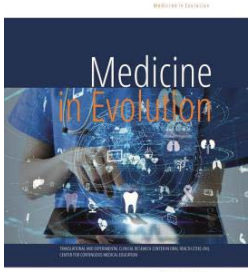
Apical resection in oral surgery: current data



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Abstract

Apical surgery is considered a standard oral surgical procedure. It is often a last resort to maintain a tooth with a periapical lesion that cannot be managed with conventional endodontic (re)treatment. The main goal of apical surgery is to prevent bacterial leakage from the endodontic system into the periradicular tissues by placing a filling at the root end after its resection.

The microscope and the endoscope in dentistry have enabled a significant evolution in apical surgery techniques. Indeed, the microscopic enlargement with the addition of light optimizes the visibility of the operating field and improve the results.

Keywords: Apical surgery, periapical lesion, resection

INTRODUCTION

Over time, many authors tried to define and understand the history of apical surgery. The increase in endodontic surgical methods before 1900 was combined with a few clinicians and scientists who were lucid enough to document and register their work.

Indeed, the current apical resection would have been identified by Saville in 1720 following the discovery of a skull with a pierced tooth, but this theory was refuted by Fastlicht [1].

In literature, Hullihen is also credited with surgical trephination (1845). The "Hullihen operation" consisted of "making a hole through the gum, the outer edge of the alveolar process, and the root of the tooth into the nerve cavity, and then opening the blood vessels of the nerve." Unfortunately, this technique aimed at allowing the conservation of a tooth, it was very rarely used because of its difficulty. However, existing studies show Smith's (1871) technique was the first apical resection used on a tooth with necrotic pulp. Claude Martin was also the inventor of apical resection in 1881. The latter describe the utility and use of this method to treat teeth with a sinus draining path.

John Farrar in 1884 recommended radical removal by amputation of parts of the roots that were no longer needed. In that same article, he wrote that root surgery was “a bold act, which removes the entire cause and which will lead to a permanent cure, may not only be the best in the end, but the most human”. Since then, endodontic surgeries have become inevitable in the choice of root canal treatment and periapical disease [1].

At the beginning of the 20th century, the development of endodontic surgery was progressive and regressive. Indeed, while major progress has been made in Europe and the United States in improving techniques and even in all aspects of endodontics and oral surgery, the medical profession was reluctant to these advances. However, surgical advances and diverse applications highlighted the entry of endodontics into this century.

Between 1915 to 1920, root resection took an important part in the dental science. The crescent or semilunar incision were standard, as was the sealing of the gutta-percha with a hot burnisher after resection. Zinc oxyphosphate was frequently used as a sealant with gutta-percha. In the early 1930s, extractions were often the first choice of treatment. But a handful of practitioners have persisted in promoting periapical surgery [1].

Karl Peter published in 1936 his text “Die Wurzelspitzenresektion der Molaren” which will be the foundation of contemporary endodontic surgery [1]. He gives a classification of the position of the inferior alveolar canal in relation to the molar roots and indicates the connections with the maxillary sinus and its position in relation to the roots of the maxillary teeth. After the Second World War, Louis Grossman also gave details on the apical resection technique. Indeed, he recommended surgical curettage followed by a through-canal obturation technique. He used eucalyptol with the gutta-percha and cut off the excess at the apex with a hot instrument.

The period 1960-2000 is essential in the history of surgical endodontics, it represents the development of new procedures for the 21st century. While many authors around the world have written textbooks consecrated exclusively to endodontic surgery.

After the 1990s and the introduction of microsurgical principles, apical surgery's technique was significantly improved. Microsurgical instruments for root cavity preparation and the development of magnification tools such as the surgical microscope or endoscope are the most significant acquisitions. Those two innovations have considerably facilitated the apical surgical technique and improved its result. By several studies, successful healing is more frequent with the microsurgical technique than with the conventional technique [2].

Interest in using this treatment in addition to apical surgery after performing tissue regeneration techniques in periodontics and implant dentistry has increased. A rising number of practitioners are recommending the use of regenerative techniques (RT) in apical surgery [2].

