific factors can influence the procedure's success. The accuracy of these techniques is not only essential for their effectiveness but also for reducing operative times and minimising the potential for iatrogenic errors, particularly in challenging cases. However, the existing literature often lacks standardised and objective metrics for measuring these outcomes. Future research should employ well-defined, validated measurement tools to ensure precise and reproducible data on surgical time reductions and iatrogenic error reductions as well as focus on establishing standardised guidelines and protocols to ensure the reproducibility and accuracy of guided endodontic surgery across diverse clinical settings.

While guided endodontic surgery shows promise, its cost-effectiveness compared to traditional methods remains a subject of debate. In-depth economic evaluations are essential to provide insights into the economical implications of adopting guided techniques in clinical practice, ultimately guiding healthcare decision-makers and clinicians.

CONCLUSIONS

Seventeen case reports and one case series were reviewed using a scoping approach to determine the current applications of guided surgical endodontics. Within the limits of cases described, guided surgical endodontics reported satisfactory results in the management of most challenging endodontic cases, including complex anatomic scenarios, presence of significant root canal calcifications, and persistent pain following apparently adequate orthograde treatment. Several shortcomings have been identified in how current reports are managed and presented. It is crucial to consider these limitations when planning future experimental and cohort studies. These limitations include the need for thorough follow-up and radiological bone healing verification, ensuring the procedures are accurate and can be replicated, assessing cost-effectiveness, and using objective measures to evaluate how much time is saved and how often mistakes occur during surgery.

AUTHOR CONTRIBUTIONS

Conceptualization: Eugenio Pedullà, Giusy Rita Maria La Rosa. Data curation: Giusy Rita Maria La Rosa, Alberto Bianchi, Andrea Venticinque, Matteo Peditto Formal analysis: Andrea Venticinque, Giusy Rita Maria La Rosa, Antonia Marcianò. Investigation: Giusy Rita Maria La Rosa, Andrea Venticinque. Methodology: Eugenio Pedullà, Alberto Bianchi. Project administration: Eugenio Pedullà, Alberto Bianchi. Resources: Eugenio Pedullà. Software: Giusy Rita Maria La Rosa. Supervision: Eugenio Pedullà, Antonia Marcianò. Validation: Eugenio Pedullà, Giusy Rita Maria La Rosa, Matteo Peditto. Visualisation: Giusy Rita Maria La Rosa, Andrea Venticinque, Matteo Peditto. Roles/Writing–original draft: Giusy Rita Maria La Rosa, Andrea Venticinque. Writing–review & editing: Eugenio Pedullà, Giusy Rita Maria La Rosa, Antonia Marcianò, Matteo Peditto, Alberto Bianchi. All authors have read and approved the manuscript.

CONFLICT OF INTEREST STATEMENT

All authors report no conflicts of interest related to this study.

ORCID

Giusy Rita Maria La Rosa https://orcid.org/0000-0001-5127-5299
Matteo Peditto https://orcid.org/0000-0002-6995-6276
Andrea Venticinque https://orcid.org/0000-0001-5664-3118
Alberto Bianchi https://orcid.org/0000-0001-9374-2748
Eugenio Pedullà https://orcid.org/0000-0001-6231-8928

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