Outcome of nonsurgical retreatment and endodontic microsurgery: a meta-analysis

Minji Kang · Hoi In Jung · Minju Song · Sue Youn Kim · Hyeon-Cheol Kim · Euiseong Kim

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Abstract
Objectives The purpose of this study was to evaluate and compare the clinical and radiographic outcomes of nonsurgical endodontic retreatment and endodontic microsurgery by a meta-analysis.

Materials and methods Electronic databases including PubMed, Embase, Medline, and The Cochrane Library were searched, and the references of related articles were manually searched to identify all the clinical studies that evaluated the clinical and radiographic outcomes after retreatment or microsurgery. The first and second screening processes were conducted by three reviewers independently. The final studies were selected after strict application of the inclusion and exclusion criteria. The random effects meta-analysis model with the DerSimonian-Laird pooling method was performed. The weighted pooled success rates and 95 % confidence interval estimates of the outcome were calculated. Additionally, the effects of the follow-up period and study quality were investigated by a subgroup analysis.

Results Endodontic microsurgery and nonsurgical retreatment have stable outcomes presenting 92 and 80 % of overall pooled success rates, respectively. The microsurgery group had a significantly higher success rate than the retreatment group. When the data were organized and analyzed according to their follow-up periods, a significantly higher success rate was found for the microsurgery group in the short-term follow-up (less than 4 years), whereas no significant difference was observed in the long-term follow-up (more than 4 years).

Conclusions Endodontic microsurgery was confirmed as a reliable treatment option with favorable initial healing and a predictable outcome.

Clinical relevance Clinicians may consider the microsurgery as an effective way of retreatment as well as nonsurgical retreatment depending on the clinical situations.

Keywords Endodontic microsurgery · Meta-analysis · Nonsurgical retreatment · Outcome · Success

Introduction
Primary root canal treatment is a well-defined and reliable treatment with long-standing reports of high clinical and radiographic success rates [1–3]. The presence of persistent periapical radiolucency is frequently associated with failure in root canal treatment, resulting in an indication for clinical intervention [4]. One of the most common causes of failure is a complex root anatomy that has not been sufficiently cleaned or shaped such that microbial flora remain in the apical sections of the root canals [5].
Nonsurgical retreatment is generally indicated if a previously treated tooth has persistent apical periodontitis. Ng et al. [6] reported that the weighted pooled success rate of nonsurgical retreatment judged by complete healing was 76.7% and that by incomplete healing was 77.2%. Surgical endodontic treatment is a treatment of choice for persisting apical periodontitis because it can manage the infection source and provide a hermetic seal of the apical area directly [7]. Recently, the use of higher magnification devices, such as a microscope and ultrasonic preparation instruments, allows more accurate but less traumatic surgical procedures [8–10]. Biocompatible retrofilling materials, such as intermediate restorative material (IRM), Super EBA (Harry J. Bosworth, Skokie, IL, USA), and mineral trioxide aggregate (MTA), are preferred over amalgam or other conventional materials [11–13]. Such advancement of modern techniques makes the clinical outcome of surgical endodontic treatment more predictable than before [14, 15]. A recently updated review [16] reported that endodontic surgery performed with a modern technique achieved successful outcome in 89% of patients.

Although the clinical evidence for nonsurgical retreatment and endodontic surgery is based on many clinical trials, selecting which procedure to use remains complicated and difficult [17–19]. A few studies have compared nonsurgical retreatment and endodontic surgery [20–23]. Del Fabbro et al. [21] reviewed randomized controlled trials that directly compared nonsurgical endodontic retreatment with endodontic surgery. The authors concluded that the short-term healing rates might be higher in surgically treated cases. Torabinejad et al. [23] performed a meta-analysis to calculate the pooled and weighted success rates for nonsurgical treatment and endodontic surgery. According to this study, endodontic surgery offers more favorable initial success, whereas nonsurgical retreatment offers a more favorable long-term outcome. Most of the articles included in these studies performed conventional surgical techniques without microscopes and ultrasonic instruments.

There is no systematic review comparing the following standard procedures: nonsurgical retreatment and endodontic microsurgery. The use of advanced techniques such as microscopes and ultrasonic instruments has become the protocol of endodontic surgeries. An evaluation and comparison of the outcomes in nonsurgical retreatment and those in endodontic microsurgery with recent advanced techniques is necessary. The purpose of this study is to evaluate and compare the clinical and radiographic outcomes of nonsurgical endodontic retreatment and endodontic microsurgery by calculating the pooled weighted success rates.