Aim and objectives

The advent of new root filling materials has provoked debate about the long-term outcome of endodontic microsurgery performed on teeth with post-treatment apical periodontitis. The purpose of this study is to evaluate the results of endodontic microsurgery in teeth diagnosed, by radiographic examination, with secondary apical periodontitis.

MATERIAL AND METHODS

Study is a systematic review, and the question in the center of the research was: ”What is the long-term clinical and radiographic outcome of endodontic microsurgery in teeth diagnosed with secondary apical periodontitis?”.

Two websites have been consulted: Pubmed and The Cochrane Library. The studies included were meta-analyses and systematic reviews, critical reviews, longitudinal studies and case reports. The review of research articles followed the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

The following medical terms have been used for the selection of articles: ”root canal treatment”, ”endodontic microsurgery”, ”apical root resection”, ”apicoectomy”, ”root canal filling”, ”retreatment”, ”periapical surgery”, ”endodontic surgery”, ”root resection”, ”radiographic outcome”, ”root cavity preparation”.

A specific selection of clinical studies that examined clinical and radiographic outcomes after endodontic microsurgery was made through the searching criteria.

Inclusion criteria:

- Studies from 1990 to 2020.
- Studies evaluating the long-term clinical and radiographic outcome after endodontic microsurgery.
- Clinical studies on endodontic microsurgery (using microscope, endoscope, ultrasonic ultrasonic root-end preparation).
- Clinical and radiographic results according to the criteria given by Rud & al. [3] and Molven & al. [4].
- The given success rate of endodontic microsurgery.

Exclusion criteria:

- Studies including patient under 18 years old.
- Studies using perforated or fractured tooth samples.
- Studies that do not use microsurgery.
- Studies without periapical or clinical radiographic evaluation.
- The lack of evaluation of the success rate of endodontic microsurgery.

Data collection:

An initial selection was based on the article titles. Then, the abstracts were analyzed to retain meta-analyses and systematic reviews, critical reviews, longitudinal studies and case reports. Finally, a manual search was performed using the sources contained in the selected reviews and not detected by the search equation.

RESULTS

An extraction, data analysis and methodology evaluation in a total of 10 articles corresponding to the previously explained inclusion criteria was performed.

Table 1 summarises the information from the systematic review. Thus, 6 prospective clinical studies and 4 randomized clinical trials constitute the 10 selected articles. The smallest sample size examined was 87 teeth (Truschnegg & al. 2020) [5] and the largest sample size was 339 teeth (Von Arx & al. 2014) [10] over a period of 2 to 13 years. These studies used filling materials such as MTA, IRM, dentine-bonded resin composite and SuperEBA. The recall rate of the studies ranged from 59% (Chong & al. 2003) [14] to 89% (Taschieri & al. 2008) [13].

Table 1. Studies included in the clinical review and success rates

Study	Type	Number of teeth	Follow-up	Obturation material	Recall Rate	Success rate of obturation material	Overall success rate
Truschnegg & al. [5]	Prospective clinical study	87	10 to 13 years	IRM	71 %	not available	76 %
Von Arx & al. 2019 [6]	Prospective clinical study	119	10 years	MTA grey *44 teeth* MTA white *75 teeth*	61 %	84 % 80 %	82 %
Kim & al.[7]	Randomized clinical trial	260	4 years	MTA *83 teeth* SuperEBA *99 teeth*	70 %	92 % 90 %	91 %
Caliskan & al, [8]	Prospective clinical study	103	2 to 6 years	MTA	87 %	not available	80 %
Tawil & al. [9]	Prospective clinical study	155	3 years	MTA grey and SuperEBA	82 %	not available	69 %
Von Arx & al. 2014 [10]	Prospective clinical study	339	5 years	MTA *134 teeth* Dentine-bonded resin composite *137 teeth*	80 %	93 % 77 %	85 %
Song & al. [11]	Randomized clinical trial	172	6 to 10 years	IRM, MTA grey and SuperEBA	61 %	not available	93 %
Von Arx & al. 2012 [12]	Prospective clinical study	191	5 years	MTA *44 teeth* SuperEBA *49 teeth* Dentine-bonded resin composite *77 teeth*	88 %	86 % 67 % 75 %	76 %
Taschieri & al. [13]	Randomized clinical trial	113	2 years	SuperEBA	89 %	not available	92 %
Chong & al. [14]	Randomized clinical trial	183	2 years	MTA *61 teeth* IRM *47 teeth*	59 %	92 % 87 %	90 %

