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REVIEW

Efficacy of microsurgery and comparison to macrosurgery for gingival recession treatment: a systematic review with meta-analysis

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Abstract

Objectives Microsurgical principles, techniques, and armamentarium have made significant contributions to the periodontal plastic surgery. The present meta-analysis aimed to investigate the overall efficacy of microsurgery on root coverage, and its clinical outcomes when compared to traditional macrosurgery.

Material and methods Electronic searches on PubMed, Embase, and CINAHL were used to retrieve prospective clinical trials. Primary outcomes were the mean root coverage (mRC) and probability of achieving complete root coverage (cRC), with secondary outcomes as other periodontal parameters and patient-reported outcome measures (PROMs).

Results Nineteen studies were included in the quantitative analysis. Microsurgery was estimated to achieve 83.3% mRC and 69.3% cRC. From a subgroup of 9 comparative studies, it was estimated microsurgery increased mRC by 6.6% ($p<0.001$) and cRC by 27.9% ($p<0.01$) compared to macrosurgical control treatments. Operating microscope (OM) yielded a significantly 6.7% higher mRC than the control group ($p=0.002$), while using loupes showed 6.16% increase in mRC with a borderline significance ($p=0.09$). OM and loupes-only had a 31.05% ($p=0.001$) and 25.54% ($p=0.001$) increases in achieving cRC compared to control, respectively. As for PROMs, microsurgery reduced postoperative pain ($p<0.001$) and enhanced esthetics ($p= 0.05$).

Conclusions Microsurgery significantly improved mean root coverage, probability of achieving complete root coverage, esthetics, and post-surgical recovery. Microsurgery enhances not only subclinical healing but also clinical outcomes, possibly owing to its minimally invasive approach and surgical precision.

Clinical relevance Periodontal plastic microsurgery is minimally invasive, inducing less surgical trauma and ultimately resulting in improved clinical outcomes, patient's satisfaction, and quality of life.

Keywords Gingival recession · Microsurgery · Minimally invasive surgical procedures · Connective tissue · Surgical flaps · Plastic surgery

Introduction

One of the primary goals of periodontal plastic surgery is to treat gingival recessions and other deformities affecting the mucogingival complex. Gingival recessions are defined as the apical shift of the free gingival margin beyond the cementoenamel junction and are currently surgically treated, if indicated, to primarily improve patient esthetic and prevent

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further progression [1, 2]. The overall patient-based prevalence of recessions is as high as 80% [3], and 40% of symptomatic recessions are deeper than 5 mm [4]. Recessions may compromise esthetics, impair oral hygiene practice, and predispose to dentin hypersensitivity, root caries, or further progression [3]. Multiple surgical therapies have been developed and often consist of flaps (coronally advanced, lateral sliding flap, or tunneling) with the adjunct of autogenous soft tissue graft, collagen substitutes, or biologics [5]. Long-term outcomes are overall favorable, with stable results [6–8] and even further coronal displacement of the gingival margin overtime [9]. Investigations from the last decades have suggested that flap designs, use of connective tissue graft (CTG), and microsurgical techniques significantly improved the expected outcome after a recession coverage procedure [10].

Microsurgery refers to minimally invasive surgical protocols performed with the use of magnification, e.g., operating microscope (OM) and microinstruments. Since its adoption, it has advanced patient care in medicine unprecedently [11]. In dentistry, endodontists are among the pioneers to adopt the OM, who have benefited extraordinarily from the magnified axial view inside the root canal system [12, 13]. In the fast-evolving discipline of periodontal plastic surgery, microsurgery has changed how we perform these procedures. Microsurgery allows for biologically focused surgery as gentler tissue handling and better flap refinement could result in wound stability and faster healing [10, 14]. A landmark study on early wound healing after root coverage procedures showed higher percentage of revascularization in the microsurgical compared to the macrosurgical group (micro- vs. macrosurgery: 53% vs. 44% at 3 days; 84% vs. 64% at 1 week; $p<0.01$) [15]. The mean root coverage was also increased in the microsurgical group (98%) compared to the macrosurgical controls (90%).

OM for performing periodontal plastic surgery is a natural progression because the outcomes of these procedures heavily rely on meticulous soft tissue management. Its incomparable magnification and co-axial illumination allow for such precise surgical procedures. Microsurgical plastic protocols with the OM have shown to enhance esthetics and reduce incidence of scar formation [14]. Aside from potential clinical improvements, ergonomics is another collateral advantage. The OM forces the operators to straighten their posture, which in turn may reduce fatigue and occupational musculoskeletal pain. Improved ergonomics is also related to the adjustable focal length of the eyes, and physical detachment of the body from the device, especially when compared to wearing loupes. Despite the mentioned advantages, the use of the OM is not largely diffused in the periodontal community, in part due to a steep learning curve and uncertainty about whether it can additionally improve clinical outcomes. Alternatively, loupes gained wider acceptance due to relatively lower cost, convenience, and ease of use. Loupes provide reasonable magnification (usually ×2 to ×3.5) and external light source, and have been used either exclusively or interchangeably with OM during microsurgical periodontal plastic surgery [16].

While there is a plethora of literature describing microsurgical techniques, or positive clinical outcomes in case series or in comparison among various flap designs, no meta-analysis was published to systematically quantify the clinical benefit that microsurgery can offer over traditional protocols. Therefore, the present study aimed to investigate the efficacy of microsurgery for root coverage procedures and whether the use of microsurgical protocols improves root coverage outcomes when compared to conventional macrosurgical techniques.

Material and methods

Focused question 1: In a pool of patients in need of a root coverage procedure, what is the clinical outcome in terms of percentage in mean root coverage (mRC) and complete root coverage (cRC) of microsurgical plastic procedures implementing magnification (loupes or OM) and microinstrumentation?

Focused question 2 (PICO): In a pool of patients in need of a root coverage procedure, does a microsurgical protocol improve clinical outcomes when compared to the same surgical approach but performed under a macrosurgical protocol?

Population: Patients in need of root coverage procedures

Intervention: The microsurgical approach

Comparison: The macrosurgical approach

Outcome: Root coverage outcomes at least 6 months after treatment

A null hypothesis was generated assuming no statistical difference between the groups: microsurgery with microinstrumentation and magnification (either loupes or OM) does not improve the clinical outcome of recession coverage procedures when compared to the conventional macrosurgical approach.