Material and methods

Prior to the literature search, the review question was developed using the population, intervention, comparison, outcome (PICO) framework. The question was stated as, “In teeth that had endodontic-microsurgery (microsurgery), how was the clinical and/or radiographic outcome compared to that of nonsurgical endodontic-retreatment (retreatment)?”

Searching criteria

The following inclusion and exclusion criteria aimed to identify all the clinical studies that evaluated the clinical and radiographic outcomes after retreatment or microsurgery.

Inclusion criteria

1. Clinical studies in humans
2. Publication in English from January 1970 to June 2012
3. A minimum sample size of 20 teeth
4. Success and failure evaluated per tooth
5. A minimum follow-up period of 6 months
6. Clinical and radiographic assessment was performed to determine success or failure according to the following criteria.

- The success of the treatment included clinical and radiographic healing. Clinically, an absence of signs or symptoms indicated no pain, swelling, percussion sensitivity, or sinus tracts.
- Microsurgery group: The radiographic healing criteria of Rud et al. [24] or Molven et al. [25] were used. Success was defined as complete or incomplete healing with an absence of clinical signs and symptoms. Uncertain healing or unsatisfactory healing presented in radiographs or the presence of clinical symptoms was counted as a failure.
- Retreatment group: Success included cases with an absence of clinical symptoms and radiographic signs or a reduction in the apical radiolucency size or with a PAI score \( \leq 2 \). Failure was decided if the apical radiolucency size was increased, unchanged, or with a PAI score \( \geq 3 \). If the tooth presented clinical signs or symptoms, outcome was considered a failure regardless of the radiographic results.

7. The success rate was given or could be calculated with the criteria described above.
8. For microsurgery, the treatment protocol followed the modern technique using magnification devices over \( \times 10 \), ultrasonic preparation, IRM, super EBA, or MTA as the retrofilling material.

Exclusion criteria

1. In vitro studies, animal studies, case series or reports, or review articles.
2. The sample size was not given or was less than 20 teeth.
3. Healing was not evaluated per tooth.
4. The follow-up period was not described exactly and was less than 6 months, or the raw data over 6 months were not given.
5. The success rate was not calculated according to the healing criteria defined above and could not be recalculated based on raw data.
6. Studies that did not evaluate the clinical or radiographic outcome.
7. The intervention was not described clearly or did not provide the modern technique described above.
8. A different type of treatment was included in the data, and the outcome of the retreatment or microsurgery could not be calculated.
9. The experimental population included in the study was already a part of an earlier publication.

Searching method

1. Electronic databases: PubMed, Embase, Medline, and The Cochrane Library were searched according to the following keywords.
   For microsurgery, ((apicoectomy OR apicectomy OR “root-end filling” OR “root-end surgery” OR “retrograde filling” OR “retro-grade surgery” OR “periapical surgery” OR “periradicular surgery” OR “tooth apex surgery” OR “surgical endodontic treatment” OR “endodontic microsurgery” OR “apical microsurgery”)) AND (outcome OR success OR results)
   For retreatment, ((“secondary root canal treatment” OR “re root canal treatment” OR “re endodontic treatment” OR “root canal re-treatment” OR “endodontic re-treatment” OR “secondary endodontic treatment”)) AND (outcome OR success OR results)
2. The references of related articles obtained from the electronic databases were manually searched and added to the list.
3. Contact with researchers in the endodontic field for additional data or publications corresponds to the aim of this study.

Study selection

The first and second screening processes were conducted by three reviewers independently. The first screening was to exclude the articles that did not meet the criteria for abstract review. If there were different opinions among the reviewers, the final decision was made by discussion and consensus was reached. After eliminating the overlapping articles from different databases, a list was compiled for the full text review.

The full text was reviewed as a second screening, and the list was enhanced with additional articles from the references of the existing articles. The final studies were selected after strict application of the inclusion and exclusion criteria. The reviewers sent e-mails to the authors who published several clinical studies that had overlapping recruitment periods of patients to ask if the patient of one study was included in another study. The studies were excluded if the patient was included in another study. The decision to exclude the study was made by discussion among the reviewers. All the studies meeting the inclusion criteria passed the quality assessment and data extraction.

