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Evaluation of the Effect of Restorative Status on Root Coverage in Gingival Recessions Associated With Non-carious Cervical Lesions

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Abstract

Objective: The aim of this study was to evaluate changes in gingival recession and root coverage outcomes over a three-month follow-up period according to restorative status.

Materials and methods: A total of 104 teeth from 47 patients were included. Teeth were categorized into three groups: unrestored (43 (41.3%)), composite resin (35 (33.7%)), and resin-modified glass-ionomer cement (RMGIC) (26 (25%)). All teeth underwent surgical treatment using an appropriate technique combined with a subepithelial connective tissue graft. Gingival recession measurements at baseline and three months were compared to evaluate the percentage of root coverage and complete root coverage.

Results: Gingival recession significantly decreased in all groups at three months ($p < 0.001$). The mean percentages of root coverage were 90.03%, 85.95%, and 84.96% in the unrestored, composite resin, and RMGIC groups, respectively, while complete root coverage rates were 62.8%, 42.9%, and 50%, respectively. No statistically significant differences were observed between the composite resin and RMGIC groups in terms of gingival recession depth ($p = 0.899$) or percentage of root coverage ($p = 0.295$) at three months. Greater baseline recession depth was associated with a lower percentage of root coverage.

Conclusion: Favorable early root coverage outcomes were achieved following surgical treatment in teeth with different restorative conditions. No statistically significant differences were observed between the composite resin and RMGIC groups. Further long-term, controlled studies are needed to confirm these findings.

Categories: Dentistry
Keywords: composite resin, connective tissue graft, gingival recession, non-carious cervical lesion, resin-modified glass-ionomer cement, root coverage

Introduction

Gingival recession is defined as the apical displacement of the gingival margin beyond the cementoenamel junction (CEJ), resulting in exposure of the root surface [1]. This condition may be associated with clinical consequences such as aesthetic concerns, dentin hypersensitivity, and an increased risk of root caries. When accompanied by hard tissue loss in the cervical region, it may require a combined periodontal and restorative assessment [2]. Clinical evaluation of gingival recession should consider not only the depth of the defect but also the interdental attachment level, gingival thickness, and amount of keratinized tissue. The current classification framework relates recession type to interdental attachment loss while also emphasizing the relevance of gingival phenotype characteristics in clinical assessment [3].

Gingival recession cannot be attributed to a single etiological factor; rather, it is considered a multifactorial condition that may develop through interactions between the periodontal phenotype and various triggering factors [4]. A thin gingival phenotype, insufficient keratinized tissue, and buccal bone dehiscence are among the anatomical characteristics that may predispose individuals to recession. Local factors, including plaque-associated inflammation, traumatic toothbrushing habits, and restoration positioning, may also be clinically relevant [5,6]. Nevertheless, these characteristics should not be assumed to be direct causes of recession in every case. Accordingly, clinical assessment should include an investigation of potential etiological and predisposing factors, as well as an examination of the existing recession defect and surrounding soft tissues. Gingival thickness and keratinized tissue width are among the principal clinical parameters recorded when assessing mucogingival conditions [1]. The prevalence of non-carious cervical lesions (NCCLs) among adults was reported to be 46.7% in a systematic review, although prevalence estimates may vary according to diagnostic criteria and the populations examined. The etiology of these lesions is multifactorial. Acidic factors, mechanical wear, and occlusal loading have been proposed as potential contributing factors; however, distinguishing their individual effects with certainty remains challenging [7].

In some studies, lesion depth has been considered when planning restorative treatment, with restorative intervention evaluated for lesions measuring 1.5 mm or deeper and non-restorative monitoring considered for shallower lesions. However, this threshold should not be interpreted as a universal clinical criterion that independently determines the need for restoration [8,9].

For cervical lesions associated with gingival recession, treatment planning is based on the depth and morphology of the cavity and the characteristics of the surrounding soft tissues. Depending on clinical requirements, restoration with resin-modified glass-ionomer cement (RMGIC) or composite resin may be considered, whereas contour modification and non-restorative monitoring may be appropriate options for limited lesions [10,11]. A suitable periodontal surgical approach for treating gingival recession is also incorporated into the treatment plan [12]. Clinical studies have reported the combined use of restorative treatment and root coverage surgery for these defects [8,9].

Surgical techniques for gingival recession include the coronally advanced flap (CAF), tunnel, and modified tunnel approaches. A connective tissue graft (CTG) may be used in conjunction with these techniques to increase soft tissue thickness and support tissue characteristics, while graft-free surgery may also be appropriate in selected cases. The combination of CAF and CTG has been described as a commonly used and effective approach in comparative studies of root coverage surgery [13]. Nevertheless, decisions regarding surgical technique and graft use should be guided by the anatomical characteristics of the defect and the patient's clinical needs [14]. The combined planning of restorative treatment, cavity margin modification, or non-restorative monitoring with periodontal surgery for cervical root lesions requires a comprehensive assessment of both hard and soft tissues.

Biomaterials such as collagen-based matrices or xenogeneic collagen matrices may be used as alternatives to subepithelial CTG. By eliminating the need for a donor site, these materials may have the potential to reduce surgical morbidity and have been compared with CTG in evaluations of clinical outcomes [14]. Restorative and surgical approaches, as well as outcome measures, vary across studies investigating combined cervical defects [12,14,15].

The presence of dentin hypersensitivity may also be recorded in these cases. Dentin hypersensitivity is defined as a short, sharp pain arising from exposed dentin in response to thermal, evaporative, tactile, or osmotic stimuli [16]. Randomized controlled trials have suggested that a combined restorative-periodontal approach may provide greater reductions in dentin hypersensitivity and improvements in aesthetic satisfaction than surgery alone [17].

Different combinations of restorative materials, root coverage techniques, and grafting procedures have been investigated in the treatment of gingival recession associated with cervical root lesions. However, evidence regarding short-term clinical outcomes remains limited in cases where the restorative approach is selected according to cavity characteristics and the surgical technique is determined by the clinical condition [13]. Assessing changes in gingival recession, mucogingival thickness, and keratinized tissue measurements over a three-month follow-up period may provide insight into early clinical changes associated with these approaches. Nevertheless, this follow-up period is insufficient on its own to support conclusions regarding long-term root coverage or treatment success.

In the present study, restorative or non-restorative approaches were selected according to the clinical characteristics of cervical root lesions. Gingival recession was surgically treated using CAF, tunnel, or modified tunnel techniques, with a subepithelial CTG applied in all cases. The aim of this study was to evaluate three-month gingival recession and root coverage outcomes according to restorative status. Gingival thickness and keratinized tissue width were assessed as baseline clinical characteristics in a subset of the study population. The null hypothesis was that there would be no statistically significant differences in three-month root coverage outcomes among the restorative groups.

Materials And Methods

Ethical statement

This clinical study was conducted at the Department of Periodontology, Faculty of Dentistry, Adıyaman University, in Adıyaman, Türkiye. As there was no authorized ethics committee for interventional clinical research at Adıyaman University at the time of the study, ethical approval was obtained from the Harran University Clinical Research Ethics Committee (approval number: HRÜ/26.01.57; approval date: January 12, 2026). Although ethical approval was obtained before patient recruitment, the requirement for prospective clinical trial registration was recognized after the study had commenced. Consequently, the study was retrospectively registered with ClinicalTrials.gov (NCT07687654) on June 30, 2026. Inadvertent inaccuracies in the initial registry submission concerning the study design, eligibility criteria, primary outcome assessment time point, and study start date were subsequently identified during the manuscript revision process and corrected on October 30, 2026. Written informed consent was obtained from all participants before enrollment, including consent for the use of clinical data and photographs for research purposes. Clinical and photographic evaluations were performed at the three-month follow-up.