Search strategy, inclusion/exclusion criteria

In accordance with the PRISMA principles [17], extensive electronic searches were conducted on the databases MEDLINE/PubMed, Embase, and CINAHL to find studies related to esthetic and clinical outcomes after recession coverage procedure with microsurgical approach. The search and screening processes were conducted in May 2020. MeSH terms, keywords, and logic operators were selected based on the controlled vocabularies of the specific databases (Supplementary Figure 1). An additional screening was conducted on the websites of most notable scientific journals of *Periodontology*, *Oral Surgery*, and *Oral Medicine*. Two reviewers (RDG, LS) evaluated independently titles, abstracts,

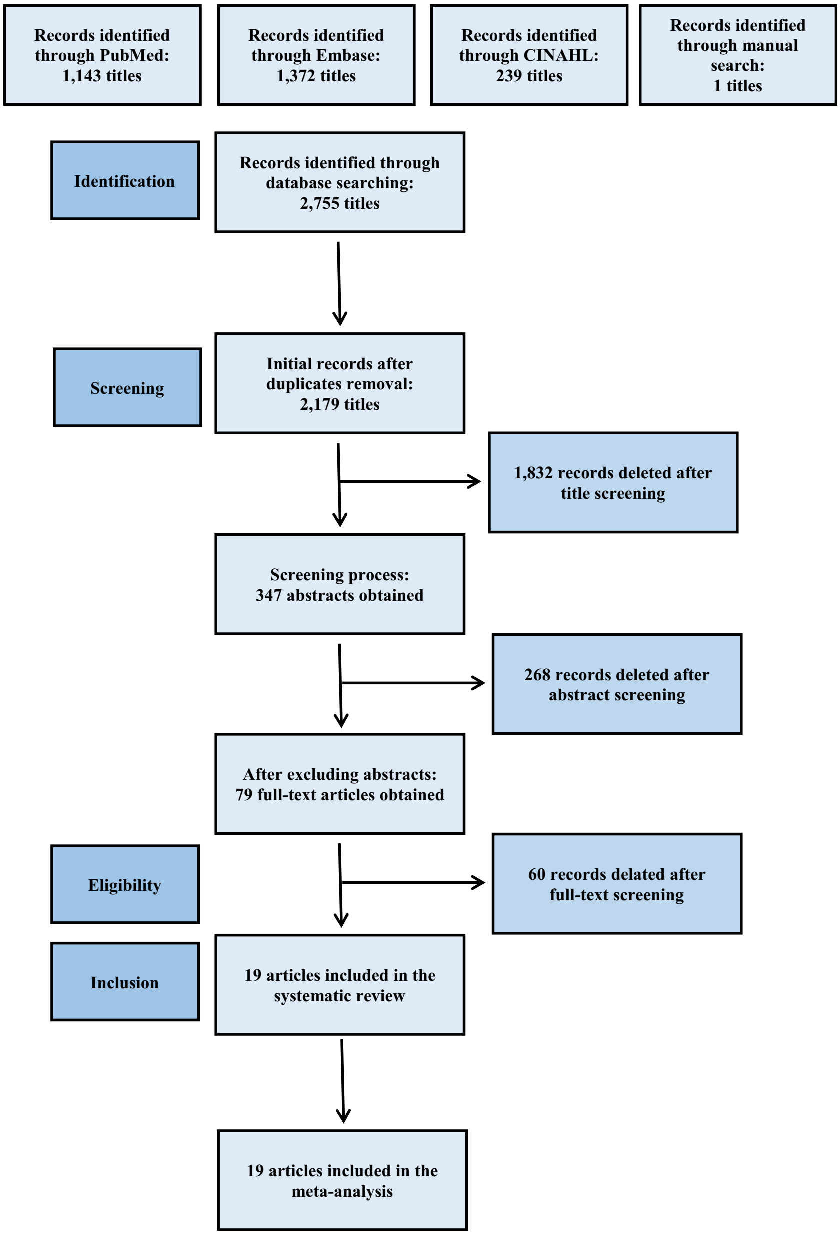


Fig. 1 PRISMA flowchart for the screening process

and full-text articles in three phases of screening (Fig. 1). At the end of each phase, reviewers consulted a third investigator (HLC) on included articles in case of disagreement. Articles eligible for inclusion had to be (1) randomized or non-randomized prospective trials, (2) reporting on root coverage after surgical treatment of recession, (3) using magnified microsurgical protocol in at least one group of treatment, (4) with a follow-up of at least 6 months, and (5) a baseline sample of at least 10 patients in each group. There was no restriction on the date of publication or language used, on the type of the surgical techniques (coronally advanced, lateral sliding, or tunneling flaps), use of autogenous soft tissue graft (connective tissue graft, free gingival graft, none), and use of collagen-based substitutes or biologics. Reviews, in vitro studies, animal studies, cross-sectional studies, retrospective studies, and repeated reports of the same study were excluded.

Data extraction and collection process

After the screening processes, articles were downloaded in their full-text version, data was extracted independently by two authors (RDG, LS), and disagreement was resolved after consultation of a third investigator (HLC). The included articles were reviewed in detail on the number of patients and number of affected teeth at baseline and at the latest follow-up, type of magnification (none, loupes, OM), magnification power, type of instrumentation (microsurgical, macrosurgical), surgical techniques, use of grafting material, use of biologics, if antibiotics were prescribed, diagnosis and severity of the baseline condition, treatment outcome, the surgical time, esthetic evaluation, pain evaluation, and complications. In case of missing data, corresponding authors were contacted asking for additional information. Domains from the Cochrane Collaboration tool [18] and the Joanna Briggs Institute Critical Appraisal tool [19] were used to review the quality of randomized clinical trials (RCTs) and other prospective studies and were reported as Supplementary Table 1 and 2, respectively. The primary outcomes were as follows: (i) mRC, defined as the percentage of exposed root successfully covered, and (ii) cRC, defined as the percentage of teeth that achieved complete resolution of the baseline recession. Secondary outcomes were as follows: (i) gain in keratinized gingiva amount (KG) defined as the linear measurement of the width of keratinized tissue apical to the recession, (ii) surgical time in minutes, and (iii) patient-related outcomes including perceived esthetics and pain.

Statistical analysis

Two meta-analyses were performed by one examiner (ICW). The first meta-analysis was a collective estimation of the mRC reported in all microsurgery (test) groups using microsurgical approaches with loupes or OM. Percentage of cRC was not suitable for meta-analysis due to a lack of reporting standard deviation; as an alternative, the effect estimate was calculated based on the relative sizes of studies [20]. The second meta-analysis was generated to compare the differences between microsurgical (test) and macrosurgical (control) groups on the primary and secondary outcomes and the results were presented as weighted mean differences (WMD with 95% confidence interval (CI)). A random-effect model was used if the heterogeneity test with the I^2 statistics was calculated as >50% [21]. Variance imputation techniques were computed where standard deviations of the differences were not reported [20, 22]. A network meta-analysis (NMA) was conducted to capture the indirect comparisons between two subgroups of loupes and OM using MetaInsight (The Complex Review Support Unit) web-based tool. Separate subgroup analyses were performed to analyze the influence of different variables reported in the studies, including the baseline characteristic of recession (recession type (RT) classification, recession depth, width of KG, tissue thickness), flap design, usage of CTG, biologics, or antibiotics. Sensitivity analysis was performed to evaluate the robustness of the results by omitting one study each time. Egger's test and funnel plot were applied to detect the possible publication bias [23]. All statistics were performed using the statistical software package Comprehensive Meta-analysis (version 3.3, Biostat, 2014). A p-value < 0.05 was considered statistically significant.

