



Root coverage and papilla reconstruction in Miller Class IV and Cairo RT3 gingival recessions: a systematic review

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Abstract

To evaluate clinical outcomes after periodontal plastic surgical treatment of Miller Class IV and Cairo RT3 recession defects as distinct classification-defined populations and assess whether any treatment approach is predictably superior. Methods: PubMed, Scopus, Web of Science, Embase, Cochrane CENTRAL, and Wiley Online Library databases on 12 June 2025 and updated the search on 19 March 2026. English-language clinical reports first published online or in print from 1986 to 2025 with ≥ 24 weeks (approximately 6 months) of follow-up were eligible. Data were synthesised narratively, with Miller Class IV and Cairo RT3 reports examined separately in a classification-stratified sub-analysis. JBI checklists, RoB 2, and GRADE were applied. Results: Twenty-five reports were included: 16 case reports, 6 case series, 2 retrospective case-series studies, and 1 randomised trial. Thirteen reports included Miller Class IV defects and 12 included Cairo RT3 defects; across both evidence sets, 13 provided direct, eight extractable target-specific, and four indirect mixed-population evidence. Within both classification groups, selected flap/graft, tunnel, papilla-oriented, and regenerative procedures were associated with favourable outcomes, but heterogeneous definitions, uncontrolled designs, and non-standardised outcomes precluded meta-analysis or cross-classification inference. Certainty was very low for all principal outcomes. Conclusions: Miller Class IV and Cairo RT3 evidence should be interpreted separately; neither evidence base establishes a predictably superior treatment protocol. Defect-specific comparative studies using standardised root coverage, papilla, aesthetic, and patient-reported outcomes are required.

Keywords Gingival recession · Root coverage · Interdental papilla · Connective tissue graft · Systematic review

Introduction

Gingival recession defects are apical displacements of the gingival margin associated with clinical attachment level (CAL) loss, occurring on any tooth surface due to various diseases or conditions [1]. They are prevalent in populations with high standards of oral hygiene [2–4]; however, populations with poor oral hygiene also show features of gingival recession [5–8]. The exact aetiology of gingival recession remains insufficiently understood. However, anatomical-morphological predisposing factors (bone dehiscence or fenestrations, the absence of the attached gingiva, and a thin periodontal phenotype), combined with triggering factors (trauma, chronic inflammation, and iatrogenic trauma from prosthetic or orthodontic treatments), can result in gingival recessions [1, 9–10].

Miller classified recession defects based on the root coverage expected to be achieved through grafting techniques. Miller's Class IV recession is defined as the condition of marginal tissue recession reaching or surpassing the mucogingival junction; severe loss of interdental bone or soft tissue; or severe misalignment of the tooth [11]. Cairo suggested a different approach, classifying recession as a treatment-oriented type to forecast the potential for root coverage by assessing interdental CAL loss. Thus, recession type 3 (RT3) defects were defined as an apical shift of the gingival margin associated with interproximal attachment loss exceeding buccal CAL [12]. Although both Miller Class IV and Cairo RT3 describe advanced recession defects with compromised interproximal periodontal support, these classifications use different diagnostic criteria. They should not be regarded as fully interchangeable.

Although complete root coverage (CRC) was considered achievable for Miller Class I and II defects and Cairo recession type 1 (RT1), only partial coverage was anticipated for Miller Class III defects and Cairo RT2. In contrast, coverage of Miller Class IV defects and Cairo RT3 was considered unpredictable [13]. In both classifications, periodontal support at proximal sites is clinically important because the probability of CRC decreases as interdental attachment loss and recession depth increase [14–15]. In Miller Class IV and/or Cairo RT3 defects, papilla reconstruction aims to address pronounced aesthetic and functional deficiencies resulting from loss of facial and interdental hard and soft tissues. Papilla loss produces black triangles that may compromise smile aesthetics and patient confidence [16], and may also contribute to food impaction, plaque retention, and periodontal inflammation [17].

Various surgical procedures, including advanced pedicle flaps and envelope or tunnelling procedures with or without soft-tissue grafts or biomaterials, have been proposed for gingival recession coverage [14–15]. These approaches have shown more predictable outcomes in shallow and moderate defects than in Miller Class IV and/or Cairo RT3 defects [14]. Reconstruction of the three-dimensional papillary architecture is constrained by limited vascular supply, extensive clinical attachment, and bone loss [18]. The available literature remains dominated by case reports and case series, precluding strong treatment recommendations. Previous systematic evidence has primarily addressed Miller Class III and Cairo RT2 recessions rather than advanced Miller Class IV and/or Cairo RT3 defects with pronounced papillary loss [13]. A specific knowledge gap, therefore, remains regarding how root-coverage and

papilla-related outcomes are reported, measured, and interpreted in these advanced defects.

Preliminary evidence suggests that complete root coverage (CRC) may be achievable in selected advanced recession defects when some interdental attachment support remains [19]. The objective of this systematic review was to evaluate reported outcomes of periodontal plastic surgical procedures for Miller Class IV and/or Cairo RT3 defects. The primary outcomes were mean or percentage root coverage (MRC) and CRC. Secondary outcomes comprised papilla reconstruction, clinical attachment level (CAL), probing pocket depth (PPD), keratinised tissue width (KTW), aesthetic and patient-reported outcomes, predictability, and long-term stability. Papilla-related outcomes were interpreted according to the construct used by each report, including papilla height or fill, interdental soft-tissue volume, black-triangle reduction, the Jemt papilla index, and qualitative clinical assessment.

In this review, papilla reconstruction was conceptualised as clinical improvement of the interdental soft-tissue complex rather than histological regeneration. It was interpreted according to the parameters reported in the included studies, including papilla height gain, papilla fill, interdental soft-tissue volume, black triangle reduction, and aesthetic indices when available. Predictability was analysed according to the consistency of success across reports, whereas stability was evaluated only when outcomes were reported at a minimum follow-up of 24 weeks.

Methods

Protocol and registration

This systematic review was structured according to the Population, Intervention, Comparison, Outcome, Time, and Studies (PICOTS) framework (Table 1) and reported in accordance with PRISMA 2020 [20]. The review was registered with PROSPERO under the verified registration ID CRD420261359774. Reports first published online or in print from 1986 to 2025 were considered.

Table 1 PICOTS Framework

Population	Patients with either Miller Class IV or Cairo RT3 recession defects, treated as distinct classification-defined populations.
Intervention	Periodontal plastic surgery with any techniques for root coverage and papilla reconstruction procedures
Comparison	Baseline condition
Outcome	Clinical root coverage, gain in papilla height or interdental tissue volume, aesthetic outcome, CAL gain, probing pocket depth (PPD) reduction, radiographic defect fill
Time	Studies reporting an eligible outcome at ≥ 24 weeks (approximately 6 months)
Studies	Randomised controlled trials, clinical trials, cohort studies, case series, and case reports

Search strategy

PubMed, Web of Science, Scopus, Embase, Cochrane CENTRAL, and Wiley Online Library were searched initially on 12 June 2025 and updated on 19 March 2026. The complete database/platform-specific strategies, exact search dates, and final cumulative yields are reported in Supplementary Table S1.

