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Guided endodontic microsurgery in apicoectomy: a review

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The purpose of this review was twofold. The first aim was to show predictable protocols of guided endodontic microsurgery (EMS) and to describe its clinical outcomes. The second aim was to verify the accuracy of this technique compared to the traditional pathway. An electronic search of publications was established from two electronic databases, Cochrane and PubMed, by two independent researchers. The search strategy used a combination of controlled vocabulary and free-text words. Inclusion and exclusion criteria were defined by the authors before the start of the study. Inclusion criteria were: all studies published in English language; studies in vivo on humans; human cadaver studies; studies analyzing guided surgery in apicoectomy. The initial search yielded 67 citations, of which 10 were included. The studies included in this review analysis have shown two different technique both for digitization of dental arch and for surgical procedures too. Guided endodontic micro-surgery is a more predictable technique with less intra-operative and post-operative complications compared to the "freehand" technique and this procedure has shown a greater accuracy.

The goals of endodontic treatment are to prevent or resolve root canal infections (1-10). In the case of periradicular pathosis, potential pathogens are usually eliminated by non-surgical root canal treatment with subsequent obturation and coronal restoration (11-15). However, treatments can fail due to anatomical difficulties, iatrogenesis and lack of bacterial removal. Therefore, when conventional endodontic techniques are exhausted, endodontic surgery becomes an alternative treatment to remove unreachable infected areas and seal the root canal, allowing for healthy periapical tissue recovery (16-18)

The success rate of conventional endodontic surgery is relatively low, between 43.5% and 74%. However, by applying contemporary techniques, including high-power magnification and illumination, microsurgical instruments, and modern filling materials, success rates of surgery have significantly increased, and, in turn, surgery has become a more effective treatment. Success rates for endodontic microsurgery (EMS) have been reported to be between 88.9% and 100%. EMS is, in its broadest sense, defined as the treatment performed on the root apices of an infected tooth, which was unresolved with conventional root canal therapy.

EMS was introduced in the 1990s and has been continuously developing over the years (19-22). Generally, procedure for EMS encompasses the removal of the buccal bone in order to accurately locate the root apices of an infected tooth, which may include the removal of intact bone. It also includes three critical steps to eliminate persistent endodontic pathogens (23-31): 1) surgical debridement of pathological periradicular tissue, 2) root end

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resection (apicoectomy), and 3) retrograde root canal obturation (root-end filling) (2) with Mineral Trioxide Aggregate (MTA) or Biodentine as a new way (32-35). Lastly the surgical site is sutured. Nowadays the use of Cone Beam Computer Tomography (CBCT) is mandatory to perform an exact diagnosis of type, and extension of the periapical lesion, shape and anatomy of the roots and of the channels system, and its use have contributed to increase the success rate.

Recently, CBCT combined to intraoral scan has been recognized as means to build an endodontic surgical guide to perform a facilitate access to the apex, similar to implant dentistry where, in the last decade, CBCT imaging was extensively used to plan and perform accurate guided implant placement by surgical guides (36-44). Surgical templates are particularly helpful in difficult cases involving teeth close to potentially problematic anatomic structures. Structures such as adjacent root tips, the inferior alveolar nerve, the mental foramen, and the maxillary sinus contribute to the difficulty in surgical approaches to the root apex (45-55).

Therefore, virtual three-dimensional (3D) planning in endodontics and the surgery guidance represents new important aspects for the treatment of complex cases. The first aim of this review was to show predictable protocols of guided EMS and to describe its clinical outcomes. The second aim was to verify the accuracy of this technique compared to the traditional pathway.

MATERIALS AND METHODS

Inclusion and exclusion criteria were defined by the authors before the start of the study. Inclusion criteria were: all studies published in English language; studies in vivo on humans; human cadaver studies; studies analyzing guided surgery in apicoectomy.

The exclusion criteria were: in vitro and in vivo on animal analysis; publications that reported the same data as later publications by the same authors; commentaries and letters to the editor and reviews of literature.

Types of interventions

All studies that presented new endodontic surgical guided techniques, thanks to the use of customized guides for the individual patient obtained through CBCT 3D planning. Besides, studies that analyzed the accuracy of these techniques compared to traditional ones.