Study design and study period

This prospective, non-randomized clinical study was conducted at the Department of Periodontology, Faculty of Dentistry, Adıyaman University, Türkiye. Patient recruitment began on January 15, 2026, and all surgical procedures were completed by April 24, 2026. The three-month clinical follow-up assessments were completed on August 7, 2026.

Study population

This clinical study included patients evaluated at the Department of Periodontology, Faculty of Dentistry, Adıyaman University, who presented with cervical lesions associated with gingival recession and had an indication for root coverage surgery. The study population comprised a total of 104 teeth from 47 patients. Teeth were categorized into three groups according to the restorative status of the cervical lesions: unrestored lesions (43 teeth, 23 patients), composite resin-restored lesions (35 teeth, 16 patients), and RMGIC-restored lesions (26 teeth, 14 patients). Six patients contributed teeth to both the unrestored and restored groups; therefore, the sum of the patient counts across the groups exceeded the total number of individual participants.

Inclusion criteria

The inclusion criteria were the presence of a cervical lesion, gingival recession extending apically beyond the CEJ, an indication for root coverage surgery in the affected tooth, and adequate oral hygiene for periodontal surgery. Only teeth with known cavity depth and restorative treatment history, for which the restorative material could be confirmed as either composite resin (Filtek™ Z250, 3M ESPE, St. Paul, MN, USA) or RMGIC (Fuji II LC, GC Corporation, Tokyo, Japan), were included in the restored groups.

Exclusion criteria

The exclusion criteria included smoking, inadequate oral hygiene, the presence of parafunctional habits such as bruxism associated with pronounced occlusal wear or excessive loss of dental hard tissue, and the absence of an appropriate indication for root coverage surgery in the affected tooth.

Teeth with defective or uncorrected cervical restorations, as well as those for which the restorative material, treatment history, or cavity depth could not be reliably verified, were excluded. Teeth presenting with extensive hard tissue loss that could not be adequately restored using composite resin or RMGIC and required an alternative restorative approach were also excluded.

Unilateral chewing habits and the presence of frenulum traction in the affected region were not considered exclusion criteria on their own. These characteristics were recorded during clinical follow-up when present.

Restorative treatment and clinical workflow

Patients presenting with NCCLs and/or gingival recession underwent periodontal evaluation in the Department of Periodontology. Patients requiring restorative treatment for NCCLs were referred to the Department of Restorative Dentistry, where the necessary restorations were performed. Baseline measurements, including cervical lesion dimensions and gingival recession parameters, were recorded before restorative treatment.

For teeth requiring restoration, restorative procedures were subsequently performed by clinicians in the Department of Restorative Dentistry. The choice of restorative material, including composite resin or RMGIC, was determined by the treating restorative clinicians according to their clinical judgment. The periodontal investigators did not influence or participate in restorative material selection.

Periodontal surgical treatment of gingival recession was performed after the completion of the restorative procedures.

Surgical procedure and clinical follow-up

Before restorative treatment and periodontal surgery, impressions were obtained from all patients, and individualized acrylic occlusal stents were fabricated. These stents were used to ensure that clinical measurements could be repeated from the same reference points at baseline and during follow-up.

At baseline, measurements of the mid-buccal region of the affected tooth were performed using a periodontal probe (UNC-15, Hu-Friedy, Chicago, IL, USA) from a fixed reference point established on the stent. Gingival recession was assessed based on the distance between the CEJ and the gingival margin. The depth of cervical lesions was measured and recorded before restorative treatment using the same periodontal probe (Figure *1*).



FIGURE 1: Representative images illustrating the clinical measurement methods

(A) Measurement of gingival recession using the occlusal stent as a reference. (B) Measurement of cervical cavity depth before restoration.

At baseline, keratinized tissue width was measured using the same periodontal probe (UNC-15, Hu-Friedy). Gingival thickness was assessed using a spreader, and the measurements were recorded with a digital caliper. These soft tissue parameters were assessed at baseline in a subset of the study population.

Following baseline measurements, teeth with cervical lesions deeper than 1.5 mm were referred to the Department of Restorative Dentistry for restorative treatment. The choice between composite resin and RMGIC was made by the treating restorative clinicians according to their clinical judgment, without intervention by the periodontal investigators. Both restorative materials were light-cured, and the restorations were completed by clinicians in the Department of Restorative Dentistry, including finishing and polishing procedures.

Following the completion of the restorations, mucogingival surgery was scheduled in coordination with the Department of Restorative Dentistry and performed as soon as possible, generally within one week. Before surgery, the affected root surfaces were clinically examined, and superficial debridement and root surface planing were performed as needed to remove residual deposits and prepare the surgical site.

All surgical procedures were performed under local anesthesia. The surgical approach was selected according to the clinical characteristics of the affected tooth and the individual indications of each patient. Accordingly, CAF, tunnel, and modified tunnel techniques were performed. Regardless of the surgical technique, a subepithelial CTG harvested from the palatal donor site was used in all cases. The graft was positioned at the recipient site according to the selected surgical technique, and soft tissue stabilization was achieved. Surgical procedures were performed by H.A., Z.B.C.E., and S.A., members of the study team. Postoperative clinical evaluations were conducted by Y.O.E., another member of the study team.

For tissue stabilization at the surgical site, 6-0 polypropylene sutures (PROLENE, ETHICON, Johnson & Johnson MedTech, New Brunswick, NJ, USA) were used. An absorbable gelatin sponge (SPONGOSTAN, Ferrosan Medical Devices, Søborg, Denmark) was applied to the palatal donor site to support hemostasis, and the site was closed using 4-0 absorbable polyglactin 910 sutures (VICRYL, ETHICON, Johnson & Johnson MedTech). Sutures at the palatal donor site were removed on postoperative day 7, whereas those at the recipient site were removed on day 14.

During the postoperative period, dexketoprofen trometamol (Arveles, Menarini, Istanbul, Türkiye) was prescribed for analgesia according to clinical needs. Patients were also instructed to use Kloroben spray (Drogsan İlaçları San. ve Tic. A.Ş., Ankara, Türkiye) three times daily for postoperative care of the surgical sites. Patients were advised to avoid mechanical trauma to the operated areas, consume soft foods, and maintain appropriate oral hygiene during healing.

Patients underwent clinical reevaluation at the third postoperative month. The individualized occlusal stents fabricated at baseline were reused to obtain periodontal probe measurements from the same reference points. Gingival recession was assessed at the same measurement sites at baseline and at three months. The amount of root coverage was calculated by subtracting the recession depth measured at three months from the baseline recession depth. Positive values indicated a reduction in gingival recession and coverage of the root surface, whereas negative values indicated an increase in gingival recession compared with baseline. A value of zero indicated no change in recession depth between the two assessments. The percentage of root coverage was calculated by dividing the amount of root coverage by the baseline recession depth and multiplying by 100. Clinical measurements were evaluated at the mid-buccal site and the three designated measurement sites, and root coverage outcomes at three months were recorded.

Statistical analysis

The tooth was considered the unit of analysis, whereas the patient was considered the clustering unit. Because multiple teeth from some patients were included in the study and six patients contributed teeth to more than one treatment group, within-patient correlation was accounted for in tooth-level inferential analyses. Continuous tooth-level outcomes were analyzed using linear mixed-effects models with patient-level random intercepts, whereas binary outcomes were analyzed using logistic generalized estimating equations (GEE) with an exchangeable working correlation structure. Results were reported using appropriate effect estimates, 95% confidence intervals (CIs), and p-values.

Gingival recession was measured at the mesial, mid-buccal, and distal sites at baseline and at three months. The percentage of root coverage was calculated using the mean recession values across the three sites according to the following formula:
$\text{Root Coverage } (\%) = [(\text{Baseline Recession} - \text{Three-Month Recession})/\text{Baseline Recession}] \times 100$
. The percentage of root coverage at the mid-buccal site was also evaluated separately. Complete root coverage was defined as a recession depth of 0 mm at all three sites at three months. Complete coverage at the mid-buccal site was considered a separate clinical outcome.

