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Major factors for the effectiveness of apical endodontic microsurgery: a systematic review

Mariana Lourenço Ribeiro[1,2*], Letycia Santos Bersaneti[1,2], Fábio Pereira Linhares de Castro[1,2]

[1] UNORTE - University Center of Northern São Paulo, Dentistry Department, São José do Rio Preto, São Paulo, Brazil.
[2] UNIPOS - Post Graduate and Continuing Education, Dentistry Department, São José do Rio Preto, São Paulo, Brazil.

*Corresponding author: Mariana Lourenço Ribeiro,
Unorte/Unipos - Post graduate and continuing education,
Sao Jose do Rio Preto, Sao Paulo, Brazil.
E-mail: marianaribeiroendodontia@gmail.com
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Abstract

Introduction: Apical endodontic microsurgery is a technique developed by the evolution of traditional apical endodontic surgery approaches and technologies. This enhancement was possible since the introduction of equipment like cone beam computed tomography, microscope, ultrasonic instruments, and biocompatibility root-end material filling, increasing the predictability and long-term success rates and survival of teeth. **Objective:** It explored and developed the main factors for the effectiveness of apical endodontic microsurgery. **Methods:** The PRISMA Platform systematic review rules were followed. The search was carried out from October to December 2023 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** A total of 118 articles were found, 43 articles were evaluated in full and 36 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 28 studies with a high risk of bias and 21 studies that did not meet GRADE and AMSTAR-2. Most studies did not show homogeneity in their results, with X^2=57.5%<50%. It was concluded that the success of apical endodontic surgery in terms of healing existing periapical pathology, together with a good long-term prognosis, depends on correct diagnosis and planning, as well as the association of surgical techniques, well-executed protocols, and biocompatible materials. The apical endodontic microsurgical approach is predictable and has a high success rate, which resulted from the introduction of cone beam computed tomography, microscope, ultrasonic instruments, and materials such as MTA and bioceramics for retro-fillings.

Keywords: Endodontic surgery. Apical surgery. Microsurgery. Efficiency.

Introduction

Knowledge about endodontic infections has increased significantly over the last 50 years and, although many issues still require elucidation, Endodontics has become the dental science that has the most improved approaches and technologies to increase the success and longevity of dental organs [1].

Even though initial endodontic therapy has high rates of predictability and success, the persistence of inflammatory disease of the periradicular tissues (apical periodontitis) is attributed to the following factors: "persistent intraradicular infection in the complex system of apical root canals; extraarticular infection, usually in the form of periapical actinomycosis; extruded root canal filling or other exogenous materials that cause foreign body reaction; accumulation of endogenous cholesterol crystals that irritate periapical tissues; true cystic lesions and healing of scar tissue from the lesion" [2].

Identifying the source of failure in endodontic treatment is a sine qua non for obtaining successful long-term results and the preferable option for managing this clinical situation is non-surgical endodontic retreatment, with an overall weighted success rate of 78 %. However, in cases where non-surgical endodontic retreatment is not feasible and/or the probability of improvement from previous treatment is very low, there is still the possibility of performing retrograde treatment through apical endodontic surgery [3,4].

However, the combination of high technology in the technical and clinical approach has become extremely essential for the success of the treatment. As techniques improved and companies developed more technological and biocompatible materials, apical endodontic microsurgery (EMS) became a safer and more predictable procedure, with success rates reaching 93.5%, according to the meta-analysis carried out by Setzer et al (2010) [5]. This new technique recommends the use of microinstruments and ultrasonic inserts to perform resection and retro preparation of the root and, the use of more biocompatible filling materials, under detailed observation promoted by high magnification and high illumination operating microscopes, allowing the surgeon the ability to identify anatomical variations, previous iatrogenesis, isthmuses, lateral canals and accessories.

Therefore, the present study explored and developed the main factors for the effectiveness of apical endodontic microsurgery.

Methods

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 08/14/2023. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 08/14/2023.

Data Sources and Research Strategy

The literary search process was carried out from October to December 2023 and was developed based on Scopus, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various eras to the present. The descriptors (MeSH Terms) were used: *"Endodontic surgery. Apical surgery. Microsurgery. Efficiency"*, and using the Boolean "and" between the MeSH terms and "or" between historical discoveries.