Search concepts were organised into condition and intervention blocks. The condition block included terms for gingival recession, Miller Class IV, Cairo Recession Type 3/RT3, interproximal attachment loss, and papillary deficiency. The intervention block included root coverage, gingival or connective tissue grafting, coronally advanced or laterally positioned flaps, tunnelling, papilla reconstruction, and relevant regenerative adjuncts. Database-specific syntax, fields, and vocabulary are reported in Supplementary Table S1.

Eligibility criteria

Table 1 presents the PICOTS framework used for eligibility [21]. English-language reports first published online or in print from 1986 to 2025 were eligible when they involved adults with either Miller Class IV or Cairo RT3 defects, evaluated periodontal plastic surgical treatment for root coverage and/or papilla reconstruction, and reported an outcome at ≥ 24 weeks (approximately 6 months). These classifications were treated as distinct and were not considered interchangeable. This operational threshold was used because periodontal studies may schedule follow-up in weeks rather than calendar months. Eligible designs were randomised trials, prospective or retrospective observational studies, non-randomised clinical studies, case series, and case reports. Mixed populations encompassing Miller Classes III and IV or Cairo RT2 and RT3 were retained only when at least one Miller Class IV or Cairo RT3 defect was present. Reports were classified as direct evidence when the entire eligible sample comprised target defects, extractable evidence when target-specific cases or subgroup outcomes could be separated, and indirect evidence when target defects were present but their outcomes were inseparable from a mixed population. Indirect evidence was not interpreted as a pure Miller Class IV or Cairo RT3 population. Animal, in vitro, non-English, review, editorial, consensus, protocol, and ongoing-trial publications were excluded, as were reports without an eligible surgical intervention, relevant defect, outcome, or ≥ 24 -week follow-up.

Study selection, data extraction, and synthesis

Three reviewers (L.T., M.A., S.J.) independently screened titles and abstracts and subsequently assessed potentially eligible full texts. Two calibration sessions were completed before screening. Records were managed using Microsoft Excel 2021 and Zotero (version 6.0.36); no machine-learning or automated eligibility-classification tool was used. Study-level data were extracted into a standardised form capturing design, evidence stratum, sample, intervention and comparator, follow-up, baseline defect characteristics, outcome definitions, numerical results, and limitations of

applicability. Numerical values were retained as reported; no missing values were imputed, and heterogeneous outcomes were not converted post hoc.

Evidence strata were assigned separately within the Miller Class IV and Cairo RT3 evidence sets: direct, when the whole eligible sample comprised defects reported with the relevant target classification; extractable, when target-specific cases or subgroup results could be separated from a mixed report; and indirect, when target defects were present but their results were inseparable from the wider population. The same reviewers independently completed critical appraisal, resolving disagreements through discussion and, when necessary, consultation with a senior reviewer (J.M.S.). Because classifications, interventions, follow-up intervals, units of analysis, and outcome definitions were heterogeneous, studies were grouped by design, evidence stratum, treatment approach, and outcome and synthesised narratively. A classification-stratified narrative sub-analysis examined Miller Class IV and Cairo RT3 reports separately; indirect mixed-population reports were retained but were not attributed to either pure classification group. No meta-analysis was undertaken.

Critical appraisal and risk-of-bias assessment

Methodological quality was assessed independently with design-appropriate tools: the JBI Critical Appraisal Checklist for Case Reports (8 items), the JBI Critical Appraisal Checklist for Case Series (10 items) for prospective and retrospective uncontrolled series, and Cochrane RoB 2 (5 domains) for the randomised trial. JBI items were coded as Yes, No, Unclear, or Not applicable. Item counts were retained only as descriptive summaries and were not used as numerical scores. Because the JBI checklists do not provide a validated common low/moderate/high classification across these designs, no composite score or overall JBI category was calculated. For Mercado et al., RoB 2 was applied to the 36-month mean root-coverage result for the Miller Class IV subgroup; domain and overall judgements were made according to the published RoB 2 algorithm. Disagreements were resolved by consensus.

Certainty was evaluated narratively for each principal outcome using the GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and publication bias. The predominantly observational, uncontrolled evidence started at low certainty and was downgraded when domain concerns were present; no upgrading factor was identified. Classification-related clinical heterogeneity, including the non-equivalence of Miller Class IV and Cairo RT3 and inseparable mixed-population outcomes, was considered under indirectness. The randomised trial enrolled a mixed population with Miller Class III and IV defects and contributed only data from its separable Miller Class IV subgroup. Its small subgroup did not eliminate the serious limitations of the broader body of evidence. Item-level JBI judgements and the result-specific RoB 2 assessment are provided in Supplementary Table S3, and outcome-level GRADE judgements are presented in Table 3.

Results

Search results

The electronic searches identified 4,863 records: PubMed ($n = 1,091$), Scopus ($n = 919$), Web of Science ($n = 1,225$), Embase ($n = 1,454$), Cochrane CENTRAL ($n = 157$), and Wiley Online Library ($n = 17$). After the removal of 2,442 duplicate records, 2,421 records underwent title/abstract screening; 2,159 were excluded as ineligible, and 262 reports were sought for retrieval. Of these, 226 were not retrieved, leaving 36 full-text reports assessed for eligibility. Eleven full-text reports were excluded, and 25 reports were included in the qualitative synthesis. Ercan et al. were excluded because their 12-week outcome did not meet the ≥ 24 -week eligibility threshold [22]. Figure 1 and Supplementary Tables S1-S2 use the same accounting.