Results

Search results

Figure 1 summarized the screening process according to the PRISMA workflow. Briefly, MEDLINE/PubMed (*n*: 1143), Embase (*n*: 1372), and CINAHL (*n*: 239) contributed to a total of 2754 titles. One additional article [24] was retrieved with the manual search. Records from each database were imported in Endnote and merged for duplicate removal. A total of 2179 articles were evaluated for title screening, 347 for abstract screening, and 79 full-text screening. Nineteen articles [15, 16, 24–40] had a microsurgery group with or without a comparative macrosurgery group and therefore were included for the 1st meta-analysis. These studies comprised a total sample size of 614 recessions in 510 patients (Table 1). Nine [15, 33–40] out of the 19 studies compared surgical outcomes between microsurgical and macrosurgical groups and were included in the 2nd meta-analysis.

Study population

Study design, treatment protocols, demographics, and clinical outcomes are reported in Table 1. Briefly, the studies enrolled a number of patients ranging from 10 [15, 39, 40] to 50 [37] and an initial number of recessions ranging from 13 [24] to 71 [30]. All studies except two had no dropouts during the follow-up. Two patients were lost in Burkhardt and Lang (2005) because of relocation, and 5 patients were lost in Nizam et al. [36] because of relocation or denial to continue the study. Patients were labeled as non-smokers except for 15 patients reported by Kaval et al. [31] and 1 patient in Cortellini et al. (2012) [26]. The mean patient age reported by the studies ranged between 25 [26, 36] and 42 years [16]. All studies included both male and female patients.

Defect types, interventions, and magnification types

All treated sites were recession type 1 (RT1, Miller Class I or II) except for Gumus and Buduneli [38] and Ucak et al. [37] who reported on RT2, and Andrade et al. (2010) [33] who treated both RT1 and RT2. Root surface condition and gingival thickness were largely undocumented. All the authors used coronally advanced flaps (CAF), except for four who used laterally positioned flaps [27, 28, 35, 37], and one [30] who reported on tunneling. Most of the studies implemented either connective tissue graft (CTG) or free gingival graft (FGG) in adjunct to the flap as follows: subepithelial CTG, de-epithelialized CTG from the palate, de-epithelialized CTG from the interdental papilla, or partially epithelialized FGG. Four studies used biologics with either enamel matrix derivatives (EMD) or platelet-rich fibrin (PRF) [29, 32, 33, 39]. Two studies used membranes for guided tissue regeneration (GTR)

Table 1 Study design and clinical outcomes of the nineteen articles included in the systematic review

Source	Treatment	Groups	Magnification (power)	Suture size	Patients (n)	Teeth (n)	REC depth baseline (mm)	REC depth end (mm)	REC depth decrease (mm)	mRC (%)	cRC (%)	KG increase (mm)	Follow-up (years)
Francetti et al. 2004	Pedicle	Microsurgery	Microscope (×4 to ×8)	5-0	16	16	3.38 ± 0.72	0.13 ± 0.29	3.25 ± 0.61	97.03 ± 7.02	81.25%	2.22±0.60	1
Burkhardt and Lang 2005	Pedicle + de.epitCTG	Conventional	None	4-0	8	8	Not reported	Not reported	Not reported	89.9 ± 8.5	25	Not reported	1
	Pedicle + de.epitCTG	Microsurgery	Microscope (×5 to ×15)	9-0	8	8	Not reported	Not reported	Not reported	98.0 ± 3.4	62.5	Not reported	1
Francetti et al. 2005	CAF+CTG	Conventional	None	5-0 to 6-0	12	12	3.38 ± 1.11	0.73 ± 0.75	2.63 ± 0.91	78	33.4	1.70 ± 1.51	1
	CAF+CTG	Microsurgery	Microscope (×15)	5-0 to 6-0	12	12	3.17 ± 1.01	0.55 ± 0.69	2.67 ± 0.87	86	58.3	1.79 ± 0.69	1
Latha et al. 2009	Pedicle	Microsurgery	Loupes (×2.5)	6-0	15	15	2.67±0.62	0.27±0.59	2.4 ± 0.03	86.67 ±35.19	Not reported	1.33 ± .13	1
Andrade et al. 2010	CAF+EMD	Conventional	None	5-0	15	15	2.47 ± 0.49	0.41 ± 0.50	2.05 ± 0.64	83	46.6	0.09	0.5
	CAF+EMD	Microsurgery	Microscope	8-0	15	15	2.40 ± 0.47	0.19 ± 0.34	2.21 ± 0.60	92	73.3	0.69	0.5
Cairo and Pini Prato 2010	CAF+subCTG	Microsurgery	Loupes and microscope	Not reported	12	25	2.6 ± 1.3	0.2 ± 0.5	2.4 ± 1.5	91	80	Not reported	2
Cairo et al. 2010	CAF+subCTG	Microsurgery	Microscope (×5 to ×20)	6-0 to 7-0	11	13	2.8 ± 0.9	0.1 ± 0.4	Not reported	95	85	Not reported	1
Bittencourt et al. 2012	CAF+subCTG	Conventional	None	8-0	24	24	2.53 ± 0.55	0.29 ± 0.42	2.24 ± 0.64	88.3	58.3	1.37 ± 1.18	1
	CAF+subCTG	Microsurgery	Microscope (×8 to ×12)	8-0	24	24	2.51 ± 0.35	0.05 ± 0.14	2.46 ± 0.38	98	87.5	1.51 ± 1.01	1
Cortellini et al. 2012	APF+paCTG	Microsurgery	Microscope (×5 to ×30)	Not reported	12	12	3.5 ± 1.1	0.3 ± 0.5	3.3 ± 0.9	94 ± 11	75	2.8 ± 0.7	1
	APF+paCTG	Microsurgery	Microscope (×5 to ×30)	Not reported	7	16	3.1 ± 1.2	0.1 ± 0.3	3 ± 1.2	96 ± 11	87.5	3 ± 0.7	1
Pandey and Metha 2013	CAF+papilCTG	Conventional	None	5-0	10	10	2.97±1.58	0.83±0.43	2.14±1.26	72.1±15.1	Not reported	0.45±0.24	0.5
	CAF+papilCTG	Microsurgery	Microscope (×10)	Not reported	10	10	2.98±1.45	0.93±0.42	2.05±1.14	68.8±9.3	Not reported	0.45±0.25	0.5
Gumus and Buduneli 2014	FGG	Conventional (no sutures)	No	Cyanoacrylate	15	15	3.33±1.30	2.42±1.32	0.92±0.44	Not reported	Not reported	Not reported	0.5
	FGG	Conventional	No	5-0	15	15	3.61±1.40	2.67±1.10	0.95±0.74	26.3±15.1	Not reported	1.11±0.98	0.5
	FGG	Microsurgery	Loupes (×2.5)	7-0	15	15	3.33±0.85	2.49±0.92	0.83±0.43	24.9±9.3	Not reported	1.07±1.04	0.5
Kaval et al. 2014	CAF	Microsurgery	Loupes (×2.5)	6-0	15	18	2.99±0.91	0.24±0.49	Not reported	94.11 ±12.00	72.2	0.66	0.5
	CAF	Microsurgery	Loupes (×2.5)	6-0	15	18	2.49 ±0.53	0.24±0.46	Not reported	90.33 ±17.84	66.7	0.45	0.5
Nizam et al. 2015	CAF+subCTG	Conventional	None	5-0	12	18	3.58 ± 0.80	0.64 ± 0.63	2.96 ± 0.69	83.46 ±16.21	50	2.09 ± 0.84	2
	CAF+subCTG	Microsurgery	Loupes (×3.5)	7-0	13	19	3.72 ± 1.01	0.20 ± 0.40	3.62 ± 0.85	95.82 ± 8.41	78.9	2.24 ± 1.17	2
Agarwal et al. 2016	CAF	Microsurgery	Microscope (×5)	6-0	23	15	1.80±0.86	1.20±0.94	Not reported	41.7	13.3	Not reported	0.5
	CAF+PRF	Microsurgery	Microscope (×5)	6-0		15	2.60±0.83	1.20±1.21	Not reported		33.3	Not reported	0.5
	CAF+AM	Microsurgery	Microscope (×5)	6-0		15	1.87±0.74	1.20±1.47	Not reported		26.6	Not reported	0.5
Azaripour et al. 2016	CAF+CTG	Conventional	Loupes	6-0	20	29	2.36±1.2	0.017±0.9	2.3±1.2	98.3±9.2	96.6	0.36±0.6	1
	Tunnel+CTG	Microsurgery	Loupes	6-0	20	42	2.11±1.1	0.06 ±0.1	2.1±1.1	97.3±7.6	88.1	0.48±0.6	1
Thankkappan et al. 2016	CAF	Microsurgery	Microscope (×6)	6-0	40	40	4.30±1.17	0.6±0.48	Not reported	81.42	3	Not reported	1
	CAF+GTR	Microsurgery	Microscope (×6)	6-0			4.20±1.00	1.15±0.60	Not reported	70.08	1	Not reported	1
Kumar et al. 2017	CAF	Microsurgery	Microscope (×10)	6-0	36	15	2.00±0.53	0.93±0.79	Not Reported	53.3	27	Not Reported	0.5
	CAF+PRF	Microsurgery		6-0		15	1.80±0.56	0.53±0.74		74.4	60		0.5