Quality assessment

For the quality assessment of the included studies, 10 questions were adapted and modified from the checklists recommended for the quality assessment of clinical trials [26, 27]. If the answer to the question was yes, one point was added to the quality score. The maximum score for a study was 10. The following were the 10 questions used in this review.

1. Was the study described as randomized?
2. Was there a description of the withdrawals and dropouts?
3. Were the objectives of the study defined?
4. Were the outcome measures defined clearly?
5. Was there a clear description of the inclusion and exclusion criteria?
6. Was the sample size justified (power calculation)?
7. Was there a clear description of the intervention?
8. Was there at least one control (comparison) group?
9. Were there calibrated and independent examiners of the outcome assessment?
10. Were the statistical analysis methods described?

The score of each study was recorded and used to classify the articles into three groups. Group A is composed of the studies scoring 7 to 10, and group B included the studies scoring 4 to 6. The studies with a score of 0 to 3 were classified as group C.

Data extraction

For the final studies, detailed information on the analysis was recorded. The noted information include the type of intervention, study design, total number of the population, follow-up period, number of successes and failures, success rates, and quality score. The studies were classified by the follow-up periods into three groups; the follow-up period of group 1 is less than 2 years, group 2 is between 2 and 4 years, and group 3 is more than 4 years.
If the study did not follow or meet the inclusion criteria that we introduced earlier, our reviewers recalculated the success and failure rates from their raw data. The excluded studies were listed after the second screening, and the detailed reasons for exclusion were described in the later section of this study.

Data analysis

The weighted pooled success rates and 95% confidence interval (CI) estimates of the outcome were calculated. The random effects meta-analysis model with the DerSimonian-Laird pooling method was performed after the heterogeneity analysis. The Wilson score method was used to provide an enhanced and refined interval. Additionally, the effects of the follow-up period and study quality were investigated by a subgroup analysis. All the statistical calculations were performed using Stata version 11.2 statistical software (StataCorp LP, College Station, TX, USA) and Excel 2010 (Microsoft Corporation, Redmond, WA, USA).

Results

Study identification and selection

The process of study identification and selection is shown as a flow chart in Fig. 1. After the first screening, 89 articles regarding microsurgery and 23 articles regarding retreatment remained. Then, the second screening, which was a full text review, excluded 72 articles regarding microsurgery and 16 articles regarding retreatment. In the microsurgery group, two additional studies were collected after communicating with experts in this field (the study by Song which is in the process of being published) and Taschieri [28]). After the full text review of these studies, only the study of Song et al. was added to the final list. Seven studies confirmed by the authors were excluded because the patients overlapped with other studies. Finally, 11 articles on microsurgery and 7 articles on retreatment were included in this study. Table 1 describes the detailed information of the final studies included in the meta-analysis and the excluded studies, and reasons of exclusion are described in Table 2.

Meta-analysis

The weights of each study and the weighted pooled success rates of the microsurgery and retreatment groups are presented in Fig. 2. Because there was heterogeneity among the included studies, the random effects model was used to calculate the weights. The weighted pooled success rate of the microsurgery group was 92% (pooled ES 0.919, 95% CI 0.881–0.957), and that of the retreatment group was 80% (pooled ES 0.797, 95% CI 0.737–0.857). A statistically significant difference was observed between the weighted pooled success rates for the microsurgery group and the retreatment group (p<0.05).

The groups of the follow-up period were analyzed separately. For the microsurgery group, the weighted pooled success rate of group 1 (<2 years) was 95% (pooled ES 0.950, 95% CI 0.913–0.988), group 2 was 90% (pooled ES 0.904, 95% CI 0.864–0.945), and group 3 was 82% (pooled ES 0.825, 95% CI 0.713–0.937). For the retreatment group, group 1 was 84% (pooled ES 0.845, 95% CI 0.804–0.886), group 2 was 71% (pooled ES 0.710, 95% CI 0.648–0.772), and group 3 was 82% (pooled ES 0.817, 95% CI 0.767–0.867). When the weighted pooled success rates were compared between the microsurgery (92%) and the retreatment groups (80%), statistically significant differences were observed for groups 1 and 2 (p<0.05). There was no statistically significant difference between the retreatment and surgery groups for group 3 (follow-up period of ≥4 years) (p>0.05).