Baseline demographic and clinical characteristics were summarized as mean ± standard deviation, median (interquartile range), or number (percentage), as appropriate. For patient-level baseline comparisons, one-way analysis of variance (ANOVA) was used for age and the chi-squared test for sex, as reported in the table below. Tooth-level categorical characteristics were evaluated using GEE logistic models, whereas continuous tooth-level characteristics were compared using linear mixed-effects models with patient-level random intercepts. Changes in gingival recession between baseline and three months were assessed using patient-clustered GEE models.

The primary outcome was the percentage of root coverage at the three-month follow-up, calculated using the mean gingival recession measurements across the mesial, mid-buccal, and distal sites. The primary comparison was performed between the composite resin and RMGIC groups using a linear mixed-effects model adjusted for baseline recession depth and cavity depth, with patient-level random intercepts to account for within-patient clustering. To evaluate the potential influence of surgical technique, an additional model included surgical approach, categorized as tunnel-based techniques (tunnel and modified tunnel) versus CAF. Secondary analyses evaluated three-month mid-buccal gingival recession depth, mean gingival recession depth across the three measurement sites, mid-buccal root coverage percentage, and complete root coverage rates.

Continuous outcomes were reported as adjusted mean differences, whereas binary outcomes were expressed as odds ratios (ORs). Adjusted risk differences were also estimated where applicable. The robustness of the findings was assessed using patient-level bootstrap resampling with 2,000 repetitions and cluster-robust regression analyses (Appendix A). The association between baseline gingival recession depth and treatment outcomes was further investigated through supplementary analyses accounting for within-patient and between-patient variability. The potential impact of differences in patient identifier coding on the results was examined under alternative scenarios.

Because lesion depth in the unrestored group (≤1.5 mm) differed from that in the restored groups (≥2 mm), comparisons among the three groups were considered exploratory. These analyses were adjusted for baseline recession depth, and Holm correction was applied to pairwise comparisons. Differences between groups were not interpreted as evidence of causal superiority of any treatment approach.

The associations of surgical technique, jaw location, and tooth position with clinical outcomes were examined while accounting for treatment group and baseline recession depth. The effects of lesion and cavity depth were evaluated separately in restored and unrestored teeth. Complication frequencies were compared among groups using a permutation-based chi-squared test and Fisher's exact test; patient-level frequencies were also reported.

Because surgical techniques were not randomly assigned, findings related to surgical approach were further evaluated through sensitivity analyses and interpreted as exploratory.

Statistical analyses were performed in Python 3.13 (Python Software Foundation, Fredericksburg, VA, USA) using the statsmodels 0.15.0 and SciPy 1.18.1 libraries. pandas 3.0.5 and NumPy 2.5.3 were used for data management, and Matplotlib 3.11.2 was used for graphical visualization. Statistical significance was set at a two-sided $p < 0.05$.

Sample size calculation and sampling method

An a priori sample size calculation was performed at the defect level before patient recruitment, using the percentage of root coverage as the outcome for sample size estimation. The calculation was informed by the randomized controlled trial by Santamaria et al. [18], which compared CTG alone with CTG combined with a resin-modified glass-ionomer restoration. In that study, the estimated root coverage was 91.91% ± 17.76% in

the CTG-only group and 88.64% ± 11.90% in the group treated with a CTG combined with a resin-modified glass-ionomer restoration. Based on the reported standard deviations, the pooled standard deviation was calculated to be approximately 15.1 percentage points.

A difference of 14 percentage points in root coverage was prespecified as clinically meaningful, corresponding to a Cohen's d effect size of approximately 0.93. Assuming a two-sided significance level of 0.05 and 80% statistical power, the initial sample size calculation for a two-group comparison indicated that approximately 20 defects per group were required. Accordingly, a minimum of 60 defects across the three study groups was targeted. Because the reference study did not directly compare composite resin with RMGIC, its reported variability was used as an indirect basis for sample size estimation rather than as evidence of an expected difference between these restorative materials.

Consecutive patients who met the eligibility criteria were enrolled during the study period. The final sample comprised 104 gingival recession defects from 47 unique patients. Of these defects, 43 were non-restored, 35 were restored with composite resin, and 26 were restored with RMGIC. Because some patients contributed more than one defect, within-patient clustering was accounted for in the statistical analyses.

Results

A total of 104 teeth from 47 patients were evaluated in this study. The unrestored group comprised 43 teeth from 23 patients, the composite resin group included 35 teeth from 16 patients, and RMGIC group consisted of 26 teeth from 14 patients. The baseline characteristics of the groups are presented in Table *1*.

Characteristic/comparison	Non-restored	Composite	RMGIC	Total	Test/effect (95% CI)	Test statistic (df)	p
Patients, n[a]	**23**	**16**	**14**	**47**	-	-	-
Teeth, n	43	35	26	104	-	-	-
Teeth per patient, median (range)	2 (1-3)	2 (1-6)	2 (1-4)	2 (1-6)	-	-	-
Age, years, mean ± SD[a]	37.2 ± 7.9	35.1 ± 8.7	32.2 ± 7.5	34.8 ± 8.2	One-way ANOVA	F(2,50) = 1.70	0.194
Female sex, n (%)[a]	14 (60.9)	9 (56.2)	8 (57.1)	28 (59.6)	Pearson χ^2	$\chi^2(2) = 0.10$	0.953
Jaw, n (%)[b]	-	-	-	-	Logistic GEE	Wald $\chi^2(2) = 1.29$	0.524
Maxilla	21 (48.8)	19 (54.3)	13 (50.0)	53 (51.0)	-	-	-
Mandible (reference)	22 (51.2)	16 (45.7)	13 (50.0)	51 (49.0)	-	-	-
Composite vs non-restored	-	-	-	-	OR 3.67 (0.38-35.30)	z = 1.13	0.768
RMGIC vs non-restored	-	-	-	-	OR 1.07 (0.80-1.43)	z = 0.46	0.768
RMGIC vs composite	-	-	-	-	OR 0.29 (0.03-2.45)	z = −1.14	0.768
Tooth position, n (%)[b]	-	-	-	-	Logistic GEE	Wald $\chi^2(2) = 0.76$	0.683
Anterior (incisor/canine)	24 (55.8)	16 (45.7)	10 (38.5)	50 (48.1)	-	-	-
Incisor/canine, n	19/5	8/8	7/3	34/16	-	-	-
Posterior (reference)	19 (44.2)	19 (54.3)	16 (61.5)	54 (51.9)	-	-	-
Premolar/molar, n	19/0	17/2	11/5	47/7	-	-	-
Composite vs non-restored	-	-	-	-	OR 0.99 (0.40-2.44)	z = −0.03	1.000
RMGIC vs non-restored	-	-	-	-	OR 0.64 (0.23-1.79)	z = −0.85	1.000
RMGIC vs composite	-	-	-	-	OR 0.65 (0.20-2.09)	z = −0.72	1.000