Table 1 (continued)

Source	Treatment	Groups	Magnification (power)	Suture size	Patients (n)	Teeth (n)	REC depth baseline (mm)	REC depth end (mm)	REC depth decrease (mm)	mRC (%)	cRC (%)	KG increase (mm)	Follow-up (years)
			Microscope (×10)						Not Reported			Not Reported	
	CAF + de.epiCTG	Microsurgery	Microscope (×10)	6-0		15	2.20±0.41	0.93±0.70	Not Reported	58	20	Not Reported	0.5
Ucak et al. 2017	Pedicle	Conventional	None	5-0	25	25	4.24 ± 0.879	0.36 ± 0.64	3.88	90.48 ±15.06	68	3.88	0.5
	Pedicle	Microsurgery	Loupes (×2.5)	7-0	25	25	4.44 ± 1.08	0.12 ± 0.44	4.32	97.64 ± 8.27	92	4.36	0.5
Patel et al. 2018	CAF+PRF	Conventional	None	Not reported	10	10	2.1 ± 0.87	0.5 ± 0.53	1.6	81 ± 20.5	Not reported	1.3 ± 0.65	0.5
	CAF+PRF	Microsurgery	Microscope (×4 to ×6)	Not reported	10	10	2.50 ± 0.70	0.40 ± 0.52	2.1	87 ± 17.5	Not reported	1.6 ± 0.48	0.5

Abbreviations: *APF*, apically positioned flap; *CAF*, coronally advanced flap; *CAL*, clinical attachment level; *CTG*, connective tissue graft; *subCTG*, subepithelial connective tissue graft; *de.epiCTG*, de-epithelialized connective tissue graft; *paCTG*, partially epithelialized connective tissue graft; *papilCTG*, connective tissue graft from interproximal papilla; *cRC*, complete root coverage; *FGG*, free gingival graft; *GTR*, guided tissue regeneration; *KG*, keratinized gingiva; *mRC*, mean root coverage; *PRF*, platelet-rich fibrin; *RT*, recession type; *REC*, recession

[25, 29]. The smallest and largest suture sizes were 9-0 and 4-0; they were reported in the same study and were used for microsurgery and macrosurgery, respectively [15]. All the other studies reported the suture size between 4-0 and 9-0, with the exception of Gumus and Buduneli [38], who reported of a macrosurgical group advocating for cyanoacrylate to stabilize the autogenous soft tissue graft without use of any suture. In the microsurgical group, 6 studies used loupes exclusively [16, 28, 30, 31, 36–38], 12 studies used the OM exclusively [15, 16, 24–27, 29, 32–35, 39, 40], and 1 study used both loupes and OM. Loupes and the OM were never compared within the same study. In the macrosurgical group, all studies had no magnification, except for Azaripour et al. [30], who implemented visual power with loupes. Magnification power for the loupes was limited to ×2.5 and ×3.5; magnification power for the OM varied considerably from ×4 to ×8 [25, 27, 29, 39], ×8 to ×15 [24, 32, 34, 35, 40], and up to ×20 [15, 26].

Descriptive outcome assessment

The mean recession depth improved from 0.83 [38] to 3.6 mm [36]. Eleven studies had at least one group with mRC > 90% [15, 16, 24, 26, 27, 30, 31, 33, 34, 36, 37]. Of those, 5 articles reported mRC >90% for microsurgery and mRC <90% for macrosurgery [15, 33, 34, 36, 37], and only 2 articles reported mRC higher than 90% in both macrosurgery and microsurgery [30, 31]. Microsurgery always had higher cRC in comparative studies. Two studies reported surgical time increased in the microsurgical group by 6 min [34] and 21 min [15]. All studies were complication-free, except for Nizam et al. who reported one case of palatal dehiscence for the microsurgical group and one case of hemorrhage in each group [36]. No studies reported biological complications involving systemic impairment [41].