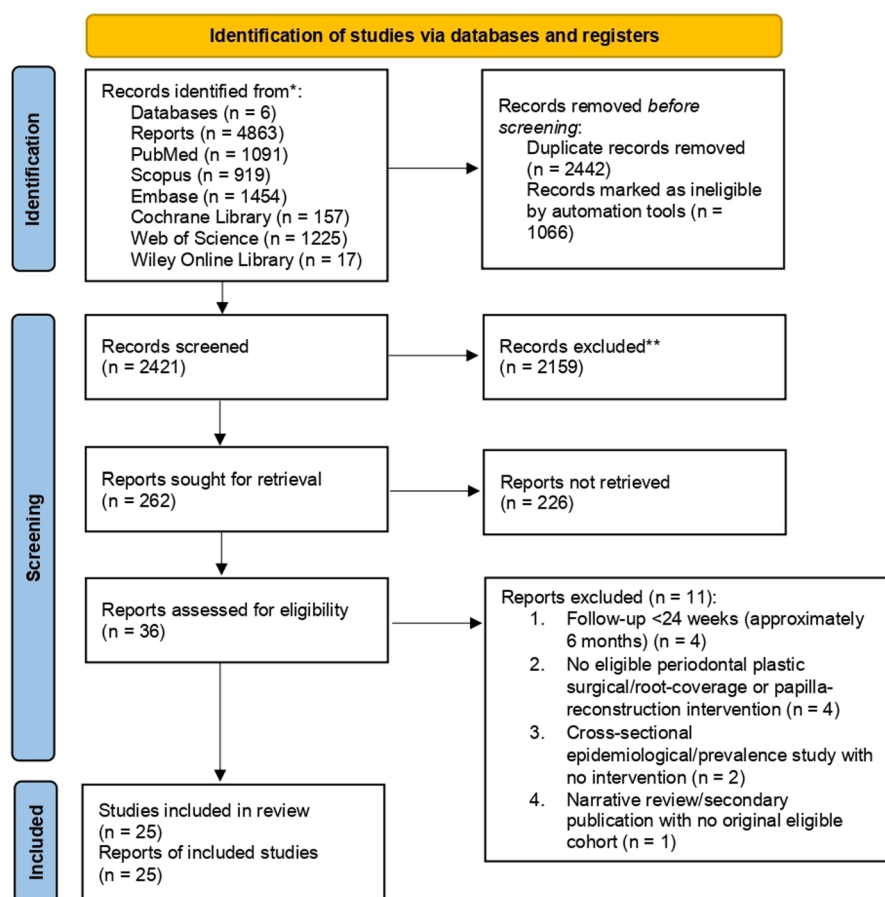


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram [20]

Description of the studies

Twenty-five reports were included: 16 case reports, 6 case series, 2 retrospective case-series studies, and 1 randomised controlled trial. Thirteen reports included Miller Class IV defects [23–35], and 12 included Cairo RT3 defects [36–47]. These classification-defined evidence sets were analysed separately and were not assumed to be interchangeable. Across both sets, 13 reports provided direct evidence [23–25, 27–29, 35, 38–39, 41–43, 46], eight provided extractable target-specific evidence [26, 30, 33, 36–37, 40, 44–45], and four provided indirect mixed-population evidence [31–32, 34, 47]. Connective-tissue grafts combined with coronally advanced, laterally positioned, or tunnel procedures were reported most often. Other approaches included free gingival or gingival-unit grafts, repeated or interposed grafting, papilla-base and inverted T-shaped graft designs, pedicled buccal fat pad procedures, platelet-rich fibrin, enamel matrix derivative (EMD), staged regenerative or phenotype-modification procedures, and creeping attachment after a laterally repositioned flap.

Eligible follow-up ranged from 24 weeks to 8 years. Outcomes included recession depth, MRC, CRC, CAL, PPD, KTW, papilla height or fill, aesthetic indices, patient-reported outcomes, and radiographic defect change. Because defect classifications, baseline severity, treatments, units of analysis, and outcome definitions varied substantially, numerical results are not pooled. Table 4, therefore, presents source-level values and identifies mixed populations, case- or subgroup-level eligibility, inseparable outcomes, and internally inconsistent published values.

Critical appraisal and risk of bias

Item-level appraisal revealed recurrent limitations, particularly incomplete adverse-event reporting in case reports and unclear ascertainment or completeness in several prospective or retrospective case series. The displayed Yes/Unclear/No counts are descriptive summaries rather than scores; no JBI low/moderate/high category was calculated. For the Mercado trial's 36-month mean root-coverage result in the Miller Class IV subgroup, RoB 2 was low for randomisation, deviations from intended interventions, missing outcome data, and outcome measurement. The selection of the reported result raised concerns because the publication did not include a sufficiently detailed prespecified analysis plan for that subgroup result. The overall RoB 2 judgement was therefore “some concerns.” Table 2 presents descriptive item/domain counts, and Supplementary Table S3 presents the complete judgements and rationale.

Certainty of evidence

Certainty was very low for root coverage, papilla reconstruction, CAL/PPD, aesthetic outcomes, and change in radiographic defect. The evidence was downgraded for recurrent methodological limitations, heterogeneous techniques, imprecision, and strongly suspected publication bias in a case-dominated literature. Publication bias was assessed qualitatively because statistical assessment was not feasible owing to insufficiently comparable effect estimates. Reporting bias was assessed qualitatively,

Table 2 Design-specific critical appraisal and RoB 2 assessment status

Authors	Study design	Tool	Yes / low risk*	Unclear / some concerns*	No / high risk*
Miller & Binkley, 1986 [23]	Case report	JBIC case report	7	1	0
Azzi et al., 1999 [24]	Case report	JBIC case report	3	2	3
Carnio, 2004 [25]	Case report	JBIC case report	6	1	1
de Castro Pinto et al., 2010 [26]	Case report	JBIC case report	6	1	1
Zucchelli et al., 2014 [27]	Case report	JBIC case report	3	2	3
Agarwal et al., 2014 [28]	Case report	JBIC case report	5	2	1
Littarru & Orgeas, 2021 [36]	Case report	JBIC case report	5	2	1
Saleh et al., 2023 [37]	Case report	JBIC case report	7	0	1
Chacón et al., 2023 [38]	Case report	JBIC case report	8	0	0
Alrmali et al., 2023 [39]	Case report	JBIC case report	8	0	0
Khabadze et al., 2024 [29]	Case report	JBIC case report	7	1	0
Kuo et al., 2024 [40]	Case report	JBIC case report	7	1	0
Zucchelli et al., 2025 (online 2024) [41]	Case report	JBIC case report	4	2	2
Watanabe et al., 2025 (online 2024) [42]	Case report	JBIC case report	6	1	1
Gutiérrez et al., 2019 [32]	Case report	JBIC case report	5	2	1
Chambrone & Chambrone, 2006 [35]	Case report	JBIC case report	6	1	1
Mourlaas et al., 2023 [43]	Case series	JBIC case series	5	3	2
Fernández-Jiménez et al., 2024 [44]	Case series	JBIC case series	5	3	2
Alrmali et al., 2026 (online 2025) [45]	Case series	JBIC case series	7	2	1
Monika et al., 2020 [31]	Case series	JBIC case series	7	2	1
Dias et al., 2020 [34]	Case series	JBIC case series	6	2	2
Bendary et al., 2023 [46]	Case series	JBIC case series	8	1	1
Vergara & Caffesse, 2004 [30]	Retrospective case series	JBIC case series	10	0	0
Ni et al., 2025 [47]	Retrospective case series	JBIC case series	7	3	0
Mercado et al., 2020 [33]	Randomised trial	RoB 2	4	1	0

considering publication bias, selective outcome reporting, and preferential reporting of favourable outcomes, as formal statistical assessment was not applicable. Serious indirectness reflected the non-equivalence of Miller Class IV and Cairo RT3 criteria, mixed populations with inseparable target-defect outcomes, and non-standardised outcome measurement. Table 3 reports the outcome-specific domain judgements.