A subgroup analysis of the quality score was performed. For the microsurgery group, the pooled success rate of group A was 90% (pooled ES 0.904, 95% CI 0.860–0.947), and that of group B was 95% (pooled ES 0.947, 95% CI 0.893–

![Fig. 1 A flow chart of the study identification and screening for (a) the retreatment group and (b) the microsurgery group](image-url)
For the retreatment group, the pooled success rate of group A was 74% (pooled ES 0.743, 95% CI 0.627–0.858), that of group B was 80% (pooled ES 0.797, 95% CI 0.750–0.843), and that of group C is 85% (pooled ES 0.854, 95% CI 0.818–0.890). Figures 3 and 4 show the forest plots of the subgroup analysis.

Discussion

To compare the outcomes of nonsurgical retreatment and endodontic microsurgery, the ideal systematic review should analyze randomized controlled studies of the two procedures. We conducted this review as an indirect comparison by separately pooling the outcomes of each procedure because no clinical studies directly compared the outcomes of retreatment and microsurgery.

Each study found in the databases had a various number of patients, follow-up periods, and intervention techniques. To standardize these two different procedures and perform the process of selection as fairly and uniformly as possible, there were several factors that had to be considered. Relatively few studies remained after the first and second screening for the final list because of the following reasons and factors.

The first reason for exclusion was the absence of consensus on the success criteria in the studies on retreatment or apical surgery. Standardization of the success criteria between the two procedures is a critical aspect of this review. Rud et al. [24] or Molven et al. [25] suggested radiographic criteria for assessment of healing after apical surgery. These criteria are widely used in outcome studies of apical surgery and are used in our review. If the criteria were to be applied to evaluate the retreatment group, data from many studies would have to be rearranged because of its lack of use in the studies. Comparing the apical lesion size or the PAI scoring as a radiographic assessment, instead of the Rud-Molven criteria, was allowed in the retreatment group; a reduction in size without clinical symptoms was evaluated as success. In our study, 2 of 23 studies in the retreatment group and 30 of 90 studies in the microsurgery group were excluded because of the difference in the criteria and the lack of information regarding the raw data for recalculation (Table 2). Consensus regarding the success criteria for each intervention is a crucial factor in accumulating homogenous data from many different studies and is critical in a meta-analysis of high-level studies.

The second important factor is the assessment unit used in each study. In this review, the assessment unit was limited to only a tooth, in which the result is based on the worst state of one root in a multi-rooted tooth. The outcome could be