Outcome measures

Each study that showed a new micro-surgical endodontic guided technique and evaluated clinical outcomes and precision of guided surgery compared with the traditional approach in apicoectomy.

Research question

Pico question. We have formulated a specific question based on the PICO format where P stands for participants, I for intervention, C for comparison and O for the objective. The question was: “Does exist an improvement of clinical outcomes and accuracy (O) using guided surgery (I) respect to traditionally surgery (C) in the treatment of patients (P) affected by periapical/periradicular lesion requiring apicectomy?”. An electronic search of publications was established from two electronic databases: Cochrane and PubMed. The search strategy used a combination of controlled vocabulary and free-text words. The detailed search design and strategies, including keywords, developed for each database are presented below.

Search strategy

(guided[All Fields] AND (“surgery”[Subheading] OR “surgery”[All Fields] OR “surgical procedures, operative”[MeSH Terms] OR (“surgical”[All Fields] AND “procedures”[All Fields] AND “operative”[All Fields]) OR “operative surgical procedures”[All Fields] OR “surgery”[All Fields] OR “general surgery”[MeSH Terms] OR (“general”[All Fields] AND “surgery”[All Fields]) OR “general surgery”[All Fields])) AND (“endodontics”[MeSH Terms] OR “endodontics”[All Fields]) OR (guided[All Fields] AND (“surgery”[Subheading] OR “surgery”[All Fields] OR “surgical procedures, operative”[MeSH Terms] OR (“surgical”[All Fields] AND “procedures”[All Fields] AND “operative”[All Fields]) OR “operative surgical procedures”[All Fields] OR “surgery”[All Fields] OR “general surgery”[MeSH Terms] OR (“general”[All Fields] AND “surgery”[All Fields]) OR “general surgery”[All Fields])) AND (“apicoectomy”[MeSH Terms] OR “apicoectomy”[All Fields])

RESULTS

The search from electronic databases resulted in 55 titles, for an amount of 67 title by 12 additional records identified by manual searching. Following the first stage of screening, setting the filter at last 10 years, 30 potentially relevant studies were identified.

After the second stage screening 14 articles were eliminated by reading the titles, 4 further articles by reading the abstract. Afterwards, after the full text reading of the 12 articles eligible, only 10 articles were included in the quantitative analysis (Fig. 1).

DISCUSSION

Apicoectomy consists in the resection of the dental apex associated to periapical lesion and in the retrograde seal of the root canal. The approach to apicoectomy has significantly changed over the years; the advent of new technologies, in fact, has allowed the transition from “freehand” surgery to guided surgery. Traditional approach consisted: mucoperiosteal flap preparation, ostectomy if necessary, surgical debridement of the periradicular tissue, resection of the end of the root and retrograde obturation of the canal. The freehand technique showed, by the literature, numerous disadvantages: removal of a greater quantity of bone, longer intervention time, post-operative problems, such as pain and swelling (56-62). Less experienced clinicians could mistakenly perform excessive osteotomy in difficult anatomical cases.

The diameter of a bony defect influences healing outcomes after endodontic surgery. Extensive bone destruction tends to result in uncertain or unsuccessful healing, delays in the healing process, and risk for postoperative complications. However, one of the most critical disadvantages of conventional root-end resection included the damage to anatomically vital structures such as inferior dental nerve, mental nerve, adjacent root and maxillary sinus. The guided EMS involves the creation of a