Clinical outcomes

Because the included studies were predominantly case reports and case series and differed in recession classification, baseline defect severity, surgical technique, grafting material, follow-up duration, and outcome measurement, all outcomes are presented descriptively. No formal comparative analysis or standardisation of outcomes across studies was performed. The classification-stratified narrative sub-analysis was descriptive and was not a statistical subgroup analysis. Therefore, reported findings should not be interpreted as evidence of the superiority of any specific technique.

Table 3 Certainty of evidence assessment using GRADE domains

Outcome	Evidence base	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty
Root coverage (MRC/ CRC)	Reported across most studies; one small Class IV RCT subgroup; otherwise mainly uncontrolled.	Serious	Serious	Serious	Serious	Strongly suspected	Very low ⊕○○○
Papilla reconstruction	Case reports/series with heterogeneous measures	Serious	Serious	Serious	Serious	Strongly suspected	Very low ⊕○○○
CAL and PPD	Sparse, heterogeneous clinical measurements	Serious	Serious	Serious	Serious	Strongly suspected	Very low ⊕○○○
Aesthetic outcomes	Mostly qualitative photographs or non-standardised indices	Serious	Serious	Serious	Serious	Strongly suspected	Very low ⊕○○○
Radiographic defect change	Few case-based reports; no consistent CBCT/re-entry/histology	Serious	Serious	Serious	Serious	Strongly suspected	Very low ⊕○○○
Serious indirectness reflected the non-equivalence of Miller Class IV and Cairo RT3 criteria, mixed populations with inseparable target-defect outcomes, and non-standardised outcome measurement							Very low ⊕○○○

Classification-stratified narrative sub-analysis

Miller class IV

Thirteen reports included Miller Class IV defects [23–35]. Target-specific evidence from case reports, case series, the Vergara retrospective subgroup, and the Mercado randomised-trial subgroup described variable outcomes, ranging from partial or complete coverage in selected cases to CRC in 2 of 12 sites in Vergara and 0% CRC in both Mercado arms [23–30, 33, 35]. Three reports contained inseparable mixed Miller populations and remained indirect [31–32, 34].

Cairo recession type 3

Twelve reports included Cairo RT3 defects [36–47]. Direct or extractable evidence from selected tunnel, graft, papilla-oriented, staged, and CTG-wall procedures described outcomes ranging from complete coverage in individual reports to residual recession or partial papillary fill in series data [36–46]. Fernández-Jiménez et al. reported MRC of 62.43% and CRC in 0 of 5 RT3 defects, whereas Bendary et al. reported residual recession at all sites [44, 46]. Ni et al. included RT3 sites but reported only aggregate RT1-RT3 outcomes and therefore remained indirect [47].

Root-coverage outcomes

Among reports providing direct or extractable target-specific evidence, selected sites treated with flap/graft, tunnel, papilla-oriented, or staged procedures showed complete or near-complete facial coverage [23–27, 29, 35–43, 45]. In contrast, persistent residual recession was reported after pedicled buccal fat pad treatment and in larger Cairo RT3 case series [28, 44, 46]. In the Vergara retrospective Miller Class IV subgroup, CRC occurred in 2 of 12 sites [30]. In the Mercado trial, the Miller Class IV subgroups showed a 36-month MRC of 61.40% with CTG + EMD and 52.08% with CTG alone, with 0% CRC in both groups [33]. Monika, Gutiérrez, Dias, and Ni reported aggregate outcomes in mixed populations that could not be specifically attributed to Miller Class IV and/or Cairo RT3 defects [31–32, 34, 47]. These observations are descriptive and do not demonstrate predictable comparative superiority.

Papilla reconstruction outcomes

Papilla reconstruction was reported as height gain, fill, Jemt papilla index, black-triangle reduction, or qualitative contour change, with no uniform method of measurement [24–27, 35, 37–39, 41–45]. Selected reports described coronal papillary advancement or partial-to-near-complete fill, while Chambrone and Chambrone documented progressive interdental and marginal soft-tissue improvement over 8 years [35]. These case-based findings do not establish predictable complete papilla reconstruction in defects with pronounced interproximal attachment loss.

Interdental soft-tissue volume and fill

Interdental soft-tissue volume or fill improved in selected CTG-based, free-graft, and papilla-oriented reports [24–27, 29, 35–45]. Outcomes were derived from direct linear measurements, papilla indices, clinical photographs, or descriptive contour assessment and therefore represented different constructs. Interdental graft placement using CTG-wall, papilla-base, inverted T-shaped, or vertical-tunnel approaches was associated with local soft-tissue gain in selected cases. Still, these findings could not be quantitatively combined.

Aesthetic outcomes

Aesthetic outcomes were assessed inconsistently, most often through clinical photographs, qualitative descriptions of gingival contour or colour match, black-triangle reduction, or non-standardised indices. Selected reports described favourable aesthetic integration after flap/graft, tunnel, papilla-base, or staged procedures [23, 26–27, 36, 41–43]. Patient-reported outcomes were sparse and were not measured with a common instrument. Accordingly, neither aesthetic performance nor patient-perceived benefit could be compared across treatment approaches.

Clinical attachment-level changes

CAL gains of approximately 2–7 mm were reported across selected case reports and case series [24, 27, 37, 39–40, 42–43, 46]. Bendary et al. reported mean CAL improvement from 7.0 ± 2.0 to 5.0 ± 2.16 mm at 6 months [46], whereas Ni et al. reported an aggregate change from 3.22 ± 1.16 to 1.64 ± 0.90 mm in a mixed cohort encompassing Cairo RT1–RT3 defects [47]. Differences in baseline severity, classification, follow-up, and co-interventions precluded attribution of these changes to a specific graft, flap, or regenerative adjunct.

Probing pocket-depth changes

PPD reductions were reported following several CTG-, free-graft, tunnel-, or regenerative procedures [24–25, 27, 36, 39–40, 42–43, 46–47]. Bendary et al. reported a mean reduction from 4.8 ± 0.42 to 2.8 ± 0.8 mm at 6 months [46]. Ni et al. also reported aggregate periodontal measurements, but RT3-specific means were not separable [47]. These findings remain descriptive.

Radiographic defect change

Radiographic defect change was assessed inconsistently. Selected reports described radiographic improvement following CTG-wall, EMD, bone-graft, or staged regenerative procedures [27, 29, 42–43, 46]. Bendary et al. reported a mean change in defect depth from 3.97 ± 1.39 to 3.77 ± 1.29 mm at 6 months [46]. In the absence of consistent three-dimensional imaging, surgical re-entry, or histological confirma-

tion, these observations cannot be interpreted as proof of bone gain or periodontal regeneration.