Surgical technique, n (%)[b]	-	-	-	-	Logistic GEE	Wald $\chi^2(2) = 0.81$	0.667
Tunnel-based (reference)	32 (74.4)	31 (88.6)	20 (76.9)	83 (79.8)	-	-	-
Tunnel/modified tunnel, n	24/8	29/2	18/2	71/12	-	-	-
CAF	11 (25.6)	4 (11.4)	6 (23.1)	21 (20.2)	-	-	-
Composite vs non-restored	-	-	-	-	OR 0.80 (0.46-1.42)	z = −0.75	1.000
RMGIC vs non-restored	-	-	-	-	OR 1.28 (0.49-3.36)	z = 0.50	1.000
RMGIC vs composite	-	-	-	-	OR 1.59 (0.52-4.91)	z = 0.81	1.000
Mid-buccal GR, mm[c], mean ± SD	2.55 ± 1.28	3.66 ± 1.51	3.13 ± 1.26	3.07 ± 1.43	LMM	LRT $\chi^2(2) = 8.23$	0.016
Composite − non-restored	-	-	-	-	Difference 0.91 (0.29 to 1.53)	z = 2.87	0.012
RMGIC − non-restored	-	-	-	-	Difference 0.40 (−0.39 to 1.19)	z = 1.00	0.504
RMGIC − composite	-	-	-	-	Difference −0.51 (−1.38 to 0.36)	z = −1.15	0.504
Mean GR (3 sites), mm[c], mean ± SD	2.21 ± 1.23	3.40 ± 1.27	2.81 ± 1.03	2.76 ± 1.29	LMM	LRT $\chi^2(2) = 12.84$	0.002
Composite − non-restored	-	-	-	-	Difference 0.93 (0.43 to 1.44)	z = 3.60	<0.001
RMGIC − non-restored	-	-	-	-	Difference 0.43 (−0.25 to 1.12)	z = 1.25	0.401
RMGIC − composite	-	-	-	-	Difference −0.50 (−1.27 to 0.27)	z = −1.28	0.401
Lesion/cavity depth, mm[d]	0.74 ± 0.28	2.06 ± 0.16	2.06 ± 0.22	1.51 ± 0.69	-	-	-
Gingival thickness, mm[oe], mean ± SD	1.61 ± 0.27	1.69 ± 0.31	1.47 ± 0.28	1.60 ± 0.30	LMM	LRT $\chi^2(2) = 1.71$	0.425
Composite − non-restored	-	-	-	-	Difference 0.01 (−0.16 to 0.19)	z = 0.12	0.904
RMGIC − non-restored	-	-	-	-	Difference −0.12 (−0.34 to 0.09)	z = −1.12	0.703
RMGIC − composite	-	-	-	-	Difference −0.13 (−0.35 to 0.09)	z = −1.19	0.703
Keratinized tissue width, mm[oe], mean ± SD	3.42 ± 0.69	3.44 ± 0.93	2.88 ± 0.60	3.29 ± 0.81	LMM	LRT $\chi^2(2) = 2.96$	0.228
Composite − non-restored	-	-	-	-	Difference 0.33 (−0.17 to 0.82)	z = 1.29	0.391
RMGIC − non-restored	-	-	-	-	Difference −0.16 (−0.79 to 0.47)	z = −0.50	0.617
RMGIC − composite	-	-	-	-	Difference −0.49 (−1.11 to 0.14)	z = −1.52	0.385
Teeth/patients measured, n[e]	19/9	27/12	17/8	63/25	-	-	-

TABLE 1: Baseline demographic and clinical characteristics

Interpretation: Values are n (%), mean ± SD, or median (range). Bold rows show global tests; comparison rows show adjusted estimates (95% CI) and

Holm-adjusted p-values. Pairwise Wald z-statistics are unadjusted.

[a]Patient-level data: The study included 47 unique patients and 104 teeth. Six patients contributed to two groups; thus, group-specific patient counts (23/16/14) total 53 and overlap. The total column represents 47 unique patients. Age and sex were compared using ANOVA and Pearson's chi-squared test. Excluding overlapping patients: age $F(2,38) = 2.18$ ($p = 0.127$); sex $\chi^2(2) = 0.17$ ($p = 0.919$). Patient-clustered analyses: age Wald $\chi^2(2) = 4.41$ ($p = 0.110$); sex Wald $\chi^2(2) = 0.13$ ($p = 0.937$).

[b]Tooth-level categorical data: Logistic GEE (104 teeth, 47 patients; exchangeable correlation, robust SEs). Reference categories: mandible, posterior teeth, and tunnel-based surgery. Global tests: Wald $\chi^2(2)$. Pairwise ORs compare the first group with the second.

[c]Tooth-level continuous data: LMMs with patient random intercepts. Global tests: maximum-likelihood LRT $\chi^2(2)$; pairwise tests: Wald z with Holm-adjusted p-values.

[d]Lesion/cavity depth: Lesion depth was measured in non-restored teeth and cavity depth in restored teeth. No between-group test was performed because depth defined group allocation (≤1.5 vs ≥2.0 mm).

[e]Subset: Gingival thickness and keratinized tissue width were measured in 63 teeth from 25 patients (non-restored: 19 teeth/9 patients; composite: 27 teeth/12 patients; RMGIC: 17 teeth/8 patients).

SD: standard deviation; GR: gingival recession; RMGIC: resin-modified glass-ionomer cement; CAF: coronally advanced flap; GEE: generalized estimating equations; LMM: linear mixed-effects model; LRT: likelihood-ratio test; OR: odds ratio; CI: confidence interval; ANOVA: analysis of variance; SE: standard error

Baseline mid-buccal gingival recession depth differed significantly among the groups ($p = 0.016$), with the lowest value observed in the unrestored group. No statistically significant differences were found between the composite resin and RMGIC groups in baseline mid-buccal recession depth ($p = 0.435$) or cavity depth ($p = 0.675$). In accordance with the group allocation criteria, lesion depths were lower in unrestored teeth than in restored teeth. At the three-month follow-up, gingival recession depth decreased significantly from baseline in all groups ($p < 0.001$ for all groups; Table 2).

Outcome	Group	n (teeth)	Baseline, mm mean ± SD	3 months, mm mean ± SD	Reduction, mm mean (95% CI)	Wald z	p
Mid-buccal GR	Non-restored	43	2.55 ± 1.28	0.48 ± 0.76	2.07 (1.74-2.40)	12.34	<0.001
	Composite	35	3.66 ± 1.51	0.70 ± 0.89	2.96 (2.14-3.78)	7.08	<0.001
	RMGIC	26	3.13 ± 1.26	0.54 ± 0.80	2.60 (2.01-3.18)	8.71	<0.001
	Overall	104	3.07 ± 1.43	0.57 ± 0.82	2.50 (2.13-2.87)	13.08	<0.001
Mean GR (3 sites)	Non-restored	43	2.21 ± 1.23	0.29 ± 0.51	1.92 (1.63-2.21)	12.89	<0.001
	Composite	35	3.40 ± 1.27	0.51 ± 0.75	2.88 (2.13-3.63)	7.54	<0.001
	RMGIC	26	2.81 ± 1.03	0.40 ± 0.53	2.41 (1.91-2.91)	9.42	<0.001
	Overall	104	2.76 ± 1.29	0.39 ± 0.61	2.37 (2.02-2.71)	13.34	<0.001

TABLE 2: Gingival recession at baseline and three months after treatment

n denotes the number of teeth (gingival recession defects), not the number of patients. A total of 104 teeth from 47 unique patients were evaluated (non-restored: 43 teeth/23 patients; composite: 35 teeth/16 patients; RMGIC: 26 teeth/14 patients). Six patients contributed teeth to two groups. Values are presented as mean ± SD for measurements at each time point and as mean (95% CI) for the reduction. Reduction was calculated as baseline minus three-month gingival recession; positive values indicate improvement.

Within each group and overall, the mean reduction was estimated using an intercept-only GEE with an identity link and independence working correlation, applied to tooth-level reduction values. Robust sandwich standard errors accounted for clustering of teeth within patients. Wald z-tests evaluated the null hypothesis of zero mean reduction (two-sided p-values). The reported tests assess within-group changes over time, not between-group differences. All Wald tests have one degree of freedom when expressed as $\chi^2 = z^2$.

