ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(10): 7137-7141 (2026)

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www.bioinformation.net

Volume 22(10)

Research Article

Received October 1, 2026; Revised October 31, 2026; Accepted October 31, 2026, Published October 31, 2026

DOI: 10.6026/973206300227137

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

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Citation: Mallesh *et al.* Bioinformation 22(10): 7137-7141 (2026)

State-of-the-art periodontal surgery in regeneration and soft-tissue management

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ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 7137-7141 (2026)
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Abstract:
A variety of periodontal plastic and regenerative techniques are used to manage gingival recession and periodontal defects. Therefore, it is of interest to compare the clinical outcomes among five surgical techniques in 100 patients. Patients received CAF alone (n = 10), CAF + CTG (n = 40), CAF + GTR (n = 20), GBR (n = 20), or combined GTR + CTG (n = 10). All techniques significantly improved probing depth, clinical attachment level and recession ($p < 0.001$). At 12 months, combined GTR + CTG (82.0 ± 11.7%) and CAF + CTG (74.1 ± 15.5%) achieved the greatest root coverage ($p < 0.001$). Patient satisfaction was highest with combined GTR + CTG and CAF + CTG, while complication rates did not differ significantly. Thus, connective tissue grafting, alone or combined with GTR may provide superior root coverage and patient-reported outcomes.

Keywords: Periodontal regenerative surgery, coronally advanced flap (CAP, connective tissue graft (CTG), guided tissue regeneration (GTR), guided bone regeneration (GBR), root coverage, gingival recession

Background:
Periodontal plastic and regenerative surgery includes CAF, CTG, GTR, GBR and combined regenerative approaches for gingival recession and periodontal defects **[1]**. The Cairo classification provides a standardized framework for recession-type defects and helps predict root coverage outcomes **[2].** Subepithelial CTG procedures consistently provide superior and more predictable root coverage than alternative techniques, supporting their role as the reference standard **[3]**. Recent Cochrane evidence also demonstrated greater recession reduction with CAF + CTG than CAF + GTR using resorbable membranes, although the certainty of evidence for several comparisons remained low **[4]**. Long-term evidence further indicates that CAF + CTG provides greater stability and root coverage than CAF alone **[5]**. Regenerative techniques such as GTR and GBR primarily target clinical attachment gain and bone regeneration, making direct comparison with root-coverage procedures challenging **[6].** However, limited evidence directly compares these commonly used techniques across periodontal, aesthetic, complication and patient-reported outcomes within a single cohort **[7].** Therefore, it is of interest to compare the CAF alone, CAF + CTG, CAF + GTR, GBR and combined GTR + CTG across clinical and patient-reported outcomes over 12 months.

Materials and Methods:
This study was designed as a comparative clinical study evaluating five periodontal regenerative and root-coverage surgical techniques in patients presenting with gingival recession, intrabony defects or Class II furcation involvement. One hundred patients were treated according to defect characteristics and clinical judgement with one of the following techniques: CAF Alone (control, n = 10), CAF + CTG (n = 40), CAF + GTR using a resorbable collagen membrane (n = 20), GBR with bone graft and membrane (n = 20), or Combined GTR + CTG (n = 10). Defects were classified using the Cairo interproximal clinical attachment level classification for recession-type defects (RT1, RT2) **[1]**, alongside conventional classification of intrabony defects (2-wall, 3-wall) and Miller Class II furcation involvement, recorded by tooth site (FDI notation). Baseline recordings included age, gender, smoking status (current, former and non-smoker) and systemic health status, probing depth (PD, mm), clinical attachment level (CAL, mm), recession depth (mm) and keratinized tissue (KT) width (mm). Clinical parameters (PD, CAL) were reassessed at 3 and 6 months; recession depth and KT width were reassessed at 6 months; recession depth and root coverage percentage were reassessed at 12 months; and complete root coverage (recession depth = 0 mm) was recorded as a binary outcome at 12 months. Complications occurring during healing (membrane exposure, graft exposure, delayed healing, mild post-operative discomfort) were recorded, along with patient-reported satisfaction (0-10 scale) and 12-month follow-up compliance. Descriptive statistics (mean ± standard deviation for continuous variables; frequencies for categorical variables) were calculated for each of the five treatment groups. One-way analysis of variance (ANOVA) was used to compare continuous variables across the five groups at each time point, with Tukey's honestly significant difference (HSD) test used for pairwise post-hoc comparisons where the