Study Quality and Risk of Bias

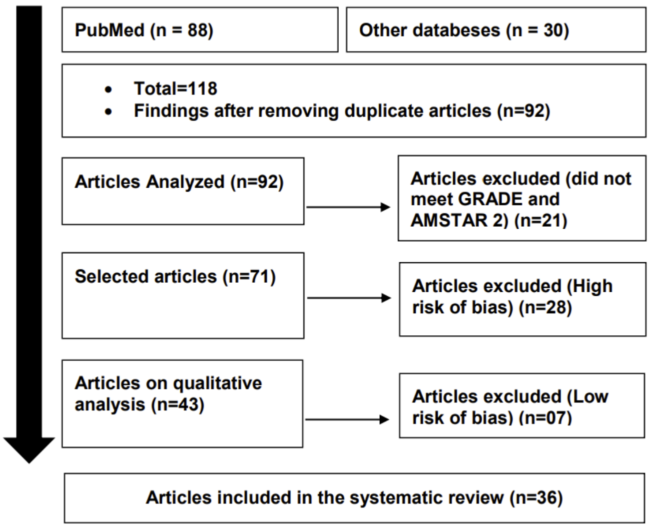
Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using the Cohen test (d).

Results and Discussion

Summary of Findings

A total of 118 articles were found that were subjected to eligibility analysis, with 36 final studies being selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. The biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies showed homogeneity in their results, with X^2=57.5%<50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 28 studies with a high risk of bias and 21 studies that did not meet GRADE and AMSTAR-2.

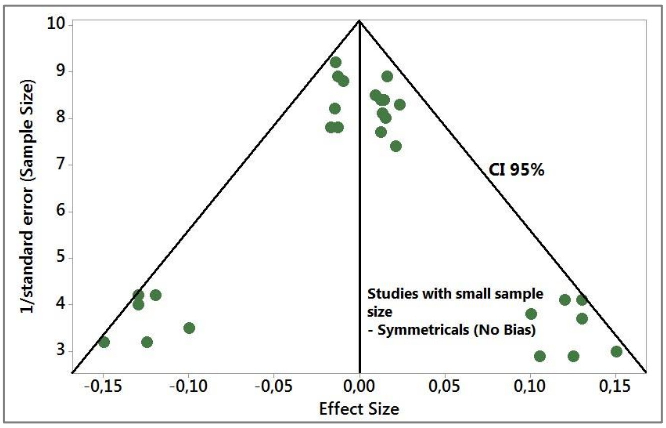
Figure 1. Article selection - exclusion process.



Source: Own authorship.

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using the Cohen Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both between studies with a small sample size (lower precision) that are shown at the bottom of the graph and in studies with a large sample size that are presented at the top.

Figure 2. The symmetric funnel plot suggests no risk of bias among the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph (n=36 studies).



Source: Own authorship.

Highlights Outcomes

Endodontic Microsurgery (EMS)

The evolution of the traditional approach to apical endodontic surgery is now called apical endodontic microsurgery. This new technique combines the use of a microscope with the appropriate use of microinstruments and biomaterials. Thus, it is possible to have better visualization of anatomical details (such as isthmuses, lateral canals, and microfractures), more conservative osteotomies, and shallower resection angles, in addition to more precise and coaxial retro preparations and fillings, meeting the requirements of biological and mechanical principles required by apical endodontic surgery [1-3].

Furthermore, the success of EMS is directly linked to a correct diagnosis and case planning. There are some possibilities for imaging evaluation, however, the best way to complement clinical evaluation currently is cone beam computed tomography (CBCT), which reproduces a three-dimensional (3D) image of the maxillofacial skeleton, unlike periapical and panoramic radiography, which only show the two-dimensional (2D) aspect of this structure [6].

The periapical disease is often neglected and/or underestimated in periapical radiographic examinations (PR), since the detection of these lesions in PR requires considerable density and/or disruption of the bone cortex, i.e., to be visible radiographically, a periapical radiolucency should reach about 30-50% of bone mineral loss. In a study promoted by Kruse et al. (2017) [7], 73% of the cases evaluated showed agreement between the results of PR and CBCT, while 19 of the 20 cases corresponding to 27% of disagreement, showed that CBCT presented failure in endodontic treatment, while PR presented a suggestive result of healing. However, traditionally, most studies related to the cure rate of surgical and non-surgical endodontic treatments were carried out through radiographic evaluation, and only in recent years, the use of CBCT was introduced. Chen et al. (2015) [8], suggest that CBCT is the best method to evaluate clinical studies that compare root-filling materials, since CBCT results correspond to histological findings, while this superior healing trend cannot be evaluated in PR. Through this study, it was observed and deduced that PR cannot detect minimal differences, such as periodontal ligament neoformation, cementum, and bone quality, and cannot even be the basis for success criteria. In the scientific field, the introduction of CBCT allowed a breadth of findings, mainly in in vivo research.