Statistical analysis of microsurgery efficacy

The compiled mRC obtained by microsurgery in the 19 articles was 83.33% under the random-effect model (95% CI: 74.74 to 91.93%, $p< 0.001$, $I^2= 98.6\%$). The sensitivity test suggested consistency of this result across the 19 studies. However, when excluding one study investigating free gingival graft (FGG) [38], the mRC was shown to be higher (86.78%, 95% CI: 80.85 to 92.72%, $p< 0.001$, $I^2= 97.1\%$; Fig. 2). The mRC was further stratified into three subgroups: 51.6% by CAF with GTR [25, 29], 77.12% by CAF or pedicle flap alone [28, 29, 31–33, 37, 39], and 90.17% by CAF or pedicle flap combined with CTG [15, 16, 24, 25, 27, 30, 32, 34–36, 40]. The differences were statistically significantly among these 3 treatment subgroups (p=0.03; Fig. 3). Sixteen included studies reported the percentage of cRC in a range of 10 to 92.4% [15, 16, 24–37]. The mean value of cRC across studies was 69.33% (95% CI: 55.8 to 82.8%). The mean cRC of each study was summarized in a bubble plot (Fig. 4).

Statistical analysis comparing microsurgery and macrosurgery efficacy

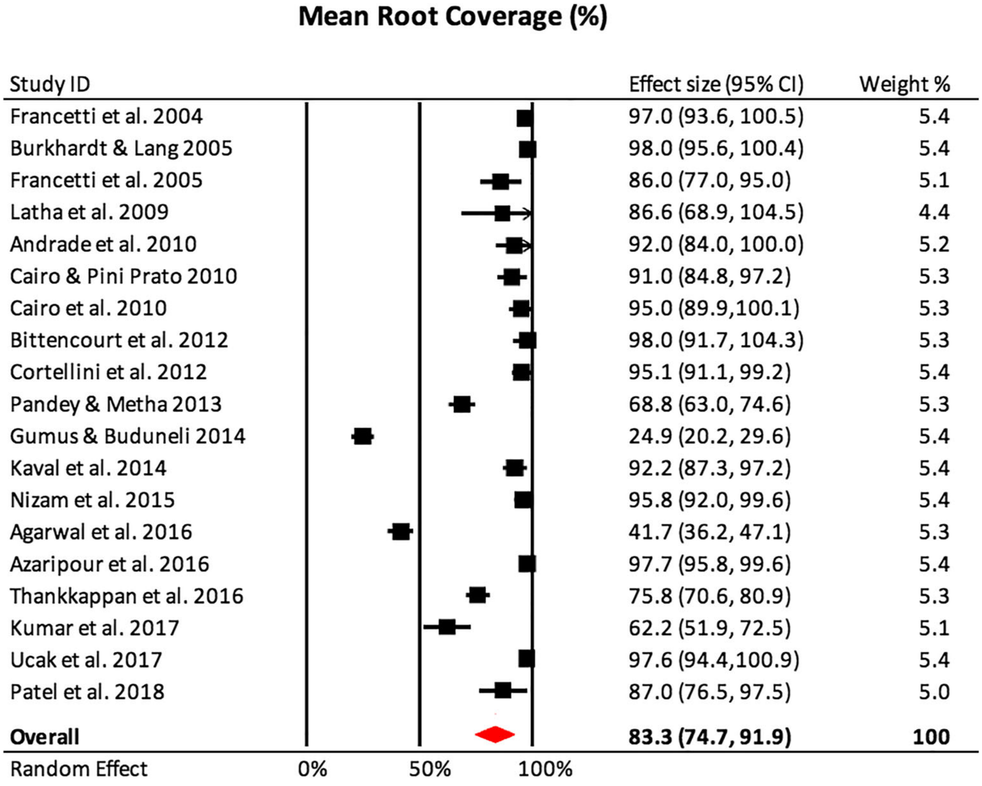
Primary outcomes

The weighed mean mRC difference was 6.64%, in favor of the microsurgery group (95% CI: 3.57 to 9.7%, $p < 0.001$, $I^2 = 9.56\%$) [15, 33–40] (Fig. 5), which was confirmed by the sensitivity test (Supplementary Figure 2). Subgroup non-parallel analysis studied the possible covariates, including the RT and type of magnification on the mRC outcome. Studies including only recession type 1 (RT1, Miller Classes I and II) showed the mean mRC difference was 7.7% (95% CI: 3.67 to 11.76%, $p < 0.001$), as opposed to 3.4% ($p > 0.05$) in the studies evaluating RT2 (Miller Class III) [37, 38]. OM subgroup yielded a significantly 6.7% higher mRC than the macrosurgery group (95% CI: 2.38 to 10.38%, $p = 0.002$, $I^2 = 35.8\%$) [15, 33–35, 39, 40], while using loupes showed 6.16% increase in mRC with a borderline significance (95% CI: −1.06 to 11.38%, $p = 0.09$, $I^2 = 79\%$) [36–38].

Microsurgery yielded a weighed mean of 27.9% increase in cRC, compared to macrosurgery (95% CI: 16.37 to 39.43%, $p < 0.01$, $I^2 = 0\%$) [15, 33–37] (Fig. 6) with the robustness confirmed by the sensitivity test (Supplementary Figure 3). Microsurgery had 31.46% and 24% higher probability of achieving cRC for treating RT1 recessions ($p < 0.001$) and RT2 recession ($p = 0.05$), respectively. OM showed a 31.05% increase in cRC (95% CI: 13.42 to 48.69%, $p = 0.001$, $I^2 = 0\%$) when compared to macrosurgery. Similarly, the loupes-only subgroup had a 25.54% higher mean cRC (95% CI: 10.3 to 40.79%, $p = 0.001$, $I^2 = 0\%$) compared to macrosurgery. No other variables exhibited significant impact in the subgroup analysis ($p > 0.05$).