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Sample size</th>
<th>Success no.</th>
<th>Minimum follow-up (years)</th>
<th>Success rate</th>
<th>Wilson score interval</th>
<th>Weight</th>
<th>Study design</th>
<th>Quality score</th>
<th>Quality group</th>
</tr>
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<tr>
<td>de Chevigny [29]</td>
<td>2008</td>
<td>126</td>
<td>104</td>
<td>4</td>
<td>0.83</td>
<td>0.749 0.881</td>
<td>14.81</td>
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<td>6</td>
<td>B</td>
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<td>Ercan [30]</td>
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<td>64</td>
<td>50</td>
<td>1</td>
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<td>0.665 0.864</td>
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<td>5</td>
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<td>0.655 0.834</td>
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<td>6</td>
<td>B</td>
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<tr>
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<td>452</td>
<td>311</td>
<td>2</td>
<td>0.69</td>
<td>0.643 0.729</td>
<td>16.53</td>
<td>PRO</td>
<td>7</td>
<td>A</td>
</tr>
<tr>
<td>Farzaneh [33]</td>
<td>2004</td>
<td>103</td>
<td>83</td>
<td>4</td>
<td>0.81</td>
<td>0.719 0.870</td>
<td>14.01</td>
<td>PRO</td>
<td>7</td>
<td>A</td>
</tr>
<tr>
<td>Allen [34]</td>
<td>1989</td>
<td>315</td>
<td>267</td>
<td>0.5</td>
<td>0.85</td>
<td>0.803 0.883</td>
<td>16.71</td>
<td>RETRO</td>
<td>3</td>
<td>C</td>
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<tr>
<td>Selden [35]</td>
<td>1974</td>
<td>52</td>
<td>46</td>
<td>1.5</td>
<td>0.88</td>
<td>0.770 0.946</td>
<td>13.01</td>
<td>PRO</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>Song [36]</td>
<td>2012</td>
<td>170</td>
<td>129</td>
<td>5</td>
<td>0.76</td>
<td>0.689 0.816</td>
<td>7.48</td>
<td>PRO</td>
<td>7</td>
<td>A</td>
</tr>
<tr>
<td>Song [37]</td>
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<td>192</td>
<td>181</td>
<td>1</td>
<td>0.94</td>
<td>0.900 0.967</td>
<td>10.97</td>
<td>RCT</td>
<td>10</td>
<td>A</td>
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<tr>
<td>Pljevljak [38]</td>
<td>2011</td>
<td>108</td>
<td>108</td>
<td>1</td>
<td>1</td>
<td>0.965 1</td>
<td>11.71</td>
<td>RETRO</td>
<td>6</td>
<td>B</td>
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<tr>
<td>Goyal [39]</td>
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<td>21</td>
<td>1</td>
<td>0.84</td>
<td>0.653 0.935</td>
<td>4.52</td>
<td>PRO</td>
<td>7</td>
<td>A</td>
</tr>
<tr>
<td>Christiansen [12]</td>
<td>2009</td>
<td>25</td>
<td>25</td>
<td>1</td>
<td>1</td>
<td>0.866 1</td>
<td>8.77</td>
<td>RCT</td>
<td>8</td>
<td>A</td>
</tr>
<tr>
<td>Taschieri [40]</td>
<td>2008</td>
<td>100</td>
<td>91</td>
<td>2</td>
<td>0.91</td>
<td>0.837 0.951</td>
<td>9.44</td>
<td>RCT</td>
<td>9</td>
<td>A</td>
</tr>
<tr>
<td>Kim [41]</td>
<td>2008</td>
<td>192</td>
<td>172</td>
<td>1</td>
<td>0.90</td>
<td>0.849 0.935</td>
<td>10.42</td>
<td>RETRO</td>
<td>7</td>
<td>A</td>
</tr>
<tr>
<td>Tsessi [42]</td>
<td>2006</td>
<td>45</td>
<td>41</td>
<td>0.5</td>
<td>0.91</td>
<td>0.792 0.964</td>
<td>7.43</td>
<td>RETRO</td>
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<td>B</td>
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<tr>
<td>Chong [11]</td>
<td>2003</td>
<td>108</td>
<td>97</td>
<td>2</td>
<td>0.90</td>
<td>0.826 0.942</td>
<td>9.4</td>
<td>RCT</td>
<td>10</td>
<td>A</td>
</tr>
</tbody>
</table>

**PRO** prospective study, **RETRO** retrospective study, **RCT** randomized controlled trial

*a* Study obtained by personal contact, which is in process of publication

1.001). For the retreatment group, the pooled success rate of group A was 74% (pooled ES 0.743, 95% CI 0.627–0.858), that of group B was 80% (pooled ES 0.797, 95% CI 0.750–0.843), and that of group C is 85% (pooled ES 0.854, 95% CI 0.818–0.890). Figures 3 and 4 show the forest plots of the subgroup analysis.
evaluated per tooth or per root. When one root is used as a unit of measure, the success rates tend to be overestimated [49]. Because most of the studies in the microsurgery group selected one tooth as an assessment unit, it is logical and reasonable for a valid comparison to exclude the articles in the retreatment group that did not meet this restriction. Thus, three studies [49, 88, 92] in the retreatment group, which had a large number of samples [49], were excluded.

The third factor to consider was the possibility of overlapping experimental populations. In the microsurgery group, there were several studies written by the same authors whose recruitment periods of patients overlapped. When the author confirmed that the outcomes of the different articles were from the same population, one or more of the studies were excluded to avoid overestimating the results. In the case of overlapping populations, our reviewers discussed which study to include. The reviewers prioritized the following factors to determine the study to exclude: (1) the follow-up periods, (2) the number of patients, and (3) the quality of the studies. The reviewers selected a study with a shorter follow-up period over a longer follow-up period for exclusion, and 7 [117, 126–131] of 18 studies were excluded after the discussion.

A significant factor during the second screening was that very few studies included long-term outcomes of the interventions. Two studies of each treatment group had a follow-up period of 4 years or longer. Barone et al. [81] evaluated the treatment outcome of microsurgery for 4 to 10 years; however, this study was not included on the final list because the PAI score, instead of the Rud-Molven criteria, was used as the success criteria.