GR: gingival recession; RMGIC: resin-modified glass-ionomer cement; SD: standard deviation; CI: confidence interval; GEE: generalized estimating equations

The mean root coverage percentages were 90.03 ± 15.03%, 85.95 ± 18.58%, and 84.96 ± 19.28% in the

unrestored, composite resin, and RMGIC groups, respectively. Complete root coverage was achieved in 27 teeth (62.8%), 15 teeth (42.9%), and 13 teeth (50%), respectively (Table 3).

Outcome	Non-restored (n = 43)	Composite (n = 35)	RMGIC (n = 26)	Total (n = 104)
Root coverage (3-site mean), %				
Mean ± SD	90.03 ± 15.03	85.95 ± 18.58	84.96 ± 19.28	87.39 ± 17.36
Mean (95% CI)	90.0 (84.0-96.0)	86.0 (77.4-94.6)	85.0 (75.3-94.6)	87.4 (83.1-91.7)
Median (IQR)	100.00 (82.21-100.00)	92.31 (83.33-100.00)	96.43 (70.45-100.00)	100.00 (81.82-100.00)
Range	50.0-100.0	40.0-100.0	46.2-100.0	40.0-100.0
Complete root coverage (all 3 sites = 0 mm), n (%)	27 (62.8)	15 (42.9)	13 (50)	55 (52.9)
95% CI, %	44.5-78.0	24.5-63.5	26.0-74.0	41.3-64.2
Complete mid-buccal coverage (mid-buccal = 0 mm), n (%)	28 (65.1)	17 (48.6)	16 (61.5)	61 (58.7)
95% CI, %	45.7-80.5	27.9-69.7	37.1-81.3	45.8-70.4
Mid-buccal root coverage, %				
Mean ± SD	84.19 ± 26.27	81.65 ± 20.46	84.55 ± 21.44	83.42 ± 23.08
Median (IQR)	100.00 (66.67-100.00)	83.33 (63.33-100.00)	100.00 (68.75-100.00)	100.00 (66.67-100.00)

TABLE 3: Root coverage and complete root coverage at three months

In the column headings, n denotes the number of teeth (gingival recession defects) included in each treatment group. For complete root coverage outcomes, n (%) indicates the number and percentage of teeth achieving complete coverage. Overall, 104 teeth from 47 patients were evaluated.

Values are presented as mean ± SD, median (IQR), range, or n (%), as appropriate. Root coverage (%) was calculated as ((baseline mean GR − three-month mean GR) / baseline mean GR) × 100, using measurements obtained at the mesial, mid-buccal, and distal sites.

The 95% CIs were estimated using patient-clustered bootstrap resampling for mean root coverage and GEE for complete root coverage outcomes.

SD: standard deviation; IQR: interquartile range; CI: confidence interval; GR: gingival recession; RMGIC: resin-modified glass-ionomer cement; GEE: generalized estimating equations

In the primary comparison between the composite resin and RMGIC groups, no statistically significant difference was observed in the percentage of root coverage at three months after adjusting for baseline recession depth and cavity depth (adjusted mean difference: −7.3 percentage points; 95% CI: −21.0 to 6.4; p = 0.295). Similar results were obtained after additional adjustment for surgical technique (adjusted mean difference: −6.0 percentage points; 95% CI: −19.6 to 7.7; p = 0.392).

In the secondary analysis, no statistically significant difference was observed in three-month mid-buccal gingival recession depth between the composite resin and RMGIC groups (adjusted mean difference: 0.03 mm; 95% CI: −0.49 to 0.56; p = 0.899). This finding remained consistent after adjustment for surgical technique (adjusted mean difference: −0.03 mm; 95% CI: −0.55 to 0.48; p = 0.896). Sensitivity analyses supported the absence of statistically significant between-group differences (Table 4 and Appendix B).

Outcome	Composite (n = 35)	RMGIC (n = 26)	Unadjusted estimate (95% CI)	p	Adjusted estimate (95% CI)	p	Technique-adjusted estimate (95% CI)	p
Primary outcome								
Root coverage (3-site), %	85.95 ± 18.58	84.96 ± 19.28	−3.5 (−15.5 to 8.6)	0.571	−7.3 (−21.0 to 6.4)	0.295	−6.0 (−19.6 to 7.7)	0.392
Secondary outcomes								
3-month mid-buccal GR, mm	0.70 ± 0.89	0.54 ± 0.80	−0.14 (−0.62 to 0.34)	0.577	0.03 (−0.49 to 0.56)	0.899	−0.03 (−0.55 to 0.48)	0.896
3-month mean GR (3 sites), mm	0.51 ± 0.75	0.40 ± 0.53	−0.10 (−0.48 to 0.28)	0.616	0.08 (−0.36 to 0.51)	0.728	0.02 (−0.41 to 0.45)	0.918
Root coverage (mid-buccal), %	81.65 ± 20.46	84.55 ± 21.44	0.5 (−12.7 to 13.7)	0.943	−2.8 (−17.1 to 11.5)	0.701	−1.6 (−16.1 to 12.8)	0.823
Complete root coverage (3 sites), n (%)	15 (42.9)	13 (50.0)	OR 0.94 (0.26-3.43)	0.920	OR 0.78 (0.19-3.26)	0.729	OR 1.19 (0.27-5.29)	0.822
Complete mid-buccal coverage, n (%)	17 (48.6)	16 (61.5)	OR 1.32 (0.36-4.83)	0.678	OR 0.95 (0.22-4.09)	0.950	OR 1.21 (0.26-5.69)	0.813

TABLE 4: Adjusted comparison of clinical outcomes between the composite and RMGIC groups

In the column headings, n represents the number of teeth (gingival recession defects) included in each treatment group (composite: n = 35; RMGIC: n = 26). Overall, 61 teeth from 30 patients were included in these comparisons.

Group values are presented as mean ± SD or n (%), as appropriate. All effect estimates compare the RMGIC group with the composite group (reference). Continuous outcomes were analyzed using linear mixed-effects models with a patient-level random intercept, whereas binary outcomes were analyzed using logistic generalized estimating equations with an exchangeable working correlation structure.

Adjusted estimates account for baseline gingival recession (mid-buccal GR for mid-buccal outcomes and mean GR for three-site outcomes) and baseline cavity depth. Technique-adjusted estimates additionally account for surgical technique (tunnel-based procedures versus CAF).

RMGIC: resin-modified glass-ionomer cement; GR: gingival recession; CI: confidence interval; OR: odds ratio; CAF: coronally advanced flap; SD: standard deviation

In the three-group comparison adjusted for baseline gingival recession, no statistically significant differences were detected in three-month mid-buccal gingival recession (p = 0.897), root coverage percentage (p = 0.472), or complete root coverage (p = 0.388) (Appendix C). Because baseline lesion depths did not overlap between the unrestored and restored groups, these comparisons were considered exploratory.

Greater baseline gingival recession was associated with greater residual recession and lower root coverage percentages at three months. In the exploratory assessment of surgical techniques, teeth treated with a CAF had lower root coverage percentages than those treated with tunnel-based techniques (adjusted difference: −12.2 percentage points; 95% CI: −22.3 to −2.2; p = 0.017). The odds of complete root coverage were also lower in teeth treated with CAF (OR = 0.25; 95% CI: 0.10-0.64; p = 0.004). In the three-category analysis, higher three-month mid-buccal gingival recession was observed in teeth treated with either CAF (adjusted difference: 0.53 mm; 95% CI: 0.08-0.97; p = 0.022) or the modified tunnel technique (adjusted difference: 0.57 mm; 95% CI: 0.04-1.11; p = 0.036) compared with the tunnel technique (overall p = 0.027) (Table *5*). No statistically significant associations were detected between three-month clinical outcomes and jaw location, anterior or posterior tooth position, or baseline lesion/cavity depth. No statistically significant differences in measured baseline characteristics were detected among the surgical technique groups. Although the association between CAF and root coverage percentage was no longer statistically significant in some sensitivity analyses, the association with complete root coverage remained statistically significant in the additional analyses for which p-values were calculated (Appendices D-E). Given the non-randomized selection of surgical techniques and the limited number of patients treated with CAF (12 patients, 21 teeth), these findings were considered exploratory.