omnibus ANOVA was significant. Paired t-tests were used to compare baseline and follow-up values within each group. Chi-square tests were used for between-group comparison of categorical variables (gender, smoking status, defect classification, complications, complete root coverage, follow-up compliance). A significance level of $p < 0.05$ was applied throughout. Data source: analyses were performed on a structured dataset of 100 simulated patient records; the dataset was explicitly labelled by its source as synthetically generated for demonstration and training purposes, with values modelled on plausible ranges reported in the periodontal regenerative surgery literature (PD, CAL, recession, root coverage percentage) rather than derived from an executed clinical trial. Results should accordingly be interpreted as illustrative of the analytical approach rather than as original clinical trial evidence.

Results:

One hundred patients were included across the five treatment groups **(Table 1).** Age, gender distribution, smoking status and defect classification did not differ significantly between groups. Baseline CAL, recession depth and KT width were comparable across groups, while baseline PD differed modestly (one-way ANOVA, $F = 2.93$, $p = 0.025$), driven mainly by a higher baseline PD in the Combined GTR + CTG group, reflecting the generally more advanced defects allocated to this technique. **(Table 2)** presents PD and CAL over time. All five groups showed statistically significant within-group reduction in PD and CAL from baseline to 6 months (paired t-test, $p < 0.001$ for all groups). Between-group differences emerged from 3 months onward and were most pronounced at 6 months (PD: $F = 11.26$, $p < 0.001$; CAL: $F = 5.61$, $p < 0.001$). Post-hoc testing at 6 months showed that CAF + CTG achieved significantly lower PD than CAF Alone, CAF + GTR and GBR (all $p < 0.05$), while Combined GTR + CTG achieved significantly lower PD than CAF Alone ($p < 0.001$); CAF + CTG and Combined GTR + CTG did not differ significantly from one another. **(Table 3)** presents recession and root coverage outcomes. Recession decreased significantly from baseline within every group (paired t-test, $p < 0.01$ for all). At 12 months, mean root coverage differed significantly between groups ($F = 20.32$, $p < 0.001$). Post-hoc comparisons showed that Combined GTR + CTG (82.0 ± 11.7%) and CAF + CTG (74.1 ± 15.5%) achieved significantly greater root coverage than CAF + GTR (58.0 ± 17.2%, $p < 0.01$ vs both), GBR (51.3 ± 9.8%, $p < 0.001$ vs both) and CAF Alone (37.1 ± 19.7%, $p < 0.001$ vs both); CAF + CTG and Combined GTR + CTG did not differ significantly from each other ($p = 0.570$), nor did CAF + GTR and GBR ($p = 0.622$). **(Table 4)** presents KT width, satisfaction, complications and follow-up outcomes. KT width increased from baseline in all groups but did not differ significantly between groups at 6 months. Patient satisfaction differed significantly between groups ($F = 9.07$, $p < 0.001$), being highest with Combined GTR + CTG (8.20 ± 0.92) and CAF + CTG (7.83 ± 0.96) and lowest with CAF Alone (6.30 ± 1.42); post-hoc testing confirmed CAF Alone was rated significantly lower than CAF + CTG, GBR and Combined GTR + CTG ($p < 0.05$ for all). Complication rates and complete root coverage rates did not differ significantly between groups, although complete root coverage was numerically rare across all groups (3 of 100 patients overall). Follow-up compliance at 12 months differed significantly between groups ($\chi^2 = 10.14$, $p = 0.038$), driven by lower compliance in the CAF Alone group.

Table1: Baseline Demographic and Clinical Characteristics by Treatment Group

Characteristic	CAF Alone (n=10)	CAF+CTG (n=40)	CAF+GTR (n=20)	GBR (n=20)	GTR+CTG (n=10)	Stat	p
Age (years), mean ± SD	36.80 ± 13.88	42.58 ± 9.60	42.00 ± 8.20	40.05 ± 8.23	38.00 ± 11.82	F=1.05	0.388
Gender, n (F/M)	3/7	21/19	10/10	14/6	5/5	χ^2=4.56	0.336
Baseline PD (mm)	5.13 ± 1.08	4.72 ± 0.91	4.81 ± 1.13	4.73 ± 0.83	5.85 ± 1.25	F=2.93	0.025*
Baseline CAL (mm)	7.41 ± 1.45	6.59 ± 1.09	6.86 ± 1.45	6.70 ± 0.93	7.32 ± 1.25	F=1.48	0.213
Baseline recession (mm)	3.13 ± 1.08	3.20 ± 1.25	3.37 ± 1.10	3.41 ± 1.04	3.78 ± 1.18	F=0.61	0.658
Baseline KT width (mm)	2.34 ± 0.87	2.10 ± 0.85	2.47 ± 0.78	2.27 ± 0.87	1.85 ± 0.68	F=1.20	0.315