Based on the four previously mentioned factors, 11 studies of the microsurgery group and 7 studies of the retreatment group were included in the meta-analysis; the total number of studies is lower than in the previous reviews of the two treatments. Ng et al. [6] reported a meta-analysis with pooled data of 17 studies to investigate the success rates of retreatment. Compared to this study, they permitted both tooth and root as an assessment unit and used a wider range of radiographic criteria. Tsesis et al. [16] identified 18 studies in a systematic review of apical surgery performed with modern techniques. The authors included the studies using loupes as a magnification device, whereas only devices with over ×10 magnification such as endoscopes and microscopes were included in this review. The overlapping data were not excluded.

Table 2  Relevant exclusion criteria for each excluded study

<table>
<thead>
<tr>
<th>Study</th>
<th>Exclusion criteria</th>
<th>Study Exclusion criteria</th>
<th>Study Exclusion criteria</th>
<th>Study Exclusion criteria</th>
<th>Study Exclusion criteria</th>
</tr>
</thead>
</table>
Thus, when compared with Tsesis et al. [16], seven fewer studies were included in this study.

Assessing the quality of the studies that were evaluated in the meta-analyses was an essential process. Because the results of a meta-analysis are significantly affected by the quality of the included studies, results included without an adequate assessment of their qualities might be less meaningful or misleading [132]. Although randomization, double blinding, and a description of the withdrawals and dropouts were considered to be directly related to bias reduction [26], most of the clinical studies included in this review were not randomized or blinded, and they reported the success rates in a single population. The checklists from Jadad et al. [26] and Detsky et al. [27] were modified and used in this study. The modified checklist primarily evaluates generalizability based on the proper practices of trials such as patient recruitment based on predetermined criteria and outcome assessment by calibrated and independent examiners.

The quality scoring and grouping of each treatment group were executed on the basis of the modified checklist. The

<table>
<thead>
<tr>
<th>Retreatment</th>
<th>ES (95% CI)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevigny, 2008</td>
<td>0.83 (0.75, 0.88)</td>
<td>14.81</td>
</tr>
<tr>
<td>Erkan, 2007</td>
<td>0.79 (0.67, 0.86)</td>
<td>12.06</td>
</tr>
<tr>
<td>Caliskan, 2005</td>
<td>0.76 (0.66, 0.83)</td>
<td>12.86</td>
</tr>
<tr>
<td>Gorni, 2004</td>
<td>0.69 (0.64, 0.73)</td>
<td>16.53</td>
</tr>
<tr>
<td>Farzaneh, 2004</td>
<td>0.81 (0.72, 0.87)</td>
<td>14.01</td>
</tr>
<tr>
<td>Allen, 1989</td>
<td>0.85 (0.80, 0.88)</td>
<td>16.71</td>
</tr>
<tr>
<td>Selden, 1974</td>
<td>0.88 (0.77, 0.96)</td>
<td>13.01</td>
</tr>
<tr>
<td>Overall (I-squared = 83.5%, p = 0.000)</td>
<td>0.80 (0.74, 0.86)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Microsurgery</th>
<th>ES (95% CI)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
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<td>Song, 2013</td>
<td>0.88 (0.81, 0.93)</td>
<td>9.23</td>
</tr>
<tr>
<td>von Arx, 2012</td>
<td>0.76 (0.67, 0.84)</td>
<td>7.48</td>
</tr>
<tr>
<td>Song, 2012</td>
<td>0.94 (0.90, 0.97)</td>
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<tr>
<td>Plijevjak, 2011</td>
<td>1.00 (0.97, 1.00)</td>
<td>11.71</td>
</tr>
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<td>Goyal, 2011</td>
<td>0.84 (0.65, 0.94)</td>
<td>4.52</td>
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<tr>
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<td>1.00 (0.87, 1.00)</td>
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<tr>
<td>Chong, 2003</td>
<td>0.90 (0.83, 0.94)</td>
<td>9.40</td>
</tr>
<tr>
<td>Rubinstein, 1999</td>
<td>0.97 (0.91, 0.99)</td>
<td>10.63</td>
</tr>
<tr>
<td>Overall (I-squared = 85.7%, p = 0.000)</td>
<td>0.92 (0.88, 0.96)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

NOTE: Weights are from random effects analysis

Fig. 2 Weighted pooled success rates for the retreatment and microsurgery group.
The microsurgery group showed a tendency of having a higher quality than that of the retreatment group. More than one-half of the studies in the microsurgery group were in group A, the highest score group, whereas none of the microsurgery studies were in group C, the lowest score group. Because the microsurgery group had more recently published articles, the studies included a higher quality in the practices and reporting of the trials. Although there are many existing clinical studies,
additional well-designed high-quality clinical trials are needed to evaluate the outcome of the procedures.