Variable/comparison	Sample, teeth (patients)	Adjusted effect estimate (95% CI)	p
CAF versus tunnel-based approaches[a]			
3-month mid-buccal gingival recession (mm)	104 (47): CAF 21 (12) vs tunnel-based 83	0.37 (−0.04 to 0.78)	0.076
Root coverage (percentage points)		−12.2 (−22.3 to −2.2)	0.017
Complete root coverage (OR)		0.25 (0.10-0.64)	0.004
Surgical technique, three-category model (reference: conventional tunnel)[b]			
3-month mid-buccal recession (mm): CAF vs conventional tunnel	104 (47)	0.53 (0.08-0.97)	0.022
3-month mid-buccal recession (mm): modified vs conventional tunnel		0.57 (0.04-1.11)	0.036
Overall effect of technique on mid-buccal recession (global test, 2 df)		-	0.027
Baseline gingival recession (per 1-mm increase)			
3-month mid-buccal recession (mm)	104 (47)	0.38 (0.28-0.49)	<0.001
Root coverage (percentage points)		−4.0 (−7.0 to −1.0)	0.008
Complete root coverage (OR)		0.63 (0.39-1.03)	0.064

TABLE 5: Adjusted associations of surgical technique and baseline gingival recession with three-month periodontal outcomes

All models included 104 teeth from 47 unique patients. Continuous outcomes were analyzed using LMMs with patient-level random intercepts. Complete root coverage (three sites) was analyzed using logistic GEE with an exchangeable working correlation structure and robust standard errors. Models were adjusted for treatment group (non-restored, composite, and RMGIC) and baseline gingival recession (mid-buccal recession for mid-buccal outcomes and three-site mean recession for other outcomes).

[a]CAF was performed on 21 teeth from 12 patients, whereas tunnel-based approaches (conventional and modified tunnel combined) were performed on 83 teeth. Two patients received more than one surgical technique. Positive estimates for recession indicate greater residual recession, whereas negative estimates for root coverage indicate lower coverage with CAF.

[b]The three-category model included surgical technique as a three-level predictor, with conventional tunnel as the reference, adjusting for treatment group and baseline mid-buccal recession. The overall p-value was obtained using a Wald χ^2 test (2 degrees of freedom). Differences between the two-category and three-category estimates reflect the different reference groups and model specifications.

Surgical techniques were not randomly assigned. Potentially relevant factors influencing technique selection, including periodontal phenotype, keratinized tissue width, vestibular depth, recession type, and operator preference, may not have been fully accounted for. Therefore, these associations should be interpreted as exploratory rather than causal.

CAF: coronally advanced flap; CI: confidence interval; GEE: generalized estimating equations; RMGIC: resin-modified glass-ionomer cement; LMM: linear mixed-effects model; OR: odds ratio

During postoperative follow-up, 15 of the 104 teeth (14.4%) had records coded as complications or other clinical events. Of these, eight (7.7%) involved suture breakage or loss, while seven (6.7%) consisted of other recorded events, such as unilateral chewing and frenulum traction. No statistically significant differences were detected in the frequency of recorded events among the three groups ($p = 0.564$) or between the composite resin and RMGIC groups ($p = 0.494$).

No statistically significant differences were observed in the measured baseline characteristics among the surgical technique groups (Appendices D-E). However, these findings were interpreted with caution because the CAF technique was performed in only 12 patients and the association with the percentage of root coverage lost statistical significance in some additional analyses. In contrast, the association with complete root coverage remained evident in the additional analyses. No statistically significant associations were found between clinical outcomes and jaw location, anterior or posterior tooth position, or lesion/cavity depth.

Discussion

In the present study, gingival recession decreased in all groups three months after the treatment of gingival recessions associated with NCCLs. After adjustment for baseline recession and cavity depth, no statistically significant differences were observed between the composite resin and RMGIC groups in terms of three-month mid-buccal gingival recession or root coverage. This finding appears consistent with previous clinical studies investigating different restorative materials in conjunction with CTG, in which no clear differences in clinical outcomes between materials were reported. However, because lesions in the non-restored group were shallower and baseline recession was less pronounced, the findings across the three groups should not be interpreted as a direct comparison of restorative materials. Furthermore, the three-month follow-up period limits the interpretation of these findings to early clinical outcomes. Although the groups showed similarities in several demographic and clinical characteristics, significant differences in baseline gingival recession were observed. These baseline differences should be considered when interpreting the comparisons between restorative groups. The finding that 45.2% of the included teeth were premolars is consistent with clinical and review-based evidence suggesting that NCCLs are frequently observed in premolars [19]. Nevertheless, tooth-type distribution did not differ significantly among the groups in the present study. Previous reports have also indicated that the prevalence and tooth-specific distribution of NCCLs may vary across studies, potentially reflecting differences in diagnostic criteria and sample characteristics.

Baseline lesion depth was lower in the non-restored group (mean: 0.74 mm), whereas the mean depth was 2.06 mm in the composite and RMGIC groups. This observation is broadly consistent with literature suggesting that decisions regarding restorative treatment of NCCLs should be guided by lesion depth and individual clinical requirements. Previous studies have suggested that restorative treatment may be considered for cervical lesions deeper than approximately 1.5 mm, whereas periodontal surgery without restoration may be appropriate for shallower defects [8,9]. However, because baseline lesion depths differed among the treatment groups in the present study, the observed follow-up outcomes cannot be attributed solely to the restorative materials used. Baseline gingival recession measurements differed significantly among the groups (mid-buccal recession: $p = 0.016$; mean recession across three sites: $p = 0.002$), with the highest values observed in the composite group for both measurements. Previous literature has suggested that baseline defect characteristics are important when evaluating treatment outcomes in gingival recessions associated with NCCLs. Although the distribution of surgical techniques did not differ significantly among the groups ($p = 0.667$), the tunnel technique was the most frequently used approach (68.3%). While the CAF has been described as a commonly used root coverage technique [20,21], surgical approaches in the present study were selected and, when necessary, modified according to case-specific clinical requirements. Therefore, a direct comparison of the effectiveness of surgical techniques was not the primary objective of this study. In addition, because some patients contributed multiple teeth or teeth to more than one treatment group, the three-month outcomes should be interpreted with consideration of baseline differences and potential within-patient clustering. At three months, both mid-buccal recession and mean recession across the three sites had decreased from baseline in all groups ($p < 0.001$ for all within-group comparisons). The mean reductions in recession across the three sites were 1.92, 2.88, and 2.41 mm in the non-restored, composite, and RMGIC groups, respectively. These findings are broadly consistent with studies reporting clinical root coverage following the surgical treatment of gingival recessions associated with cervical lesions. For example, Santamaria et al. reported estimated root coverage of approximately 92% and 89% at six months following CTG alone and CTG combined with an RMGIC restoration, respectively [18]. However, differences in follow-up duration and treatment protocols limit direct numerical comparisons between studies. Differences in baseline recession should also be considered when interpreting the observed reductions during follow-up. In particular, the lower baseline recession in the non-restored group and the greater baseline recession in the composite group may have contributed to differences in absolute recession reduction. Therefore, attributing the observed improvements directly to the restorative materials would be inappropriate, and adjustment for baseline characteristics remains important in between-group comparisons.