Patient-reported outcome measures (PROMs)

Patient-reported outcomes were reported infrequently and heterogeneously. Mercado et al. assessed postoperative pain and patient satisfaction in a mixed Miller Class III/IV population, reporting lower pain scores with CTG + EMD than with CTG alone at 2, 7 and 14 days; most participants reported that their expectations had been fulfilled, and approximately three-quarters indicated willingness to undergo treatment again [33]. In a combined RT1–RT3 cohort, Ni et al. reported satisfaction with root coverage and gingival contour, perceived relief from hypersensitivity, and perceived improvement in quality of life; these findings were not separable for RT3 defects [47]. Some case-based reports included qualitative statements concerning aesthetic satisfaction, hypersensitivity or postoperative morbidity [27, 29, 32, 38, 45]. No consistent or validated PROM instrument was identified across the available reports, and most provided no evaluable PROM data [23–26, 28, 30–31, 34, 36–37, 39–44, 46].

Discussion

This review identified 13 Miller Class IV and 12 Cairo RT3 reports within the 25 included reports. The evidence consisted predominantly of case reports and uncontrolled case series, with only two retrospective case-series studies and one randomised trial. Clinical heterogeneity, inconsistent outcome measurement, and recurrent item-level methodological limitations substantially constrained interpretation. Accordingly, Miller Class IV and Cairo RT3 evidence was examined separately, and direct or extractable target-specific evidence was distinguished from indirect mixed-population evidence throughout the synthesis (Table 4).

The two classification-defined evidence sets should not be conflated. Miller Class IV and Cairo RT3 use different criteria [11–12]: Cairo RT3 requires interproximal CAL greater than buccal CAL, whereas Miller Class IV does not provide an equivalent paired-CAL rule. Paired buccal and interproximal CAL measurements were generally unavailable in Miller Class IV reports. Although Azzi et al. reported 10 mm of interdental attachment loss with 3–4 mm of facial recession, that single compatible report cannot justify relabelling the remaining Miller Class IV evidence as RT3 [24]. Miller Class IV findings were therefore interpreted within their original classification [23–30, 33, 35], RT3 findings within Cairo-classified reports [36–46], and inseparable mixed-population evidence only as indirect [31–32, 34, 47].

The 22 case reports and uncontrolled case series generated most of the favourable observations. Miller Class IV target-specific reports described free gingival or connective-tissue grafting, pedicle or coronally advanced flaps, staged reconstruction, and papilla-oriented procedures [23–29, 35]. Cairo RT3 target-specific reports described tunnel, free-graft, connective-tissue graft, papilla-oriented, staged, and CTG-wall procedures [36–46]. Three additional Miller Class IV case-based reports provided only inseparable mixed-population outcomes for pedicled buccal fat pad,

Table 4 Characteristics and outcomes of the 25 included reports, stratified by recession classification

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Miller Class IV (13 reports)									
Root cover-age and ridge augmentation in Class IV recession using a coronally positioned free gingival graft [22]	Miller & Binkley, 1986	Case report	Direct: 1 patient; Miller Class IV; maxillary left central incisor	Large free gingival graft followed by coronal positioning and gingivoplasty	Baseline	12 months; stability reported to 4 years	Recession 5 mm midfacial and 7 mm middistal	Root cover-age and ridge/papilla augmentation	Approximately 90% facial and 75% interproximal root cover-age at 1 year; stable through 4 years.
Root cover-age and papilla reconstruction in Class IV recession: a case report [23]	Azzi et al., 1999	Case report	Direct: 1 patient; 3 Miller Class IV anterior teeth	Coronally positioned flap plus tuberosity CTG	Baseline	3, 12 and 18 months	Recession 3/4/3 mm; interdental attachment loss 10 mm	Root coverage, papilla height, CAL and PPD	Complete facial coverage at the central incisor and canine; 1-mm residual recession at the lateral incisor; papilla height gain 4 mm; CAL gain 4–5 mm.
Surgical reconstruction of interdental papilla using an interposed subepithelial connective tissue graft: a case report [24]	Carnio, 2004	Case report	Direct: 1 patient; two Miller Class IV defects	Three interposed palatal CTG procedures at 8-week intervals	Baseline	4 years	Two 2-mm recessions	Root coverage, papilla fill, PPD and KTW	Both recessions were 0 mm, and the papilla remained filled at 4 years; PPD ≤ 2.5 mm; KTW increased from 6 to 9 mm.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
The subepithelial connective tissue pedicle graft combined with the coronally advanced flap for restoring missing papilla: a report of two cases [25]	de Castro Pinto et al., 2010	Case report	Extractable: Case 1 only: natural-tooth Miller Class IV defect	Subepithelial CTG pedicle graft plus CAF	Baseline	4 and 12 months	Recession 3 and 4 mm at lateral incisor/canine	Root coverage, papilla-to-contact distance and stability	Root coverage was 87.5% and 100% at 4 months; the papilla-to-contact distance improved from 7 to 3.5 mm; and it remained stable at 12 months.
The connective tissue graft wall technique and enamel matrix derivative to improve root coverage and clinical attachment levels in Miller Class IV gingival recession [26]	Zucchelli et al., 2014	Case report	Direct: 2 patients; Miller Class IV defects with intrabony involvement	CTG wall technique plus CAF and EMD	Baseline	6 and 12 months	Severe recession and interproximal attachment loss	Root coverage, papilla gain, CAL and radiographic change	At 6 months, canine CRC was achieved in both cases; lateral-incisor coverage was 3.5/5 and 4/5 mm; papilla gain was 1.5 mm; findings remained stable at 1 year.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
An innovative technique for root coverage using pedicled buccal fat pad [27]	Agarwal et al., 2014	Case report	Direct: 1 patient; posterior Miller Class IV defect	Pedicled buccal fat pad	Baseline	24 weeks	Baseline recession depth not reported consistently	CAL, PPD, KTW and root coverage	Partial root coverage and 4-mm CAL gain at 24 weeks; no complication was reported.
A Modern View on The Treatment of Class IV Recession According to Miller [32]	Khabadze et al., 2024	Case report	Direct: 1 patient; 4 Miller Class IV teeth	Staged hard- and soft-tissue reconstruction	Baseline	12 months after stage 2	Midbuccal recession 1/6/7/3 mm	Root coverage, papilla height and stability	Midbuccal recession improved to 0/1/2/0 mm; papilla height increased by approximately 4–5 mm.
Localized gingival recessions treated with the original envelope technique: a report of 50 consecutive patients [39]	Vergara & Caffesse, 2004	Retrospective case-series study	Extractable: 50 patients; 115 sites, including 12 Miller Class IV sites	Envelope technique with CTG	Baseline	6 months	Class IV baseline recession 5.09 ± 2.07 mm	Recession reduction and CRC	Published Class IV values report residual recession 1.86 ± 0.14 mm and CRC in 2/12 sites; the reported dispersion/range is internally inconsistent and should be interpreted cautiously.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Evaluation of root coverage with pedicled buccal fat pad in class III and class IV gingival recession defects [40]	Monika et al., 2020	Case series	Indirect: Mixed Miller Class III and IV defects; Miller Class IV subgroup is inseparable	Pedicled buccal fat pad	Baseline	6 months	Overall recession 5.60 mm	Root coverage, CAL and PPD	Overall recession decreased to 2.87 mm, root coverage was 46.78%, and CAL improved from 6.40 to 4.53 mm; Class IV outcomes were not separable.
Root Coverage with Platelet-Rich Fibrin in Miller's Class I, III, and IV Gingival Retractions [42]	Gutiérrez et al., 2019	Case report	Indirect: 1 report including Miller Class I, III and IV defects	Platelet-rich fibrin-based root-coverage procedure	Baseline	3, 6 and 12 months	Mixed defect classes	Root coverage and clinical periodontal parameters	Clinical improvement was reported, but the available report could not fully separate tooth-level Miller Class IV numerical outcomes.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/ population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Subepithelial connective tissue graft with or without enamel matrix derivative for the treatment of multiple Class III-IV recessions in lower anterior teeth: A 3-year randomized clinical trial [43]	Mercado et al., 2020	Randomised trial	Extraction: 41 patients; 156 teeth; Miller Class IV subgroup: 17 test and 12 control teeth	CTG + EMD (79 teeth overall; 17 Class IV)	Baseline; CTG alone (77 teeth overall; 12 Class IV)	36 months	Class IV recession: test 6.59±0.51 mm; control 6.67±0.61 mm	Class IV recession, MRC, CRC, CAL, PPD and KTW	For Class IV teeth at 36 months, residual recession was 2.53±0.39 mm with CTG+EMD versus 3.17±0.52 mm with CTG alone ($P=0.008$); MRC was 61.40%±9.43% versus 52.08%±11.96% ($P=0.01$); CRC was 0% in both groups. CAL was 3.91±0.54 versus 4.54±0.79 mm, and KTW was 4.18±0.22 versus 2.83±0.15 mm.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/ population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Management of inadequate keratinized gingiva and Miller's class III or IV gingival recession using two-stage free gingival graft procedure [44]	Dias et al., 2020	Case series	Indirect: 10 patients; mixed Miller Class III and IV defects	Free gingival graft followed by CAF	Baseline	12 months	Mixed Class III/IV population	Root coverage and keratinised tissue outcomes	Overall root coverage was 76.4%; Class IV-specific outcomes were not separable.
Root coverage in a class IV recession defect achieved by creeping attachment: a case report [45]	Chambrone & Chambrone, 2006	Case report	Direct: 1 patient; maxillary right central incisor; Miller Class IV	Laterally positioned flap	Baseline	4 months and 8 years	Recession 7 mm	Root coverage, gingival margin stability and papilla appearance	Root coverage was 4 mm (57.1%) at 4 months; complete coverage was achieved by 8 years via creeping attachment, with a stable shallow sulcus.