Secondary outcomes

Keratinized gingiva (KG) increased in both groups with a weighted mean difference of 0.17 mm favoring the microsurgical group (95% CI: 0.03 to 0.3 mm, $p = 0.02$, $I^2 = 14.1\%$) [33–40] (Supplementary Figure 4). Meta-regression analysis failed to demonstrate the significant influence of the baseline KG width to the mean difference of KG increase between two groups. Length of the surgery in minutes was found to be statistically significantly longer in the microsurgery group (mean difference: 11.7 min, 95% CI: 6.7 to 16.6 min, $p < 0.001$, $I^2 = 89.7\%$) compared to the conventional macrosurgical approach [15, 34, 36, 38] (Supplementary Figure 5). Pain perception as the VAS score recorded at 3 and 7 days postsurgically was analyzed. At 3 days, the score was 3.57 points significantly lower in the microsurgical group



Study ID	Effect size (95% CI)	Weight %
Francetti et al. 2004	97.0 (93.6, 100.5)	5.4
Burkhardt & Lang 2005	98.0 (95.6, 100.4)	5.4
Francetti et al. 2005	86.0 (77.0, 95.0)	5.1
Latha et al. 2009	86.6 (68.9, 104.5)	4.4
Andrade et al. 2010	92.0 (84.0, 100.0)	5.2
Cairo & Pini Prato 2010	91.0 (84.8, 97.2)	5.3
Cairo et al. 2010	95.0 (89.9,100.1)	5.3
Bittencourt et al. 2012	98.0 (91.7, 104.3)	5.3
Cortellini et al. 2012	95.1 (91.1, 99.2)	5.4
Pandey & Metha 2013	68.8 (63.0, 74.6)	5.3
Gumus & Buduneli 2014	24.9 (20.2, 29.6)	5.4
Kaval et al. 2014	92.2 (87.3, 97.2)	5.4
Nizam et al. 2015	95.8 (92.0, 99.6)	5.4
Agarwal et al. 2016	41.7 (36.2, 47.1)	5.3
Azaripour et al. 2016	97.7 (95.8, 99.6)	5.4
Thankkappan et al. 2016	75.8 (70.6, 80.9)	5.3
Kumar et al. 2017	62.2 (51.9, 72.5)	5.1
Ucak et al. 2017	97.6 (94.4,100.9)	5.4
Patel et al. 2018	87.0 (76.5, 97.5)	5.0
Overall	**83.3 (74.7, 91.9)**	**100**

Fig. 2 Mean root coverage for the full set of nineteen studies investigating microsurgical protocol for recession coverage

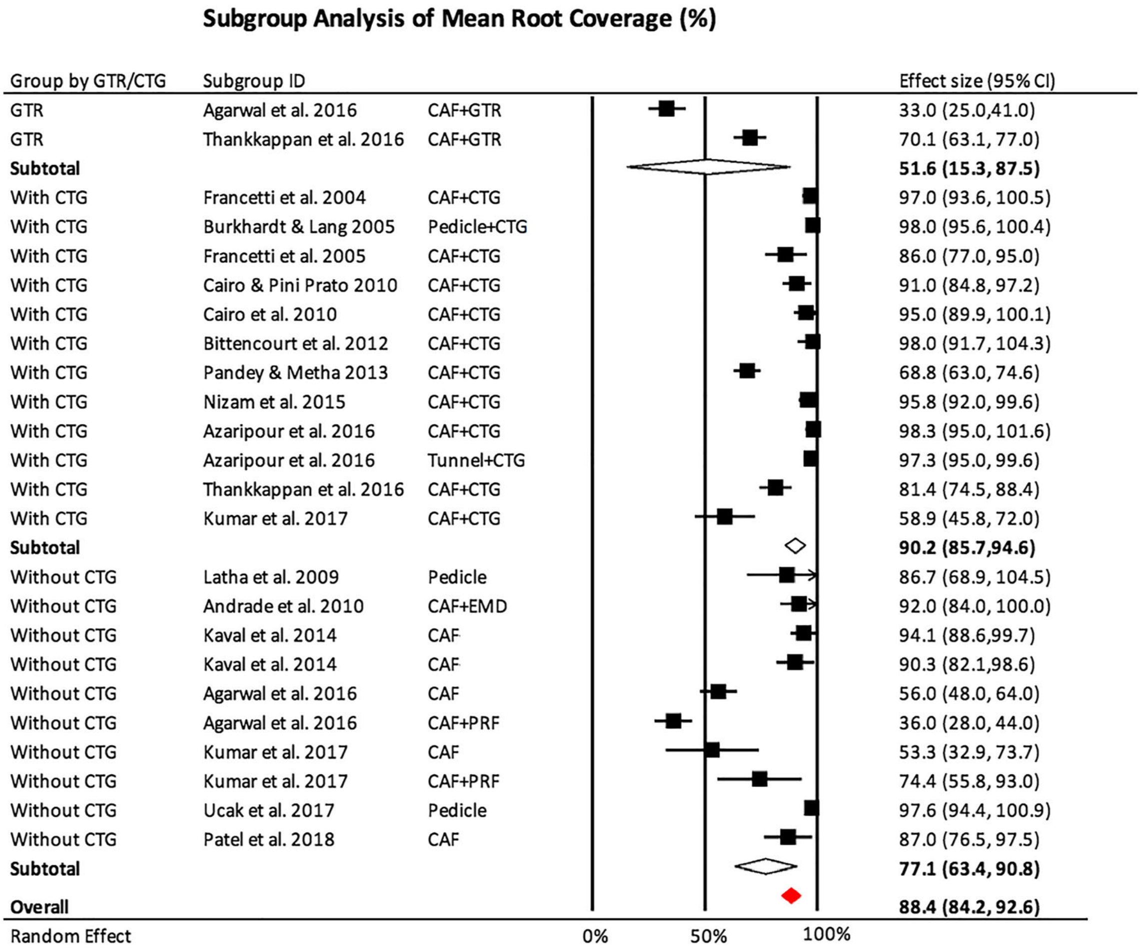


Fig. 3 The 19 included studies were further grouped based on treatment modality and categorized in membrane-based root coverage, autogenous graft-based root coverage, and other techniques not using a connective tissue graft

(95% CI: −4.26 to −2.88, $p< 0.001$, $I^2 = 27.5\%$) [36, 39] (Supplementary Figure 6). The difference between group decreased over time, but at 7 days, the score remained statistically lower for patients treated with microsurgery (mean difference: −1.74, 95% CI: −2.36 to −1.1, $p< 0.001$, $I^2 = 62.8\%$) [37, 39] (Supplementary Figure 6). Patient-reported esthetic outcome was scarcely documented [36, 37]. Improved esthetic VAS score was suggested in the microsurgery group at a level of statistical significance (VAS esthetics: 0.39, $p= 0.05$) (Supplementary Figure 7).

Discussions

Microsurgery provided surgical periodontology with a new perspective, especially in the field of periodontal plastic surgery [10]. Techniques and surgical protocols have specifically developed to optimize the use of OM and microsurgical instruments [42, 43]. To the best of our knowledge, this is the first meta-analysis to quantify the efficacy of microsurgery for periodontal soft tissue augmentation and its outcome in comparison to macrosurgery. In the present study, microsurgery achieved improved mean root coverage, probability of complete coverage, esthetics, and patient comfort at a level of statistically significance, when compared to the same surgical protocols using conventional instruments without magnification. Of special notice is that microsurgery was estimated to have approximately 30% increase in complete root coverage than macrosurgery. The optimal healing potential has been acknowledged as the reason for the improved outcomes after microsurgical treatments [15]. At the technical level, microinstruments allow for more precise incision, gentler tissue handling, reduced flap trauma, and less invasive suturing, which could all contribute to lower vascular impairment and accelerated wound healing. These findings are also in accordance with the improved outcomes of microsurgery after use of CTG compared to flap alone, stressing a beneficial role of microsurgery for biologically challenging procedures such as free autogenous soft tissue graft.