In this study, the estimated overall success rate of the microsurgery group is 92%, which is in a similar range with that of other systematic reviews. Setzer et al. [14] evaluated the outcomes of endodontic microsurgery and compared them to traditional root-end surgery. They reported the overall success ratio as 94% based on nine studies. Setzer’s estimates and
those of our study reflect the fact that microsurgery using specific techniques developed recently is a reliable treatment option that promises high success rates.

The overall outcome of the retreatment group in this study is 80%, which is similar to the estimates by Ng et al. [6]. Although the improvement of the procedure is not recent, additional clinical trials of retreatment performed by recent widely used techniques are necessary to reevaluate the treatment outcome.

In the comparison of the overall outcomes between the two procedures, a significantly higher success rate was found for the microsurgery group. Torabinejad et al. [23] reported no significant difference in the weighted success rates between the retreatment group and the endodontic surgery group, which included studies using traditional techniques and modern techniques. It appears that the results of this study were influenced by the improvement in the techniques and devices of microsurgery.

The outcomes of the procedures are affected by many clinical factors as follows: the presence and size of the apical lesion [6, 31, 127], the root-end filling material [11, 13], coronal restoration [49, 127], and the status of previous root canal treatment [32, 133]. Because of the completely different process of the two treatments and lack of information regarding the subjects, it was difficult to classify studies by the various related factors for the subgroup analysis. Among those factors, only for the follow-up period factor was possible to evaluate its influence on whether the success rates change with time. A significantly higher success rate for microsurgery than for retreatment was found in the groups with a follow-up period of less than 2 years and of 2–4 years. Whereas these results represented the effect of rapid bone healing in microsurgery, there was no significant difference in a group that had a follow-up period of more than 4 years. The result might represent the fact that these two treatment modalities have the identical effect in long-term follow-up. Another possible explanation of this finding is that a very small number of studies that include long-term follow-up could hamper an evaluation of the true effect and could have statistical power.

With regard to the follow-up periods, the length of time necessary for the outcome assessment remains controversial. A short follow-up period such as less than 2 years might be insufficient to detect a recurrence of apical periodontitis [81]. Occurrence of a reversal to disease after traditional endodontic surgery was reported to be 5 to 25% of the apparently healed cases within 4 years after the treatment [134–136]. Those studies include samples primarily using a bur, instead of ultrasonic instruments, as well as amalgam root-end fillings without any magnification. It should be considered that reports of those cases do not provide the conclusive outcome or prognosis of endodontic microsurgery. Recently, some studies reported long-term outcomes of microsurgery. Von Arx et al. [36] reported that 11.3% of the teeth (16/141) assessed as healed at 1 year regressed to unhealed at 5 years. On the contrary, 17.2% of the teeth (5/29) assessed as unhealed at 1 year progressed to healed at 5 years, which resulted in a 7.8% reduction of the success rate. Additionally, Song et al. [126] evaluated the outcomes, up to 10 years, of cases that were classified as successes in a 1-year follow-up. Regression occurred in approximately 6.7% of the teeth classified as successes at the short-term follow-up. They noted that the long-term outcomes of more than 6 years are not less favorable than the short-term outcomes. To confirm the efficacy and validity of the outcome in a short-term follow-up, one should take careful notice of the well-designed clinical trials of microsurgery comparing the short-term and long-term follow-up.

On the basis of this study, some directions of clinical studies of retreatment and the microsurgery are recommended. First, good quality clinical trials are clearly needed to enhance the scientific evidence of treatment modalities and identify predictors of success and failure. Second, the outcome of trials must be expressed in a standardized format of success criteria to allow for combining or comparison in systematic reviews. Additional trials of long-term outcome must be conducted in microsurgery and retreatment.

It appears that endodontic microsurgery and nonsurgical retreatment have stable outcomes presenting 92% and 80% of overall pooled success rates, respectively. When the data were organized and analyzed according to their follow-up periods, a significantly higher success rate was found for the microsurgery group in the short-term follow-up (less than 4 years), whereas no significant difference was observed in the long-term follow-up (more than 4 years). Based on this study, endodontic microsurgery was confirmed as a reliable treatment option with favorable initial healing and a predictable outcome. Further long-term clinical studies investigating endodontic microsurgery and retreatment are needed in the future.

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Conflict of interest The authors deny any conflicts of interest.

References