Cairo Recession Type 3 (12 reports)

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/ population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Interdental Papillae Loss and Multiple RT2 and RT3	Littarru & Orgeas, 2021	Case report	Extractable: 1 patient; 6 anterior recessions, including 5 Cairo RT3 defects	Combined tunnel/CTG and papilla-oriented approach	Baseline	24 months	Multiple RT2/RT3 defects	Midfacial coverage and interdental soft-tissue outcome	All five RT3 sites showed 0-mm midfacial recession at 2 years; the report remains case-based and includes mixed defect types.
Gingival Recession Defects: A Case Report of a Combined Surgical Treatment Approach [28]	Saleh et al., 2023	Case report	Extractable: Case 1 only: natural tooth adjacent to an implant; advanced papillary defect	Vertical interproximal tunnel with CTG	Baseline	18 months	Severe papilla deficiency and attachment loss	CAL, root coverage and papilla fill	CAL gain of 6 mm, substantial root coverage and near-complete papilla fill, with some residual deficiency at 18 months.
Papilla reconstruction for an iatrogenic RT3 gingival defect using a tuberosity soft tissue graft: A case report [30]	Chacón et al., 2023	Case report	Direct: 1 patient; iatrogenic RT3 defect	Tuberosity soft-tissue graft	Baseline	9 and 18 months	Advanced localized RT3 defect	Clinical root coverage and aesthetic resolution	Complete aesthetic resolution was reported qualitatively and remained stable at 18 months; quantitative root-coverage data were not reported.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Inverted T-shape free gingival graft for treatment of RT3 gingival recession defects: Reporting of two cases [31]	Alrmali et al., 2023	Case report (2 cases)	Direct: 2 patients; 4 Cairo RT3 defects at teeth 24–25	Inverted T-shape free gingival graft	Baseline	3-month measurements; clinical photographs at 6 and 12 months	Case 1: VR 3/5 mm, CAL 5/6 mm, KTW 2/1 mm; Case 2: VR 3/4 mm, CAL 4/5 mm, KTW 0/1 mm	PD, CAL, vertical recession, KTW and papillary contour	At 3 months, VR was 2 mm at all four sites (reductions of 1–3 mm), CAL improved by 2–4 mm, and KTW was 4 mm at every site; clinical photographs documented maintenance at 6 and 12 months. The published KTW 'gain' column is arithmetically inconsistent, so baseline and follow-up values are reported instead.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/ population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Partial-Full-Thickness Tunnel Technique and Supra-Crestal Sling Suture for Treatment of RT2 and RT3 Gingival Recessions: Technical Report with Two Cases [33]	Kuo et al., 2024	Technical case report (2 cases)	Extractable: 2 patients; 8 defects, including Cairo RT3 sites	Partial-full-thickness tunnel plus supracrestal sling suture and CTG	Baseline	12 months	Mixed RT2/RT3; tooth 33 was RT3	Recession, MRC, CRC, CAL, PPD, KTW and phenotype	At 12 months, overall MRC was 93.75% (mesio-buccal), 95.83% (buccal), and 100% (disto-buccal), with corresponding CRCs of 87.5%, 87.5%, and 100%. At RT3 tooth 33, recession improved from 2/3/1 mm to 0/0/0 mm, and CAL improved by 3/2/2 mm.
The Papilla Base CTG: A Novel Approach for Interdental Soft Tissue Reconstruction [34]	Zuchelli et al., 2025	Case report	Direct: 1 patient; teeth 22–23 with Cairo RT3 defects	Papilla Base CTG	Baseline	6 and 12 months	RT3 defects with papillary loss	Root coverage, papilla height and CAL	Both recessions were 0 mm at 6 months, papilla height increased by 2 mm, and the result was stable at 12 months.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/ population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Staged Regenerative-Phenotype Modification Therapy for Multiple RT3 Gingival Recessions in Periodontally Compromised Anterior Mandibular Teeth: A Case Report [35]	Watanabe et al., 2025	Case report	Direct: 1 patient; teeth 42–43 with multiple Cairo RT3 defects	Regeneration followed by phenotype modification/tunnel CTG	Baseline	12 months after stage 2	Multiple anterior mandibular RT3 defects	Recession, CAL, papilla and tissue phenotype	Tooth 42 recession was 0 mm at all sites, and tooth 43 was 0/1/0 mm; mean CAL gain 5.3 mm and root-coverage height 4.5 mm.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
The Tunnel Wall Approach and Enamel Matrix Derivative to Cover Exposed Roots and Improve Clinical Attachment Levels in Cairo Class III Defects Associated with an Intrabony Lesion in the Anterior Area: Three Cases [36]	Mourlaas et al., 2023	Case series	Direct: 3 patients; 4 Cairo RT3-associated sites	Tunnel Wall Approach plus CTG and EMD	Baseline	6 and 12 months	Advanced recessions with intrabony lesions	Recession, CAL, papilla and radiographic change	All four sites showed 0-mm recession at 6 months; CAL gain ranged from 4 to 6 mm. Papilla improvement occurred in 3 of 4 sites; 1-year CAL data were available for selected sites.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Treatment of deep single RT2 and RT3 antero-mandibular gingival recessions with a combination of surgical techniques: A case series study [37]	Fernández-Jiménez et al., 2024	Case series	Extracetable: 15 defects: 10 Cairo RT2 and 5 Cairo RT3	Laterally positioned flap/lateral tunnel plus CTG	Baseline	12 months	RT3 baseline recession 5.8 mm	RT3-specific RD, MRC, CRC and KTW	For five RT3 defects, recession decreased to 2.3 mm (mean reduction 3.5 mm), MRC was 62.43%, CRC was 0/5, and KTW increased from 0.6 to 2.9 mm.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/ population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
Inverted T-Shape Connective Tissue Graft for Interdental Papilla Reconstruction: A Clinical Case Series [38]	Alrmali et al., 2026	Case series	Extractable: 5 cases, including 2 Cairo RT3 cases	Inverted T-shape CTG	Baseline	6–12 months	RT3 cases with 5- and 6-mm papillary defects	Papilla fill and Jemt papilla index	The two RT3 cases showed partial filling (about 2–3 mm and 4–5 mm); the Jemt papilla index improved from 0 to 2.