Patient-centered outcomes have become increasingly important as a part of the study results and the included studies

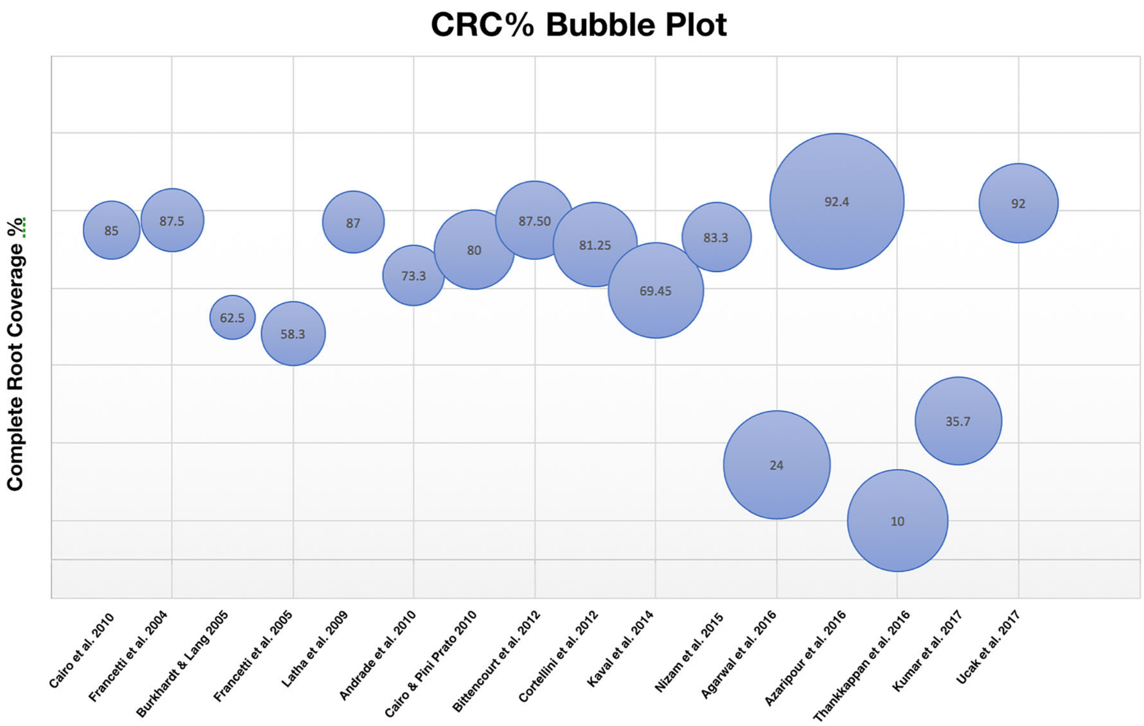


Fig. 4 Graphic representation of complete root coverage with bubble plot. Sample size was reported as bubble diameter

provided some preliminary insights on how patients perceived after microsurgery [10, 44]. Overall, microsurgery received higher patient satisfaction and quality of life during the early healing period, due to the significant less pain and improved esthetics. At 7 days postoperatively, significantly less pain was still perceived in the microsurgery group [36, 39]. Concerning esthetics, all available articles unequivocally favored the microsurgery group. Bittencourt et al. reported patients' satisfaction of 100% in the microsurgical group compared to a 79% in the conventional approach (p<0.05) [34]. Ucak et al. reported on root coverage esthetics score that was also higher in microsurgery vs. macrosurgery (9.2 vs. 8.4, microsurgery vs. macrosurgery, p=0.02) [37]. Francetti et al. reported on more favorable indices for papilla appearance, scarring, and marginal profile in the microsurgical compared to the conventional group (p<0.05) [35]. Therefore, minimally invasive tissue management and optimized tissue healing have resulted in improving not only clinical surrogate outcomes but also patient-perceived outcomes.

The magnification device is the key to perform minimally invasive periodontal plastic surgeries. Loupes have gained popularity and are now considered a standard equipment due

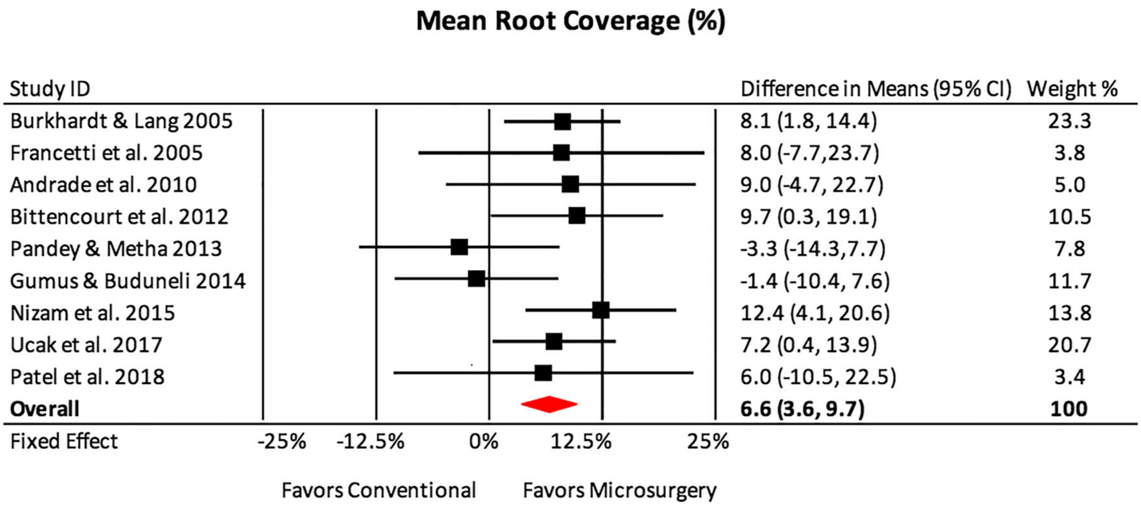
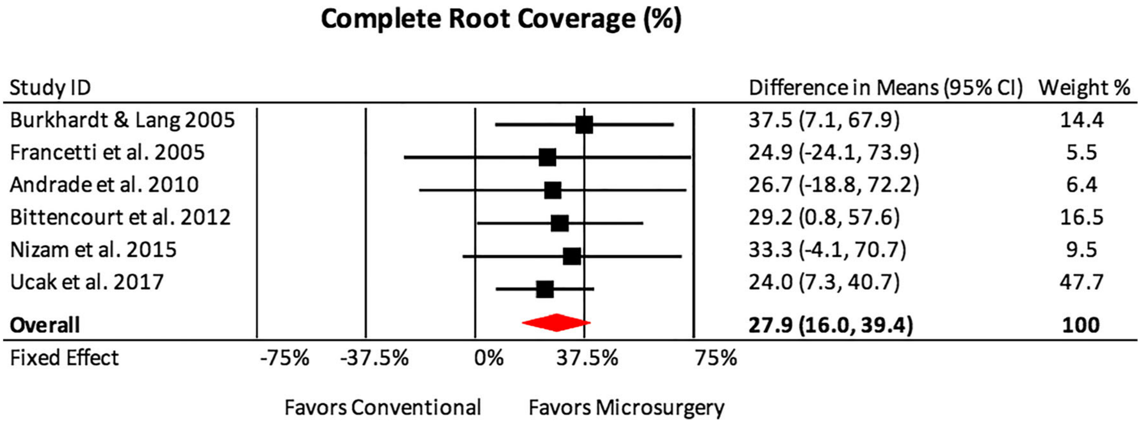