In 2000, the North American Food and Drug Administration (FDA) approved the first CBCT unit for dental use in the United States. Cone beam technology uses a conical beam of radiation to obtain a volume in a 360° rotation, similar to a panoramic X-ray. They can be classified into limited CBCT (dental or regional) and total CBCT (ortho or facial). The most important and clinically useful feature of CBCT is the software that allows the reproduction of the enormous volume of data collected, allowing the visualization of axial and proximal sections, a factor unattainable by conventional radiographs [9,10].

Furthermore, researchers concluded that the acquisition of three-dimensional images plays an important role in EMS. CBCT, in addition to allowing the detection of changes in apical bone density at an earlier stage and other periradicular pathological conditions, also allows clear identification of the anatomical relationship of root apices with important neighboring anatomical structures, such as the maxillary sinus, mandibular canal, and mental foramen. The thickness of the cortical plate, the cancellous bone pattern, fenestrations, root morphology, and canal identification [11,12]. This allowed the diagnosis and intervention planning of the case to become more precise and the results more predictable and assertive.

For a long time, the presence of persistent and recurrent infections in endodontics was considered a factor that would end up leading to tooth extraction, mainly due to the existence of limitations in traditional apical surgeries, such as lack of knowledge of apical anatomy, the use of materials low biocompatibility with adjacent tissues, difficulty in visualization, access and execution of the procedure, which resulted in studies reporting low success rates. This was often reinforced by the different specialties of dentistry, which differed in their treatment approach, recommending the placement of implants, and making the incidence of high-evidence studies on long-term results low [13-16].

In recent decades, with the development of new technologies in both equipment and materials, many studies have been carried out to report the results of EMS and definitively introduce this technique into clinical approaches to saving a dental element [1]. In 2009, Torabinejad et al. [17] already demonstrated in a systematic review, with articles published up to 38 years before this meta-analysis, the success rates for endodontic surgery and non-surgical endodontic retreatment were very similar. (about 75-78%). However, despite the minimum follow-up time of 2 years for inclusion in this review, many studies were carried out by students, using teeth with pre-operative predictors of failure, some without carrying out preparations and fillings of the root end or the report of the technique used.

The lack of high-quality, long-term randomized clinical trials was also an important factor to be considered in the systematic review carried out by Setzer et al. (2010) [5]. This meta-analysis, which was carried out to compare the results of traditional endodontic surgeries and apical endodontic microsurgery and presented stricter article selection criteria, had to define a minimum follow-up time of 6 months, to achieve a sufficient number of data for traditional technique cases. This would produce a bias in the results, as there are no studies for EMS with a follow-up of less than 12 months.

Carrying out new high-quality studies comparing these techniques would currently be unfeasible, since the implantation of amalgam, containing mercury, in the connective tissue would not be approved by the ethics committee. Thus, studies began to evaluate the success rates of EMS alone and evaluate which factors were contributing to the significant improvement in this index [18-22].

The introduction and evolution of CBCT in dentistry was essential for the better quality of scientific studies and indication of EMS. Although few studies compare the healing of apical periodontitis on periapical radiographs versus CBCT after apical endodontic surgery with a follow-up period ranging from 4 to 12 months postoperatively, the results presented when studies are performed with CBCT follow-up are different when performed by 2D images [23-25]. Safi et al. (2019) [26], presented a randomized controlled study that is in line with others carried out previously, in which the difference in value between the completely healed category on PA radiography versus CBCT has a discrepancy in the range of 25%. Completely healed teeth on CBCT imaging was 50% compared to 74% on PA radiography. These data often do not indicate a failure in the success of EMSs, but rather that the need for more reliable tools in the real clinical situation is necessary for better diagnosis and planning of cases, as well as for monitoring the success of treatment [27,28].