Table 4 (continued)

Title	Author/year	Design	Evidence stratum and eligible defect/population	Intervention	Comparator	Follow-up	Baseline	Outcomes	Key results/eligibility note
The Connective Tissue Graft Wall Technique for treating Patients with Cairo's RT3 Gingival Recession and Intrabony defects: A Case Series [46]	Bendary et al., 2023	Case series	Direct: 10 patients; 10 RT3 defects with intrabony lesions	CAF/simplified papilla preservation plus de-epithelialised CTG wall	Baseline	6 months	Recession 3.4 ± 0.84 mm; PPD 4.8 ± 0.42 mm; CAL 7.0 ± 2.0 mm	Recession, PPD, CAL, defect depth and CRC	Recession decreased to 2.0 ± 0.62 mm, PPD to 2.8 ± 0.8 mm, and CAL to 5.0 ± 2.16 mm; defect depth changed from 3.97 ± 1.39 to 3.77 ± 1.29 mm. All sites re-tained residual recession.
Clinical efficacy of tunnel flap combined with de-epithelialized connective tissue graft in treating gingival recession: a case-series study [47]	Ni et al., 2025	Retro-spective case-series study	Indirect: 34 patients; 201 sites, including 37 Cairo RT3 sites	Tunnel technique with soft-tissue grafting	Baseline	6–21 months; mean 11.97 ± 4.11	Mixed recession types; RT3 subgroup outcomes are inseparable	Recession, CAL, KTW, MRC and CRC	Overall recession improved from 2.13 to 0.48 mm, CAL from 3.22 to 1.64 mm, and KTW from 2.58 to 3.72 mm; overall MRC was 77.26% and CRC 59.2% . RT3-specific means were not separable.

Miller Class IV and Cairo RT3 were treated as distinct classification-defined evidence sets and were not assumed to be interchangeable

platelet-rich fibrin, or two-stage free-graft procedures [31–32, 34]. These reports describe technical feasibility and generate hypotheses, but their uncontrolled designs, selective case presentation, and small sample sizes preclude comparative inference.

The non-case-report evidence was more cautious. Vergara and Caffesse observed CRC in only 2 of 12 Miller Class IV sites, whereas Ni et al. reported favourable aggregate outcomes but did not provide separable Cairo RT3 estimates [30, 47]. Mercado et al. included a small Miller Class IV subgroup within a randomised trial that also included Miller Class III and IV defects; CTG + EMD was associated with lower residual recession and higher MRC at 36 months, but CRC remained 0% in both arms [33]. These data do not establish predictable superiority and should not be extrapolated beyond the reported populations.

Recent reports have emphasised vertical interproximal access, microsurgical tunnels, papilla-base or inverted T-shaped grafts, staged phenotype modification, and CTG-wall treatment of combined recession/intrabony defects [29, 37–47]. These approaches aim to preserve vascularity, stabilise grafted tissue, and increase interdental soft-tissue volume, but the evidence does not allow isolation of the active component. Chambrone and Chambrone documented progression from 4-mm coverage at 4 months to complete coverage at 8 years after a laterally repositioned flap, suggesting possible creeping attachment rather than a predictable cause-and-effect relationship [35].

Taken together, outcomes appear to depend on baseline interdental attachment and bone support, recession depth, defect morphology, soft-tissue phenotype, tooth position, wound stability, operator experience, and follow-up duration. The apparent success of multicomponent procedures cannot be assigned to a particular flap, graft design, or adjunct. Therefore, interpret the evidence as preliminary and do not translate it into firm comparative recommendations.

Synthesis by treatment approach

Treatment approaches were grouped by principal soft-tissue access, graft design, and adjunctive component. Because most reports were non-comparative and many procedures combined several elements, these groups describe the evidence base rather than rank treatment effectiveness.

Pedicle or coronally advanced flaps combined with CTG were associated with root-coverage, CAL, KTW, and papilla-related gains in selected reports [24, 26–27, 41–46]. The proposed rationale was increased tissue thickness, flap support, and wound stability. However, outcomes varied with interproximal attachment loss and intrabony morphology, and the evidence does not establish superiority over alternative access or graft designs.

Tunnel and minimally invasive procedures were intended to preserve papillary vascularity and facilitate coronal displacement of the gingival complex [36–37, 40, 44, 47]. Selected reports described favourable stability, but direct comparative evidence was absent. The broader tunnel literature provides biological and technical context [48]. Yet, observations from mixed cohorts containing Cairo RT2 and RT3 defects, or from selected cases, cannot be generalised as predictable outcomes for advanced target defects.