Restorative treatment of cervical lesions may help re-establish lost tooth contours and provide a surface that facilitates soft tissue adaptation during periodontal surgery. Nevertheless, root coverage outcomes may depend on several factors beyond the properties of the restorative material, including baseline defect morphology, surgical approach, and graft adaptation [12]. Previous studies have suggested that glass-ionomer-based materials may exhibit deterioration in marginal adaptation over time, whereas water sorption-related changes in composite resins may influence their long-term restorative performance [22,23]. Although the literature contains varying findings regarding the comparative clinical performance of these materials, some studies have reported similar treatment outcomes in appropriately selected cases [24]. The comparable root coverage observed in the composite and RMGIC groups in the present study appears consistent with these findings in the short term. Furthermore, previous evidence has suggested that partial restorations performed in conjunction with grafting may provide limited additional benefits for root coverage itself while potentially offering clinical advantages such as improved cervical contour and reduced dentin hypersensitivity [14]. The higher root coverage observed in the non-restored group should not be attributed directly to the absence of restorative material, particularly given the lower baseline recession and lesion depth in this group. In the present study, no statistically significant difference in three-month root coverage outcomes was observed between the composite and RMGIC groups after accounting for baseline recession and cavity depth. This finding is consistent with the results reported by Santamaria et al., who evaluated CTG alone or in combination with an RMGIC restoration [18]. Similarly, another clinical study

investigating different restorative materials in combination with CTG and a modified CAF reported no statistically significant differences in root coverage outcomes [25]. Taken together, these findings suggest that baseline defect characteristics and surgical healing may contribute to root coverage outcomes alongside the type of restorative material. However, given the width of the CIs, the absence of a statistically significant between-group difference should not be interpreted as evidence of clinical equivalence between the materials. In sites treated with CAF, lower percentages of root coverage and lower frequencies of complete root coverage were observed compared with tunnel-based approaches, whereas the difference in mid-buccal recession was not statistically significant. These findings differ somewhat from meta-analyses of randomized controlled trials reporting generally comparable mean root coverage outcomes between CAF and tunnel techniques [26,27]. Previous literature has suggested that preservation of papillary integrity and graft vascular support in tunnel techniques, as well as adequate coronal mobilization of the flap in CAF procedures, may influence treatment outcomes [27-29]. However, because surgical techniques in the present study were selected according to case-specific clinical characteristics, the observed differences cannot be attributed directly to the surgical approaches themselves. The association between greater baseline recession and increased residual recession, together with reduced root coverage at follow-up, is also consistent with literature suggesting that root coverage may be more limited in advanced defects. Accordingly, findings related to surgical techniques should be considered exploratory and interpreted in the context of baseline defect characteristics and potential confounding factors.

Several limitations of this study should be acknowledged. First, the treatment groups were not compared using a matched split-mouth design within the same patients. Although oral hygiene was standardized to some extent, this may have limited the ability to control fully for individual healing responses and patient-specific factors. In addition, differences in tooth position and baseline recession characteristics, together with the absence of assessments of buccal bone thickness and dehiscence, may have limited anatomical standardization. Clinical measurements were performed by multiple investigators, and inter-examiner calibration was not evaluated, which may have introduced measurement variability. Similarly, restorative and periodontal surgical procedures were performed by different clinicians, and the potential influence of operator-related technical differences cannot be excluded. The non-randomized, case-specific selection of surgical techniques further limits comparative interpretation. Moreover, some patients contributed multiple teeth or teeth to different treatment groups, introducing potential within-patient dependence and confounding. Although within-patient clustering was accounted for in the statistical analyses, this approach may not fully address all patient-specific differences. Furthermore, restorative material selection was based on clinical judgment rather than random allocation; therefore, confounding by indication cannot be excluded. The absence of a documented examiner-blinding procedure may also have introduced measurement bias. Although 104 teeth were included in the study, the soft tissue analyses presented in Table *1* were limited to 63 teeth, restricting the interpretation of these findings. In addition, clustering of teeth within patients was not incorporated into the initial sample size calculation, which may have affected the effective sample size and statistical power. Finally, although the three-month follow-up period allowed the assessment of early soft tissue healing, it does not permit definitive conclusions regarding the long-term stability of root coverage or the clinical performance of restorative materials.

Conclusions

Within the limitations of this study, clinical improvement was observed in all groups at the three-month follow-up after the surgical treatment of gingival recession associated with cervical lesions using CTG. No statistically significant difference in root coverage was detected between the composite resin and RMGIC groups after accounting for baseline recession and cavity depth. These findings suggest that no clear superiority of either restorative material could be demonstrated in terms of short-term root coverage outcomes. Nevertheless, considering the differences in baseline defect characteristics and surgical approaches, treatment outcomes should be interpreted in the context of individual clinical conditions. Further standardized randomized controlled trials with longer follow-up periods are needed to confirm these findings and evaluate long-term clinical stability.

Appendices

Appendix A

Outcome/category	Analysis/measure	Estimate/value	95% CI	p
3-month mid-buccal GR (mm)	LMM, Model 1	0.03	−0.49 to 0.56	0.899
	OLS, patient-cluster bootstrap	−0.03	−0.51 to 0.54	-
	OLS, cluster-robust SE	−0.03	−0.54 to 0.49	0.924
	LMM, Model 2	−0.03	−0.55 to 0.48	0.896
	Patient-level ICC	0.53	-	-
	Shapiro-Wilk residual normality test	-	-	<0.001
Root coverage (%)	LMM, Model 1	−7.3	−21.0 to 6.4	0.295
	OLS, patient-cluster bootstrap	−1.5	−16.0 to 11.6	-
	OLS, cluster-robust SE	−1.5	−15.1 to 12.1	0.827
	LMM, Model 2	−6.0	−19.6 to 7.7	0.392
	Patient-level ICC	0.67	-	-
	Shapiro-Wilk residual normality test	-	-	0.008
Complete root coverage (3 sites)	GEE, Model 1: OR	0.78	0.19 to 3.26	0.729
	GEE, Model 1: adjusted risk difference (pp)	−6.0	−31.8 to 38.5	-
	GEE, Model 2: OR	1.19	0.27 to 5.29	0.822
	GEE, Model 2: adjusted risk difference (pp)	3.7	−24.1 to 42.8	-
Model sample	Teeth	61	-	-
	Patients	30	-	-
Model complexity	Fixed-effect parameters, Model 1/Model 2 (excluding intercept)	3/4	-	-
Complete root coverage events	Events/non-events	28/33	-	-
	Events per parameter, Model 1/Model 2	9.3/7.0	-	-
Surgical technique	Tunnel/modified tunnel/CAF (teeth)	47/4/10	-	-

TABLE 6: Sensitivity analyses and model diagnostics for the composite versus RMGIC comparison

Estimates compare RMGIC with the composite (reference). Model 1 adjusts for baseline GR and cavity depth; Model 2 additionally adjusts for surgical technique (tunnel-based vs CAF). Bootstrap CIs are based on 2,000 patient-level resamples. Root coverage estimates and risk differences are expressed in percentage points. Residual non-normality may reflect a floor effect. LMM and OLS estimates for root coverage differ because the methods weight within- and between-patient information differently; neither method showed a statistically significant difference.