Fig. 5 Mean root coverage for the subgroup of nine comparative trials comparing microsurgery vs. macrosurgery



Study ID	Difference in Means (95% CI)	Weight %
Burkhardt & Lang 2005	37.5 (7.1, 67.9)	14.4
Francetti et al. 2005	24.9 (-24.1, 73.9)	5.5
Andrade et al. 2010	26.7 (-18.8, 72.2)	6.4
Bittencourt et al. 2012	29.2 (0.8, 57.6)	16.5
Nizam et al. 2015	33.3 (-4.1, 70.7)	9.5
Ucak et al. 2017	24.0 (7.3, 40.7)	47.7
Overall	**27.9 (16.0, 39.4)**	**100**

Fig. 6 Complete root coverage for the subgroup of nine comparative trials comparing microsurgery vs. macrosurgery

to its convenience, lower costs and maintenance, flexibility in viewing angle, and field depth. However, OM provides the magnification power and co-axial illumination beyond what can be achieved with loupes [15, 45]. Additional benefits include improved posture and comfort during surgery and high-resolution built-in video output for documentation and education. Despite significant advantages, OM suffers a slow acceptance by periodontists. The reported drawbacks are the higher initial cost to purchase the device, steep learning curve, and significantly increased time spent on the procedures [15, 34, 36, 38]. In addition, microscope was perceived as an elective component in a periodontal practice. Regarding the surgical time, four studies reported on a mean 12-min increased time spent in the microsurgical group [15, 34, 36, 38]. The clinical efficiency can be improved with continuous hands-on training and clinical practice, just like when learning loupes. Also, as the focus of plastic surgery is on precision rather than on speed, a 12-min increase in surgical time would be clinically acceptable if weighted with improved precision. Finally, the minimally invasive approach might reduce the impact of the increased surgical time on wound healing complications.

Advancement in technology and further development of easy-to-use magnification devices is decisive for a broader acceptance of microsurgical techniques in the field. Special attention must be paid to the new generations of high-power magnification loupes which combine magnifying factors of up to ninefold with satisfactory working distance and field of depth. Despite that, OM maintains irreplaceable advantages including and not limited to improved postural ergonomics, axial light, and quality of video documentation. In light of the obvious technical advantages that OM can bring, interested stakeholders should actively explore the usefulness of this device. Nevertheless, the equipment (microscope) itself does not guarantee desired outcomes. Extensive training is unavoidable; it is crucial for the practitioner to face and overcome a steep learning curve to master both plastic surgery techniques and microsurgery. In adjunct to surgery-related factors, other aspects, including systemic and local factors and patient compliance, can determine prognosis [10].

The present meta-analysis advances the field for novelty and the robustness of the reported results; however, data needs to be interpreted with caution. Heterogeneity existed in the study design, magnification type and amount, and treatment modalities. Despite a larger number of clinical trials using a microsurgical protocol, only half of them had a macrosurgical control group that would qualify them for a side-by-side comparison between microsurgery and macrosurgery. No conclusions could be drawn for the contribution of the type of the magnification (OM vs. loupes) on the improved outcomes compared to macrosurgical procedures. Most of the studies recorded short-term follow-ups, raising the doubt on whether the improved coverage would be maintained or equalized by the long-term tissue remodeling. Generalizability of the reported results has to be filtered through previous experience with microsurgery and OM by the primary operator as well as the assistant, available armamentarium, patient demographic, and practice workflow to support microsurgical procedures. Finally, the present study retains the methodological limitations of systematic review with meta-analysis, which include publication bias and research bias, other than synthesis of heterogeneous data.

Clinical implications of this study are the following: (1) Efficacy of minimally invasive procedures with OM or loupes along with microinstruments is optimized in biologically challenging approaches implementing flap with autogenous soft tissue graft; (2) microsurgery improved root coverage outcomes compared to macrosurgery, and may be indicated to maximize mean root coverage and the probability of complete root coverage; (3) microsurgery may accelerate wound healing by introducing less surgical trauma and promoting wound stability, which results in reduced pain and enhanced esthetics; (4) the surgical time is increased by microsurgical procedures, but could be overcome by laboratory training and increased clinical practice.

Future research should focus on (1) a side-by-side comparison between OM and loupes for microsurgical procedures, (2) establishing a standardized methodology to present patient-reported outcomes, (3) investigating cellular and biological impacts of microsurgery, including the revascularization rate during healing process, and (4) investigating microsurgery on challenging clinical scenarios, e.g., root coverage in cases with thin phenotype, and peri-implant recession coverage.

Conclusions

Within the existing limitations, it was concluded that microsurgery with either microscope or loupes and microinstruments has an overall 83% of mean root coverage that was improved by the use of autogenous connective tissue graft. In comparison to macrosurgery, microsurgery yields an additional 6% of mean root coverage and 28% of probability for complete root coverage. Patient-reported outcomes also favored microsurgery with improved esthetics, patient's satisfaction, and reduced pain. Further randomized clinical trials are needed to study differences in the magnification power on clinical outcomes.

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Author contribution All the authors provided significant contribution to the study. RDG: study design, screening, data extraction, data interpretation, writing. IW: study design, data extraction, statistical analysis, writing. LS: screening, data extraction, writing. DV: study design, data interpretation, writing. HLW: study design, data interpretation, writing. HLC: study design, data interpretation, writing. All the authors approved the last version of the study before submission and agreed to be accountable for all aspects of the work.

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Declarations

Conflict of interest The authors declare no competing interests.

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