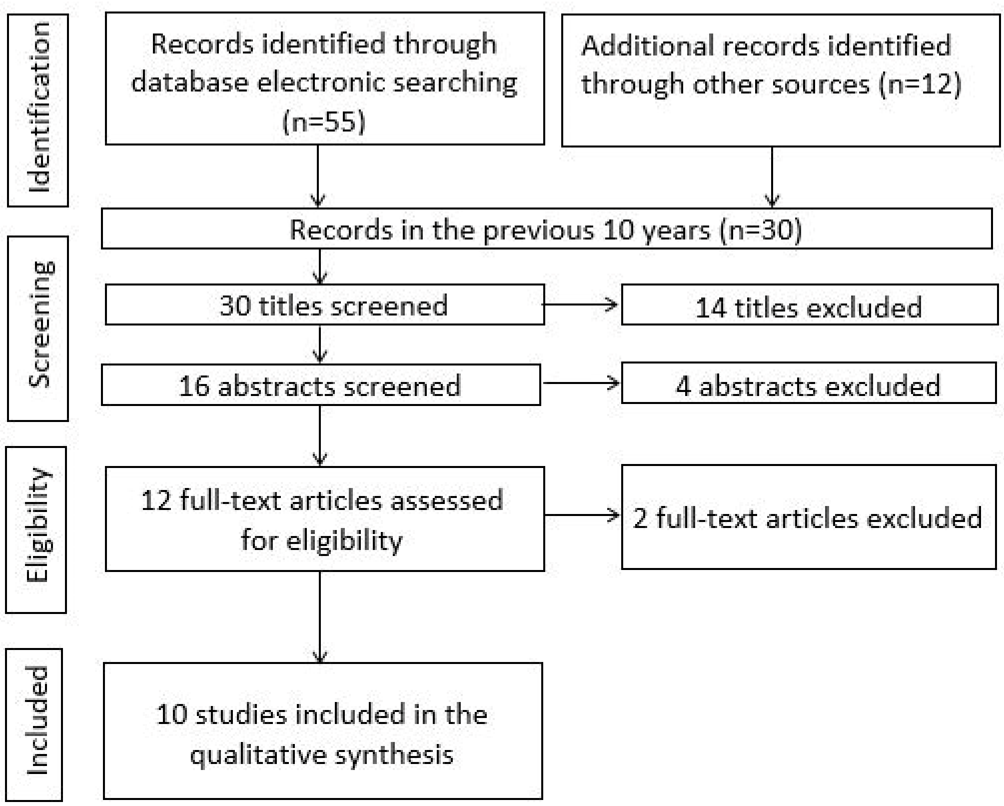

Fig. 1. *Diagram of article selection process–Search strategy.*

surgical guide through a dedicated software. This procedure is similar to the one used for the creation of a template that guides implant placement.
The 3D planning to produce the surgical templates is certainly costly and still time-consuming compared with conventional procedures and requires technical expertise, equipment, and software for merging files to designing and printing 3D surgical guides (63-67). The template allows a correct inclination of the handpiece and of the dedicated drills for a correct resection surgery of the root apex. In this way, access to the root apex is planned and performed correctly, safely and minimally invasively by minimizing the risks of damaging vital structures and by decreasing the extent of the osteotomy. Decreasing the extent of the osteotomy, by means of 3D printed surgical templates, could also help reduce surgical complications and promote healing. Compared to the conventional approach, EMS using the guide template has shown many advantages such as below:

1. root apex can be more accurately located through the provision of drilling hole, which will result in the minimal invasive preparation;
2. Surgical time and the volume of bone preparation can be significantly reduced;
3. Post-operative healing is more favorable and reduced risk of infection leads to better prognosis;
4. more predictable and less-technique sensitive

Table I. *Case reports included in the review analysis.*

Author	Year	Digitization technique*	Surgical guided procedure	Clinical Outcome(s)
Liu Y et al.	2014	Indirect	Guided ostectomy, apex localization and root resection	This case report illustrates that with additive manufacturing (AM) and digital design methods, optimal operational plans can be designed and realized for apicoectomy, and the quality and efficiency of clinical surgery are greatly improved compared with conventional methods.
Strbac GD et al.	2017	Direct	Guided ostectomy, apex localization and root resection	There were no post-operative complications, and clinical and radiologic assessments verified complete healing of the teeth. The guided microsurgical endodontic treatment presented appears to be a viable technique that allows for predefined osteotomies and root resections.
Giacomino CM et al.	2018	Indirect	Guided osteotomy, apex localization and root resection	Targeted EMS could prove to be an important breakthrough allowing precision-guided surgery in anatomically complex areas for teeth that may have otherwise required extraction. Surgical phase simplification is achieved and time is reduced.
Ahn SY et al.	2018	Indirect	Guided bone perforation and apex localization	A computer-aided design/computer-aided manufacturing (CAD/CAM)-guided surgical template minimized the extent of osteotomy and enabled precise targeting of the apex. There were no post-operative complications. A CAD/CAM-guided surgical template is useful in endodontic surgery for complicated cases.
Kim JE et al.	2019	Indirect	Guided bone perforation and apex localization	Endodontic microsurgery (EMS) using the guide template could be useful method in calcified canal which was untreatable with conventional root canal therapy and unable to track the position of the apex due to the absence of fistula.
Tavares WLF et al.	2019	Direct	Guided osteotomy, apex localization and root resection	The method employed was demonstrated to be very straightforward and reliable. This method allowed the patient to be treated expeditiously with very precise tissue removal. The patient remained asymptomatic, and the tissue healed normally.
Sutter E et al.	2019	Direct	Guided osteotomy, apex localization and root resection	Guided apicoectomy using a patient specific CAD-CAM drilling template is a precise, time-effective surgical intervention with high precision and predictability. This innovative treatment method is primarily indicated for apicoectomy in complex anatomical areas with proximity to vulnerable structures.
Avantaggiato P et al.	2020	Direct	Guided bone perforation and apex localization	Further investigation are needed to test and improve the effectiveness of the treatment but this technique seems very promising because it is less invasive for the patient and simplifies the work for the dentist who can perform micro-surgery in an easier and faster way.