GR: gingival recession; RMGIC: resin-modified glass-ionomer cement; LMM: linear mixed-effects model; OLS: ordinary least squares; SE: standard error; ICC: intraclass correlation coefficient; GEE: generalized estimating equations; OR: odds ratio; CI: confidence interval; CAF: coronally advanced flap; pp: percentage points; -: not applicable or not reported

Appendix B

Model	Difference, percentage points (95% CI)	p	Note
LMM (REML), random intercept - Model 1	−7.3 (−21.0 to 6.4)	0.295	ICC 0.67; baseline GR β = −7.09
OLS, cluster-robust SE - Model 1	−1.5 (−15.1 to 12.1)	0.827	Baseline GR β = −0.90
LMM, within-between (Mundlak) model	−4.0 (−16.9 to 8.9)	0.541	Within β = −12.1; between β = 0.2; p = 0.007
GEE, exchangeable	−9.5 (−24.5 to 5.5)	0.214	-
LMM, unadjusted	−3.5 (−15.5 to 8.6)	0.571	-
OLS, unadjusted	−1.0 (−14.2 to 12.2)	0.883	-
LMM, baseline GR only	−6.8 (−20.4 to 6.8)	0.328	Cavity depth omitted
OLS, baseline GR only	−1.5 (−15.1 to 12.2)	0.833	-
Patient-level OLS (patient means; n = 30)	−5.1 (−17.9 to 7.7)	0.436	Equal patient weights; β = −0.33
Patient-level WLS	0.4 (−14.8 to 15.6)	0.958	Weighted by teeth per patient

TABLE 7: Root coverage (%), RMGIC − composite: comparison of model specifications

Values are adjusted RMGIC − composite differences unless specified as unadjusted. Model 1 adjusts for baseline mean GR and cavity depth. The within-between model separates patient-mean GR from within-patient deviation (and includes cavity-depth decomposition). β denotes the regression coefficient for baseline GR, expressed as the estimated change in root coverage (percentage points) per 1-mm increase in baseline GR. In the within-between (Mundlak) model, within β represents the association with tooth-level deviations from the patient's mean baseline GR, whereas between β represents the association with differences in mean baseline GR between patients. The baseline GR-coverage association differed within and between patients; consequently, LMM and OLS estimates differed. No model showed a statistically significant material difference.

RMGIC: resin-modified glass-ionomer cement; GR: gingival recession; LMM: linear mixed-effects model; REML: restricted maximum likelihood; OLS: ordinary least squares; SE: standard error; GEE: generalized estimating equations; WLS: weighted least squares; ICC: intraclass correlation coefficient; β: regression coefficient

Appendix C

Outcome/contrast	Estimate (95% CI)	p	Holm-adjusted p	Global p
3-month mid-buccal GR, mm (difference)				
Composite vs non-restored	0.00 (−0.34 to 0.35)	0.989	1.000	
RMGIC vs non-restored	−0.09 (−0.48 to 0.31)	0.661	1.000	0.897
RMGIC vs composite	−0.09 (−0.53 to 0.35)	0.683	1.000	
3-month mean GR, mm (difference)				
Composite vs non-restored	−0.01 (−0.28 to 0.27)	0.964	1.000	
RMGIC vs non-restored	−0.03 (−0.33 to 0.26)	0.834	1.000	0.978
RMGIC vs composite	−0.03 (−0.35 to 0.30)	0.878	1.000	
Root coverage, % (difference)				
Composite vs non-restored	−4.1 (−12.7 to 4.5)	0.348	0.889	
RMGIC vs non-restored	−5.1 (−14.7 to 4.5)	0.296	0.889	0.472
RMGIC vs composite	−1.0 (−11.7 to 9.7)	0.855	0.889	
Complete root coverage, 3 sites (OR)				
Composite vs non-restored	0.39 (0.08-1.83)	0.234	0.701	
RMGIC vs non-restored	0.51 (0.16-1.68)	0.268	0.701	0.388
RMGIC vs composite	1.30 (0.28-5.99)	0.735	0.735	
Complete mid-buccal coverage (OR)				
Composite vs non-restored	0.38 (0.06-2.28)	0.293	0.879	
RMGIC vs non-restored	0.80 (0.27-2.41)	0.696	0.879	0.574
RMGIC vs composite	2.09 (0.40-10.81)	0.379	0.879	

TABLE 8: Exploratory three-group comparisons adjusted for baseline gingival recession

Sample size: 104 teeth from 47 unique patients.

Linear mixed-effects models (patient random intercept) were used for continuous outcomes and GEE logistic models for binary outcomes, adjusted for baseline GR. Pairwise p-values were adjusted using the Holm method. Lesion/cavity depth was not included because values did not overlap between the non-restored and restored groups. All three-group comparisons are exploratory and should not be interpreted as causal treatment effects.

GR: gingival recession; RMGIC: resin-modified glass-ionomer cement; OR: odds ratio; CI: confidence interval; GEE: generalized estimating equations

Appendix D

Variable	Tunnel	Modified tunnel	CAF	p (CAF vs tunnel-based)
Teeth, n	71	12	21	-
Patients, n	31	6	12	-
Baseline mid-buccal GR, mm	2.88 ± 1.17	4.08 ± 2.28	3.12 ± 1.44	0.433
Baseline mean GR, mm	2.66 ± 1.03	3.65 ± 2.18	2.58 ± 1.32	0.722
Lesion/cavity depth, mm	1.60 ± 0.68	1.25 ± 0.69	1.38 ± 0.69	0.589
Non-restored/composite/RMGIC, n	24/29/18	8/2/2	11/4/6	-
Maxillary teeth, n (%)	37 (52%)	7 (58%)	9 (43%)	0.105
Anterior teeth, n (%)	40 (56%)	2 (17%)	8 (38%)	0.310
Root coverage, %	89.1 ± 17.3	87.4 ± 11.2	81.5 ± 19.7	-
CRC, n (%)	44/71 (62%)	4/12 (33%)	7/21 (33%)	-

TABLE 9: Baseline characteristics and clinical outcomes by surgical technique and sensitivity analyses of the association with CAF

Values are mean ± SD unless otherwise indicated. Baseline comparisons are CAF versus tunnel-based procedures (tunnel and modified tunnel); p-values were obtained using linear mixed-effects models for continuous variables and GEE logistic models for binary variables. Patient counts are group-specific and may overlap.

CAF: coronally advanced flap; GR: gingival recession; RMGIC: resin-modified glass-ionomer cement; CRC: complete root coverage; n: number; SD: standard deviation; GEE: generalized estimating equations

Appendix E

Analysis	RC difference, percentage points (95% CI)	p	CRC, OR (95% CI)	p
LMM/GEE: treatment group + baseline GR (main analysis, Table 5)	−12.2 (−22.3 to −2.2)	0.017	0.25 (0.10-0.64)	0.004
Additional adjustment for jaw and tooth position	−11.8 (−22.0 to −1.6)	0.024	0.26 (0.10-0.67)	0.005
Unadjusted	−11.4 (−21.4 to −1.4)	0.025	0.33 (0.13-0.85)	0.022
Cluster-robust OLS (RC)/independence GEE (CRC)	−8.2 (−19.9 to 3.4)	0.167	0.28 (0.11-0.69)	0.006
Patient-cluster bootstrap (2,000 resamples)	−8.4 (−21.3 to 2.6)	-	0.25 (0.06-0.71)	-
Within-between (Mundlak) LMM	−12.2 (−22.1 to −2.3)	0.016	-	-
Leave-one-CAF-patient-out (12 refits), range	−14.1 to −7.5	0.007-0.153	-	-
Patient-level comparison (CAF n = 11 vs tunnel-based n = 35; Mann-Whitney)	79.7 vs 89.5	0.053	29% vs 60% of teeth per patient	0.034

TABLE 10: Sensitivity analyses: CAF versus tunnel-based techniques

CAF was performed in 12 patients (21 teeth); two patients received more than one surgical technique. Technique selection was not randomized, and potential unmeasured determinants (e.g., tissue phenotype, keratinized tissue, vestibular depth, recession type, and operator preference) could not be accounted for. Associations should therefore be interpreted as exploratory.

CAF: coronally advanced flap; CI: confidence interval; CRC: complete root coverage; GEE: generalized estimating equations; GR: gingival recession; LMM: linear mixed-effects model; OLS: ordinary least squares; OR: odds ratio; RC: root coverage

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Harran University Clinical Research Ethics Committee issued approval HRÜ/26.01.57. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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