The overall success rate is between 69% (Tawil & al. 2015) [9] and 93% (Song & al. 2012) [11]. Nevertheless, in order to evaluate the influence on the outcome of endodontic microsurgery of each clinical trial, a statistical analysis of potential prognostic factors is presented in the following paragraphs.

Truschnegg & al. 2020 [5], produced a prospective clinical study through assessment parameters such as: age, gender, smoking and drinking habits, tooth location, previous endodontic surgery, pre- and postoperative lesion size and perioperative antibiotic use. During a 10 to 13 years follow-up on 73 patients and 87 teeth, the radiographic success rate was 76% healing. Prognostic factors described a lower success rate in smokers (33.3%) than in non-smokers (80%), but no significant differences for other parameters evaluated (age, sex, alcohol habits, tooth location, previous endodontic surgery, size of the pre and postoperative lesion, or perioperative antibiotics).

Von Arx & al. 2019 [6], produced a prospective clinical study through assessment parameters such as: sex, age, tooth type, type of MTA used (grey or white), surgery (first-time or repeat surgery). During a 10 years follow-up on 119 teeth, the radiographic success rate was 82% healing (gray MTA group 84% and white MTA group 80%). The prognostic factors describe a significant difference in success rate according to tooth type (higher for maxillary molars: 95,2%, compared to maxillary premolars: 66,7%). No significant differences for other parameters evaluated (age, sex, type of MTA, or first-time versus repeat surgery).

Kim & al., 2016 [7], produces a randomized clinical trial through a type of material used (MTA, Super EBA). During a 4 years follow-up on 260 teeth, the radiographic success rate was 91% healing (MTA group 92% and Super EBA group 92%). Thus, prognostic factors describe no significant difference in success rate by material type used.

Çalışkan & al., 2016 [8], produced a prospective clinical study through assessment parameters such as: sex, age, tooth type and location, quality of the root canal filling, presence/absence of a post, previous endodontic treatment/retreatment, previous nonsurgical or surgical endodontic treatment, size and histopathology of periapical lesions, antibiotic therapy, postoperative healing. During a 2 to 6 years follow-up on 108 patients and 108 teeth, the radiographic success rate was 80% healing. Thus, the prognostic factors describe no significant difference in success rate according to the parameters assessed.

Tawil & al., 2015 [9], produced a prospective clinical study through assessment parameters such as: sex, age, tooth location, presence/absence of dentinal defect, root-end filling material (Super EBA/MTA). During a 3 years follow-up on 155 teeth, the radiographic success rate was 69% healing (dentinal defect group 32% and intact dentinal group 97%). Prognostic factors described a lower success rate in the dentinal defect, but no significant differences for other parameters evaluated.

Von Arx & al., 2014 [10], produced a prospective clinical study through assessment parameters such as: type of material (MTA or dentine-bonded resin composite, age, sex, tooth type (maxillary anterior, premolar, and molar or mandibular anterior, premolar, and molar), presence or absence of post, type of surgery (first-time surgery or repeat surgery). During a 5 years follow-up on 339 patients and 339 teeth, the radiographic success rate was 85% healing (MTA group 93% and dentine-bonded resin composite group 77%). The prognostic factors describe a significant difference in type of material used (higher for MTA treated teeth). No significant differences for other parameters evaluated (age, sex, type of tooth treated, presence of post, or type of surgery).