Table 2: Probing Depth (PD) and Clinical Attachment Level (CAL) Over Time

Parameter / time point	CAF Alone	CAF+CTG	CAF+GTR	GBR	GTR+CTG	F	p
PD baseline (mm)	5.13 ± 1.08	4.72 ± 0.91	4.81 ± 1.13	4.73 ± 0.83	5.85 ± 1.25	2.93	0.025*
PD 3 months (mm)	4.36 ± 0.86	3.32 ± 0.66	3.65 ± 0.77	3.75 ± 0.63	3.68 ± 0.51	4.95	0.001*
PD 6 months (mm)	3.66 ± 0.70	2.58 ± 0.48	3.07 ± 0.55	3.02 ± 0.55	2.53 ± 0.32	11.26	<0.001*
CAL baseline (mm)	7.41 ± 1.45	6.59 ± 1.09	6.86 ± 1.45	6.70 ± 0.93	7.32 ± 1.25	1.48	0.213
CAL 3 months (mm)	6.65 ± 1.38	5.19 ± 0.96	5.60 ± 1.30	5.69 ± 0.96	6.16 ± 1.34	4.19	0.004*
CAL 6 months (mm)	6.29 ± 1.28	4.69 ± 0.98	5.12 ± 1.29	5.20 ± 0.89	5.83 ± 1.19	5.61	<0.001*

Within-group change, baseline to 6 months, paired t-test (all $p < 0.001$ except CAF Alone PD/CAL $p < 0.0001$ and $p < 0.0001$, $n = 10$ each; CAF+CTG $n = 40$; CAF+GTR $n = 20$; GBR $n = 20$; GTR+CTG $n = 10$). 6-month post-hoc (Tukey): CAF+CTG PD lower than CAF Alone, CAF+GTR and GBR ($p < 0.05$); GTR+CTG PD lower than CAF Alone ($p < 0.001$).

Table 3: Recession and Root Coverage Outcomes

Parameter	CAF Alone	CAF+CTG	CAF+GTR	GBR	GTR+CTG	F	p
Recession baseline (mm)	3.13 ± 1.08	3.20 ± 1.25	3.37 ± 1.10	3.41 ± 1.04	3.78 ± 1.18	0.61	0.658
Recession 6 months (mm)	1.73 ± 0.61	0.69 ± 0.37	1.23 ± 0.55	1.45 ± 0.56	0.55 ± 0.46	17.25	<0.001*
Recession 12 months (mm)	1.83 ± 0.63	0.75 ± 0.40	1.35 ± 0.58	1.64 ± 0.61	0.67 ± 0.48	17.82	<0.001*
Root coverage 12 months (%)	37.11 ± 19.65	74.08 ± 15.52	58.04 ± 17.22	51.33 ± 9.76	82.03 ± 11.69	20.32	<0.001*

Post-hoc (Tukey), 12-month root coverage: CAF+CTG and GTR+CTG each significantly greater than CAF+GTR, GBR and CAF Alone ($p < 0.01$ for all); CAF+CTG vs GTR+CTG $p = 0.570$ (ns); CAF+GTR vs GBR $p = 0.622$ (ns). Within-group recession reduction, baseline to 12 months, paired t-test significant for all groups ($p < 0.01$).

Table 4: Keratinized Tissue Width, Satisfaction, Complications and Follow-Up

Parameter	CAF Alone	CAF+CTG	CAF+GTR	GBR	GTR+CTG	Stat	p
KT width 6 months (mm)	3.14 ± 0.96	3.49 ± 0.85	3.68 ± 0.95	3.27 ± 0.93	3.30 ± 0.76	F=0.93	0.450
Patient satisfaction (0-10)	6.30 ± 1.42	7.83 ± 0.96	7.15 ± 0.59	7.05 ± 0.69	8.20 ± 0.92	F=9.07	<0.001*
Any complication, n (%)	5 (50%)	9 (23%)	9 (45%)	9 (45%)	1 (10%)	χ^2=8.30	0.081
Complete root coverage, n (%)	0 (0%)	2 (5%)	0 (0%)	0 (0%)	1 (10%)	χ^2=3.78	0.437
12-month follow-up compliance, n (%)	7 (70%)	38 (95%)	19 (95%)	20 (100%)	9 (90%)	χ^2=10.14	0.038*

Satisfaction post-hoc (Tukey): CAF Alone significantly lowers than CAF+CTG, GBR and GTR+CTG ($p < 0.05$ for all).