**Indirect: arch digitalization from traditional impression with extra-oral scanner; Direct: arch digitalization with intra-oral scanner.*

results can be expected regardless of clinician's experience.

The case reports included in this review article demonstrated the presence of two different techniques described in literature both regarding the planning of 3D surgical guides and surgical procedures (Table I.).

The surgical strategies documented to date provide the use of guides only for bone perforation and apex localization or contrary to obtain a micro invasive osteotomy and the programmed apical resection with dedicated tips. Regarding the surgical guides we can show an indirect and a direct method of dental arch digitization.

In the indirect technique, a preliminary impression of the dental arch is detected and subsequently a stereolitography (STL) file of the plaster cast is generated using an extra-oral scanner. In the direct technique the STL file is obtained through an intraoral scanner (IOS) directly. Consequently, the STL of the dental arch and the digital imaging and communication in medicine (DICOM) CBCT files are imported into the planning software. Since the superimposition, virtual planning is performed to determine the exact localization for root resection. Subsequently, a tooth-supported drilling template is designed, and 3D printed. Accuracy of the impression process may have a significant effect on the accuracy of guide template (6). Although all case reports have come to the same conclusions previously reported; therefore, the use of a 3D printed surgical guide is a more predictable method with less intra-operative and post-operative complications compared to the "freehand" technique, further investigation is needed to compare the accuracy of the two described techniques (45-50).

According to the clinical outcomes of the case reports showed in this review, Ackerman et al. (17) have assessed the accuracy of surgical guides designed by CBCT for the use during endodontic surgery in a cadaveric model. In the experimental group, surgical guides were designed and printed using 3D printer. In the control group, surgical access was completed "freehand" by visually approximating the measurements only from the CBCT scan. The deviation of the surgical access point in the experimental CBCT-guided group versus the approximate freehand group with CBCT control were compared. The mean deviation for the guided group was 1,473 (± 0.751 mm), significantly less than that of the approximate freehand group were the mean deviation was 2,638 mm (±1.387) (P 0.0009).

Also Fan et al. (18) have conducted a human cadaver study and have compared CBCT imaging and prefabricated grids to guide apical access during EMS to the non-guided method. The mean deviation of the drill paths from the target points was 0.66 mm (± 0.54 mm) for grid-based drilling and 1.92 mm (±1.05 mm) for non-guided drilling (P < .001). Grid-based drilling was on average 1.27 mm (95% confidence interval, 0.81–1.72 mm) closer to the target point than non-guided drilling.

Both studies reached the same conclusion: the use of a surgical guide is a more accurate method for accessing the apical portion of the root during surgical endodontics than an approximate non guided method.

Within the limitations of this review study, the guided EMS, in the field of apicoectomy, appears to represent a predictable technique to manage this surgical procedure. Moreover, it has shown better results compared to the traditional "freehand" technique, in terms of accuracy, surgical time, volume of bone preparation, control of post-operative pain and swelling. Lastly, guided EMS showed less-technique sensitive results that can be expected regardless of the clinician experience.

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