Alternative graft and adjunctive strategies included free gingival or gingival-unit grafts, repeated or interposed grafting, laterally repositioned flaps, pedicled buccal fat pad, platelet-rich fibrin, and EMD [23, 25, 28–29, 31–32, 34–35, 38–39]. Selected reports combined EMD with CTG/flap or CTG-wall procedures, including the Mercado trial [27, 33, 43]. Bendary et al. evaluated a de-epithelialised CTG wall in RT3 defects with intrabony lesions [46]. These biologically distinct strategies should not be treated as interchangeable, and their independent effects remain uncertain.

Staged, repeated, or multicomponent procedures were used for selected complex defects [23, 25, 29, 42–45]. Long-term observations were uncommon: selected reports described 4-year stability after grafting and an 8-year creeping-attachment outcome [23, 25, 35]. These observations suggest that soft-tissue maturation may continue beyond early healing, but they do not define prognostic thresholds or expected long-term success rates.

No treatment category demonstrated comparative superiority. Until adequately powered and defect-specific comparative studies are available, treatment planning should remain individualised according to defect morphology, residual interproximal support, soft-tissue phenotype, vestibular depth, tooth position, patient expectations, and operator expertise.

Biological and anatomical considerations

Miller Class IV and/or Cairo RT3 defects present biological and anatomical constraints arising from interproximal attachment loss, papillary deficiency, and reduced recipient-site vascularity. Residual interdental bone and attachment support, soft-tissue phenotype, vestibular depth, and wound stability are plausible prognostic factors [24, 29, 42]. Greater tissue thickness and KTW may favour gingival-margin stability, but defect-specific thresholds remain undefined [42, 49]. Complete coverage remains uncertain when interproximal support is severely compromised [14, 50].

The limited predictability of root coverage in Miller Class IV and/or Cairo RT3 recessions may be explained biologically by the reduced vascular and structural support associated with interproximal attachment and bone loss. The exposed root surface is avascular, early flap or graft survival depends initially on diffusion and subsequently on revascularisation from the adjacent suprapariosteal, lateral, and papillary tissues [48]. Interproximal tissue loss therefore reduces both papillary support and the available vascularised recipient bed, potentially compromising tissue survival, stabilisation, and coronal integration over the root surface [51]. Although the periodontal ligament may contribute cells and vascular support to healing, its role in this setting remains uncertain [52]. Technical factors common to root-coverage procedures include excessive flap tension, clot disruption, and micromotion; may further impair vascular integration and decrease predictability [53–55], particularly as these factors were incompletely addressed in the included studies.

Interproximal bone support and radiographic defect change

Residual interproximal bone support and contact-point-to-bone distance influence papilla presence and the anatomical space available for reconstruction [24–26]. CTG-

wall and staged procedures were used to stabilise the wound and manage combined recession/intrabony defects [27, 42–43, 46]. Nevertheless, radiographic changes cannot be equated with periodontal regeneration without standardised three-dimensional imaging, surgical re-entry, or histological evidence.

Patient reported outcome measures (PROMs)

PROM evidence was limited, heterogeneous and mostly derived from mixed-classification populations or qualitative case-based observations [27, 29, 32–33, 38, 45, 47]. Consequently, no classification-specific conclusions can be drawn regarding post-operative morbidity, satisfaction, hypersensitivity or quality of life. Future studies should incorporate prospectively defined, validated PROM instruments and report results separately for Miller Class IV and Cairo RT3 defects.

Clinical implications

Advanced Miller Class IV and/or Cairo RT3 defects with papillary loss require careful case selection, realistic patient counselling, and meticulous control of flap tension, graft stability, and vascular supply. Evidence from broader recession populations suggests favourable outcomes with laterally closed tunnel procedures [56] and indicates that graft preparation may influence patient morbidity and root-coverage outcomes [57]; however, these findings cannot be directly extrapolated to advanced Miller Class IV or Cairo RT3 defects. Tunnel-wall, pedicled-graft, and biologic-adjunct concepts are biologically plausible but remain supported predominantly by case-based evidence within the present review [43, 46]. Predictable complete aesthetic reconstruction cannot be assumed [24, 27, 35, 37].

The available literature describes regenerative biomaterials as adjunctive components, but evidence remains insufficient to demonstrate predictable periodontal regeneration beyond the surgical procedure itself [58–59]. EMD should therefore be interpreted as an adjunct rather than a standalone or predictably superior therapy [60].

Limitations

The principal limitation is the dominance of case reports and small uncontrolled case series. Study populations, recession classifications, baseline severity, interventions, units of analysis, outcome definitions, and follow-up were heterogeneous. The lack of quantitative synthesis precluded pooled effect estimates, moderator and sensitivity analyses, and assessment of small-study effects. Four reports provided only inseparable mixed-population outcomes, creating indirectness, and long-term follow-up was uncommon. The predominance of favourable reports raises concern for publication bias, selective outcome reporting, and preferential reporting of technically successful or aesthetically favourable cases, potentially inflating apparent effectiveness. Restriction to English-language reports may also have excluded relevant evidence.

Papilla reconstruction and aesthetic outcomes lacked standardised, validated measures, and changes in radiographic defect were assessed inconsistently. Patient-level modifiers, including smoking, systemic health, plaque control, periodontal phenotype, tooth position, and defect morphology, were incompletely reported. Future studies should use prospectively defined eligibility, defect-specific outcome reporting, calibrated measurement methods, adequate comparative designs, and long-term follow-up.

Conclusions

The management of Miller Class IV and Cairo RT3 recession defects with papillary loss remains clinically challenging, but the two evidence bases should not be interpreted as interchangeable. For Miller Class IV, selected flap, graft, staged, and papilla-oriented reports described partial or complete coverage in selected cases [23–29, 35]; however, CRC was limited in the Vergara and Mercado subgroups [30, 33], and three mixed Miller populations provided only indirect evidence [31–32, 34]. For Cairo RT3, selected tunnel, graft, papilla-oriented, staged, and CTG-wall reports described favourable outcomes in selected defects [36–46], while residual recession, incomplete papillary fill, and indirect aggregate reporting were also evident [44–47]. Certainty was very low for every principal outcome, and neither classification-specific evidence set defines a predictable treatment protocol.

Based on the available data, no technique, graft design, or adjunct can be considered superior. Treatment planning should remain individualised according to defect morphology, residual interdental bone and attachment support, soft-tissue phenotype, tooth position, patient expectations, and operator expertise. Future research should use prospectively defined, defect-specific eligibility; calibrated and standardised root coverage, papilla, aesthetic, and patient-reported outcomes; adequate comparative designs; and long-term follow-up.

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Declarations

Conflict of interest The authors declare no competing interests.

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