Discussion:

This study compared five periodontal surgical approaches across clinical, root-coverage, aesthetic and patient-reported outcomes. All techniques produced significant improvements in probing depth, clinical attachment level and recession, while CTG-based procedures demonstrated the most favorable 12-month root coverage and patient satisfaction. The superior performance of CAF + CTG is consistent with contemporary evidence supporting connective tissue grafting as a highly effective approach for gingival recession. A 2022 systematic review and network meta-analysis identified SCTG + CAF as the highest-ranked treatment for mean root coverage, complete root coverage and keratinized tissue gain at most evaluated time points, supporting its continued role as a reference approach for single recession defects **[8]**. The greater root coverage observed with CTG-based procedures may be attributed to the additional soft-tissue volume and enhanced stability provided by the graft. Evidence from randomized clinical trials and systematic reviews indicates that adjunctive grafting can improve clinical outcomes compared with CAF alone, although treatment effects vary according to defect characteristics and surgical technique **[9]**. Recent evidence also suggests that modifications of CAF, including microsurgical approaches, can further improve recession reduction, highlighting the importance of surgical precision in achieving predictable root coverage **[10]**. The numerically highest root coverage observed with combined GTR + CTG in the present analysis may reflect the potential complementary effects of soft-tissue augmentation and barrier-assisted regeneration. However, this finding should be interpreted cautiously because treatment allocation was based on defect characteristics rather than randomization. The literature indicates that periodontal regenerative outcomes are strongly influenced by defect morphology, with defect depth, angulation and the number of remaining bony walls affecting clinical attachment and radiographic regeneration **[11].** The relatively modest root-coverage outcome observed with GBR is also clinically plausible because regenerative procedures for intrabony defects are primarily directed toward periodontal attachment and hard-tissue regeneration rather than soft-tissue root coverage. Systematic evidence demonstrates that regenerative surgery can provide greater probing-depth reduction and clinical attachment gain than access-flap surgery in intrabony defects, supporting the use of regenerative approaches according to the underlying defect morphology **[12]**. Medium- and long-term evidence similarly shows sustained clinical benefits of regenerative/reconstructive procedures for intrabony defects, including greater clinical attachment gain and shallower residual probing depths compared with conventional access-flap treatment **[13]**. The favorable periodontal improvements observed across all five groups therefore need to be interpreted according to their respective treatment indications. Regenerative procedures may be particularly advantageous when attachment regeneration and defect resolution are the primary objectives, whereas CTG-based procedures are more directly suited to gingival recession and root-coverage objectives. Recent evidence on GTR combined with bone grafting also supports the use of regenerative combinations for intrabony and furcation defects, with improvements in probing depth and clinical attachment level reported compared with conventional debridement **[14]**. Several limitations should be considered when interpreting these findings. First, the dataset was simulated for statistical demonstration and therefore does not constitute original clinical trial evidence. Second, treatment allocation was based on defect characteristics and clinical judgment rather than randomization, while baseline probing depth differed modestly between groups and group sizes were unequal. These factors limit causal interpretation of the observed between-group differences. Third, complete root coverage was uncommon, with only 3 of 100 patients achieving this outcome, limiting the statistical power of this comparison. Finally, follow-up was restricted to 12 months, preventing assessment of the long-term stability of the observed treatment effects. Overall, the findings suggest that CTG-based approaches may provide greater root coverage and patient satisfaction; whereas regenerative procedures remain relevant for defects in which periodontal attachment or osseous regeneration is the principal treatment objective. These observations should be considered hypothesis-generating and require confirmation in prospective, randomized, defect-matched clinical studies with longer follow-up.

Conclusion:

Connective-tissue-graft-based techniques, particularly CAF + CTG and combined GTR + CTG, achieved greater 12-month root coverage and patient satisfaction than the other techniques. All five approaches significantly improved probing depth, clinical attachment level and recession from baseline. Thus, data support CTG-based procedures for root coverage and highlight the need for defect-matched randomized trials to validate these outcomes.

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