Song & al., 2012 [11], produced a randomized clinical trial through assessment parameters such as: age, sex, tooth type, tooth location, type of lesion, type of material (IRM, MTA, SuperEBA). During a 6 to 10 years follow-up on 172 teeth, the radiographic success rate was 93% healing. Thus, the prognostic factors describe no significant difference in success rate according to the parameters assessed.

Von Arx & al., 2012 [12], produced a prospective clinical study through assessment parameters such as: patient-related (age, sex, smoking), tooth related (type, pain, clinical signs/symptoms, size of periapical lesion, interproximal bone level, apical extent of root canal filling, post, and previous apical surgery), treatment related (antibiotic prescription, root-end filling material, and initial postoperative healing). During a 5 years follow-up on 194 patients and 194 teeth, the radiographic success rate was 76% healing (MTA group 88%, SuperEBA group 67% and dentine-bonded resin composite group 75%). The prognostic factors describe a significant difference in success rate based on interproximal bone level (higher success rate when the mesial and distal interproximal bone level was less than or equal to 3 mm from the cementoenamel junction, there is also a significant difference in success rate based on material type (higher success rate for MTA compared to SuperEBA). No significant differences for other parameters evaluated.

Taschieri & al., 2008 [13], produced a randomized clinical trial through assessment parameters such as: type of magnification device (microscope/endoscope) and tooth location. During a 2 years follow-up on 70 patients and 113 teeth, the radiographic success rate was 92% healing. Thus, the prognostic factors describe no significant difference in success rate according to the parameters assessed.

Chong & al., 2003 [14], produces a randomized clinical trial through a type of material used (MTA, IRM). During a 2 years follow-up on 183 patients and 183 teeth, the radiographic success rate was 90% healing (MTA group 92% and white IRM group 87%). Thus, the prognostic factors describe no significant difference in success rate according to the parameters assessed.

Table 2 summarises the information from the ten selected articles whose data are explained above and compares the success rates according to the obturation material used.

Table 2. Data summary

Study	Obturation material	Follow-up	Sample size		Previous Treatments		Success rate
			Nb patients	Nb teeth	Nb re-surgery	Nb nonsurgical endodontic retreatment	
Truschnegg & al. [5]	IRM	10 to 13 years	73	87	19	0	76 %
Von Arx & al. 2019 [6]	MTA grey or white	10 years	not available	119	12	not available	Overall rate: 82 % *gray MTA: 84 %* *white MTA: 80 %*
Kim & al.[7]	MTA grey and SuperEBA	4 years	not available	260	not available	not available	Overall rate: 91 % *MTA : 92 %* *SuperEBA: 90 %*
Caliskan & al, [8]	MTA	2 to 6 years	108	108	18	42	80
Tawil & al. [9]	MTA grey and SuperEBA	3 years	not available	155	not available	not available	Overall rate: 69 % *dentinal defect: 32 %* *intact dentina : 97 %*
Von Arx & al. 2014 [10]	MTA and Dentine-bonded resin composite	5 years	339	339	31	not available	Overall rate: 85 % *MTA: 93 %* *Dentine-bonded resin composit: 77 %*
Song & al. [11]	IRM, MTA grey and SuperEBA	6 to 10 years	not available	172	not available	not available	94 %

Von Arx & al. 2012 [12]	MTA, SuperEBA and Dentine-bonded resin composite	5 years	194	194	16	not available	Overall rate: 76 % *MTA: 88 %* *SuperEBA: 67 %* *Dentine-bonded resin composite: 75 %*
Taschieri & al. [13]	SuperEBA	2 years	70	113	not available	113	92 %
Chong & al. [14]	MTA and IRM	2 years	183	183	not available	not available	Overall rate: 90 % *MTA: 92 %* *IRM: 87 %*
AVERAGE :		**6 YEARS**	–	**339 TEETH**	–	–	**83,4 %**

Table 3 compares the success rates of the different studies according to the obturation material used. The studies by Tawil & al [9] and Song & al [11] have been excluded from this comparison because their work do not detail the number of teeth studied according to the type of obturation material used.