Another factor that demonstrated a direct relationship with the prognosis of EMSs was the high magnification and visualization of the operative field through the microscope, reproducing a better perspective on execution and results. The meta-analysis by Von Arx et al. (2010) [29] found that the use of an endoscope significantly improved outcomes compared to cases where no magnifying devices were used. This result was confirmed by a more recent meta-analysis by Setzer et al. (2012) [30] based on 14 longitudinal studies in which the probability of success for modern endodontic surgery using a microscope or endoscope was significantly higher than endodontic surgery using loupes or without magnifying devices. Thus, the use of adequate magnification during surgical procedures seems important [31].

Furthermore, at the level 3 mm from the original apex, 90% of the mesiobuccal roots of the upper first molars have an isthmus, 30% of the upper and lower premolars, and more than 80% of the mesial roots of the lower first molars have an [22]. The inability to treat these regions using the traditional technique proved to be one of the main causes of failure in both orthograde and retrograde surgical treatment, reaffirming the efficiency and precision achieved by the microscope and preparations with ultrasonic instrumentation.

The depth and sealing property of the root filling material was also a significant prognostic factor postoperatively. In general, having an inadequate depth resulted in failed PR and CBCT imaging. When the MTA was at an inadequate depth, there was a significant association with PR failure. Cases with inadequate MTA depth were 18 times more likely to fail CBCT imaging. As the depth of the root end filling correlates with an adequate seal, it can be speculated that for the MTA and RRM seal it should be a minimum depth of 2.5 mm or more. This is only possible through preparation with ultrasound tips [26].

Despite excellent results obtained with retropreparations with ultrasound tips, some studies reviewed in the meta-analysis by Abella et al. (2014) [4], demonstrate the occurrence of dentin cracks in dry ends after retrograde preparation with ultrasound. However, in these in vitro studies, some factors such as the stress exerted by extraction, risk, and storage of these roots, and inadequate handling, may produce a bias about the results of these studies. When the study is carried out on fresh cadavers, it can be observed that the periodontal ligament acts as a shock absorber, preventing the propagation of cracks caused by these vibrations, and that ultrasonic tips do not produce a significant number of microcracks.

Given the technical development of EMS, the importance of biocompatibility and mechanical properties of filling materials is of equal relevance. Studies carried out in dogs, by Chen et al (2015) [8], to evaluate healing after apical endodontic surgeries and compare the results of RRM and MTA, showed the formation of tissue similar to cementum and periodontal ligament in the surfaces of both materials, suggesting high healing induction and biocompatibility.

Also, *in vitro* studies demonstrate that these materials have similar physical and mechanical characteristics, with overall success rates for MTA and RRM cases on two-dimensional radiography of 94.7% and 92%, respectively [26]. According to Nair et al. (2006) [25], despite the positive results presented by RRM, a more elaborate design of prospective clinical studies is still necessary to evaluate this new material, since laboratory models of bacterial infiltration can generate inconsistent results. However, RRM may have better inductive/conductive properties of mineralized tissue, accelerating the deposition of cemental tissue and making healing better and faster than MTA [32,33].

According to Siqueira and Rôças (2011) [34], if bacteria continue to remain in the canal after resection, elimination by retro preparation and enclosure of residual bacteria by the filling material is necessary. This fact was proven by the meta-analysis carried out by Kohli et al. (2018) [23], in which the sum of the best available evidence showed that the axial cavity preparation promoted by ultrasonic instruments with retro-filling materials such as MTA, significantly increases the success rates of EMS, when compared to shallow concave preparations and the use of composite resin as the material of choice. This tells us how important the evolution of the traditional apical endodontic surgery technique to apical endodontic microsurgery was [35,36].

Conclusion

It was concluded that the success of apical endodontic surgery in terms of healing existing periapical pathology, together with a good long-term prognosis, depends on correct diagnosis and planning, as well as the association of surgical techniques, well-executed protocols, and biocompatible materials. The apical endodontic microsurgical approach is predictable and has a high success rate, which resulted from the introduction of cone beam computed tomography, microscope, ultrasonic instruments, and materials such as MTA and bioceramics for retro-fillings.

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Informed consent

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Data sharing statement

No additional data are available.

Conflict of interest

The authors declare no conflict of interest.

Similarity check

It was applied by Ithenticate@.

Peer Review Process

It was performed.

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