Table 3. Success rates by comparison of obturation material

Obturation material	**Study**	**Number of teeth**	**Success rate**
IRM	Truschnegg & al. [5] Chong & al. [14]	134	81,5 %
MTA	Von Arx & al. 2019 [6] Kim & al.[7] Caliskan & al, [8] Von Arx & al. 2014 [10] Von Arx & al. 2012 [12] Chong & al. [14]	544	87,5 %
SuperEBA	Kim & al.[7] Von Arx & al. 2012 [12] Taschieri & al. [13]	539	83 %
Dentine-bonded resin composite	Von Arx & al. 2014 [10] Von Arx & al. 2012 [12]	331	76 %

The quality the assessment of the risk of bias of randomized clinical trials, were done according to the Cochrane recommendations. For Kim & al, 2016 [7] and Taschieri & al, 2008 [13], the randomization process, deviations from planned interventions, missing outcome data, outcome measurement, and selection of the reported outcome presents a low risk. For Song & al, 2012 [11], the randomization process has some concerns, deviations from planned interventions and missing outcome data have a high risk of bias while the outcome measurement and selection of reported outcome has a low risk. Chong & al, 2003 [14], the randomization process, deviations from planned interventions, outcome measurement, and selection of the reported outcome has a low risk while missing outcome data has a high risk of bias.

The quality risk of bias assessment of the included prospective clinical studies, were done according to the Cochrane recommendations. For Von Arx & al, 2019 [6] and Von Arx & al, 2012 [12], has a low risk of bias for confounding, selection of participants, classification of interventions, deviations from planned intervention, missing data, outcome measures and selection of reported outcomes. Truschnegg et al, 2020 [5], had a moderate risk of bias for

confounding factors and a low risk for participant selection, intervention classification, deviations from planned intervention, missing data, outcome measures, and selection of reported outcomes. In the study by Çalışkan & al. 2016 [8], moderate risk of bias for confounding and outcome measures and low risk for participant selection, intervention classification, deviations from planned intervention, missing data, and selection of reported outcomes. Tawil & al, 2015 [9], has a low risk for confounding, participant selection, intervention classification, deviations from planned intervention, missing data, but a moderate risk for outcome measurement and selection of reported outcomes. Von Arx et al, 2014 [10], presents in the study a low risk for confounding, participant selection, classification of interventions, deviations from planned intervention, missing data, selection of reported outcomes, but a moderate risk for the outcome measure.

The risk of bias in the included randomized clinical trials and prospective clinical studies was found to be low except for the study by Song & al, 2012 [11] which presents some concerns.

DISCUSSIONS

According to the results of these studies, 2 to 13 years after the procedure, the overall success rate of endodontic microsurgery varies from 78% for prospective clinical studies to 91% for randomized clinical trials. This success rate varies from 69% for the study of Tawil & al. [9] to 93% for the study of Song & al. [11], a difference of 24%. This difference could be explained by the methodology of these studies. Indeed, Tawil & al, 2015 [9], using transillumination, were to evaluate the post-surgical periapical healing of teeth with dentinal defects compared to healthy teeth. This work concluded that the success rate was significantly lower for the group of teeth with root dentinal defects compared to the group of teeth evaluated. Moreover, Tawil & al. considered cases with incomplete healing as unhealed. For these reasons, there is a significant decrease in the overall success rate. And the work of Song & al, 2012 [11], only resulted in the outcome of healed teeth at the less than one year to five years follow-up. Thus, the actual recall rate is 39% instead of 61%, which probably leads to biased results.

Among the evaluation of potential prognostic factors, only five showed statistically significant differences in the outcome of endodontic microsurgery: smoking, location and type of tooth, presence/absence of a dentinal defect, interproximal bone level and type of obturation material. The effect of the type of obturation material was the most frequently analyzed factor in the selected studies.

The use of gutta-percha alone or glass ionomer cement (GIC) in endodontic microsurgery was not specified in these studies, nor was the use of amalgam as a type of obturation material [15.] The materials used for the evaluation of the results were: intermediate restorative material (IRM) [5, 11, 14], athoxy benzoic acid (SuperEBA) [7, 9, 11-13], resin-based cements [12], mineral trioxide aggregate (MTA) [6-12,14]. Chong & al, 2003 [14], Song & al, 2012 [13], and Truschnegg & al. 2020 [5] have used IRM as a root filling material in their studies of endodontic microsurgery. Chong et al. 2003 is the only study with comparative results between IRM and MTA, and no significant difference was found. The study by Von Arx & al, 2012 [12], was the only one that found significant differences between the MTA group (86%) and the SuperEBA group (67%).

In the present study, two articles (Von Arx & al., 2014 and Von Arx & al., 2012) [10,12] using a dentin bonding agent (MTA, Super EBA, dentin-bonded resin composite) estimated the outcome of endodontic microsurgery. Both studies concluded that the success rate was higher when using MTA. These results can be explained by the need for a dry field during the etching/priming/bonding process [16] and the moisture control of the filling material [15].

Due to their high biocompatibility, the materials of the generation of hydraulic calcium-silicate cements (MTA and Biodentine) have caused great interest. MTA has been used as an obturation material by many authors selected for this study [6-12,14]. Indeed, this material has shown higher success properties than SuperEBA and dentin-bonded resin composite. These results can be explained according to Torabinejad M, Higa RK, McKendry DJ, and other, by good tissue tolerance, fibrous formation on contact with MTA, excellent sealing, wet setting, antibacterial activity, antifungal activity (alkaline pH), a non-absorbable and radiopaque material [17]. But MTA causes some clinical concerns due to the fact that its mechanical properties are only maximal after 24 hours and the difficulty of handling due to its sandy consistency after mixing with sterile water [18].

Recently, new obturation materials such as bioceramic-based root canal sealants have been developed to improve the setting time [19]. However, as scientific evidence remains rare and due to the short follow-up period, studies using this type of obturation material were excluded from this work.

The risk of bias was assessed for all randomized clinical trials and prospective clinical studies. A low risk was recorded with the exception of the study by Song & al., 2012 [11] due to the lack of data on recall rates. However, several selected authors considered teeth extracted from follow-up as a dropout because the rationale for extraction was unknown or not related to endodontic microsurgery (fractures, prostheses) [7, 10, 12]. Another concern is related to the risk of bias due to the results. The selected studies classified their radiographic results according to Rud & al [3] and Molven & al [4]. However, Tawil & al, classified cases with incomplete healing as non-healed. This classification therefore compromised the assessment of the risk of bias. Indeed, an underestimation of the outcome of endodontic microsurgery may have occurred.

The European Society of Endodontology (ESE) and the American Association of Endodontists (AAE) recommend regular clinical and radiographic follow-up for a minimum of one year after endodontic microsurgery. The ESE also recommends to increase the follow-up period at 5 years when a radiolucent area defined as "surgical defect" persists 1 year after surgery [20].

However, this follow-up time is still debated. Indeed, some studies show a relapse 4 years after traditional endodontic surgery, which confirms that a short follow-up period might be insufficient to identify a recurrence of apical periodontitis [19]. But in studies using a modern microsurgical approach, these results were not recorded [7, 9, 14].

Recently, studies with long-term follow-up have looked for significant differences in outcome compared to outcomes assessed over a short-term follow-up period. The study by von Arx & al., 2019 [6] presented a lower success rate after 10 years (82%) compared with success rates following a 1-year (91.6%) and 5-year (91.4%) recall. In the study by Kim & al, 2016 [7], the overall success rate after 4 years (89.5%) was lower than the 1-year follow-up (94.3%), thus a reduction in success rate of 4.8%. This cause of decrease can be explained by a lower recall rate at the 1-year follow-up. Von Arx & al, 2014 [10] confirmed that cases recorded as healed after 1 year were still healed after 5 years in 93.9% of cases.

For all the above reasons, a 1-year follow-up may be not sufficient to assess the success of endodontic microsurgery. It is necessary to continue the follow-up after 1 year and to take in consideration the obturation material in cases of uncertain healing. Furthermore, long-term follow-up gives a more reliable result and increases knowledge of the risk factors involved in long-term failures: root fracture [6], prosthesis [12], endodontic or periodontal reasons [5], caries and crown fractures [7].

In order to obtain the most reliable results, strict inclusion and exclusion criteria were selected for this systematic review. Articles in which the surgical procedure was not

performed under endoscope or microscope were excluded and each article used the same classification of radiographic findings (Rud & al [3] and Molven & al [4]).

However, this work has some limitations. Firstly, only studies with a long-term follow-up period were included. This risks the quality of some studies, since the longer the follow-up, the higher the drop-out rate. This may result in a loss of scientific validity of some conclusions [11]. Secondly, the inclusion of comparative studies between two-dimensional and three-dimensional outcome measures was not chosen due to short follow-up time [21] or the lack of classification of clinical and radiographic criteria according to Rud & al. and Molven & al. Although some studies show that two-dimensional assessment overestimates healing compared to three-dimensional assessment [22, 23], the study by Kruse & al [24] aims to determine the periapical lesions diagnosed by these two different radiographic methods. In this study, it is reported that after histopathological examination, 40% of the unsuccessful cases diagnosed by CBCT did not show signs of periapical inflammation. It is therefore concluded that CBCT may underestimate the healing outcome as it may diagnose incomplete healing as the presence of pathology (uncertain healing). According to the European Society of Endodontology, CBCT should only be used when its benefits exceed those of conventional imaging [25].

There are some concerns about the validity of the results obtained. Firstly, it is known that the outcome is influenced by the operator [26]. However, the 10 studies selected for this work were performed in a hospital or university environment, which may overestimate the results compared to when the procedure is performed in a private environment. It is therefore important to develop multicentric studies under conditions similar to daily clinical practice to evaluate the results of endodontic microsurgery. In addition, the study by Chong & al, 2003 [14] established strict exclusion criteria, such as a probing depth of 4 mm or more. The study of Taschieri & al, 2008 [13], established exclusion criteria for teeth that have not undergone non-surgical endodontic retreatment or for teeth with traumatic injuries. These criteria serve to increase the effectiveness of the procedure and therefore contribute to the overestimation of the results of endodontic microsurgery.

Finally, none of the selected studies reported the cost-benefit ratio of the obturation material. For the dentist and the patient, this information should be taken into account in the treatment decision.

CONCLUSIONS

This work has shown that the application of a strict surgical protocol, in accordance with the latest scientific data, leads to excellent results. This therapeutic approach is highly reliable when performed with modern surgical techniques such as the use of magnification instruments (microscope or endoscope) and biocompatible obturation materials.

This surgical technique, which was very uncertain at the beginning, has benefited from extensive studies, the development of new obturation materials (such as MTA, SuperEBA and IRM) and micro-instruments (such as ultrasonic tips), making it a safe and approved alternative nowadays.

The chance of preserving a tooth averages 83.4% in patients with a mean follow-up of 6 years after endodontic microsurgery. However, relapse is observed 10 years after surgery, confirming that a short follow-up period may not be sufficient to identify a recurrence of apical infection. A 1-year follow-up may not be sufficient to evaluate the success of endodontic microsurgery. It is necessary to continue the follow-up after 1 year and to consider the filling material if healing is uncertain. In addition, long-term follow-up gives a more reliable result and provides insight into the risk factors involved in long-term failures such as root fractures, prosthesis, endodontic or periodontal reasons, caries and crown

fractures. Indeed, the long-term success rate of endodontic microsurgery is influenced by various significant factors such as smoking, the presence or absence of a dentin defect, the level of interproximal bone, the use of magnifying instruments (microscope or endoscope) and the type of material used for the root obturation.

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