

Factors Affecting the Outcomes of Coronally Advanced Flap Root Coverage Procedure

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Background: The coronally advanced flap (CAF) has been used to treat gingival recession. However, the final outcomes (percentage of root coverage) vary from case to case. Hence, the purpose of this study was to analyze the factors that may affect the results of CAF root coverage procedures.

Methods: Twenty-three systemically healthy patients (mean age, 43.8 ± 11.9 years) each with one Miller's Class I buccal recession defect were included. Baseline clinical parameters included recession depth (RD), recession width (RW), gingival thickness (GT), width of keratinized tissue (WKT), clinical attachment level (CAL), probing depth (PD), plaque index (PI), and gingival index (GI). CAF root coverage procedures were performed to correct the recession defects. Patients were followed at 2, 4, 12, and 24 weeks post-surgery, at which time wound healing index (WHI) and other measurements were recorded.

Results: The mean baseline RD was 2.9 ± 0.4 mm; RW, 3.4 ± 0.6 mm; WKT, 2.7 ± 1.3 mm; and GT, 1.1 ± 0.3 mm. At mid-buccal, the mean CAL was 4.5 ± 0.8 mm. Six months after surgery, the average RC was $82.3\% \pm 24.7\%$; RD, 0.5 ± 0.7 mm; RW, 0.4 ± 0.9 mm; WKT, 3.2 ± 0.9 mm; and GT, 1.5 ± 0.5 mm. At mid-buccal, the mean CAL was 1.8 ± 1.1 mm. From baseline to the 6-month follow-up, the changes of RC, RD, RW, WKT, GT, and CAL showed statistical significance ($P < 0.05$). Fourteen patients achieved 100% RC. The mean RC in partial coverage cases was $54.8\% \pm 16.8\%$. Analysis revealed that an initial GT thicker than 1.2 ± 0.3 mm was associated with complete root coverage at the 6-month follow-up ($P < 0.05$).

Conclusions: CAF is a predictable procedure to treat Miller's Class I mucogingival defects. Initial GT was the most significant factor associated with complete root coverage. *J Periodontol* 2005;76:1729-1734.

KEY WORDS

Gingival recession/surgery; gingival recession/therapy; outcomes assessment; surgical flaps.

Gingival recession causes periodontal attachment loss. If left untreated or unmonitored, it can be detrimental to periodontal or dental health. Therefore, various root coverage procedures have been suggested to correct the recession defects. Among these techniques, the coronally advanced flap (CAF) has been used solely^{1,2} or combined with other procedures, e.g., guided tissue regeneration (GTR)-based root coverage³ and subepithelial connective tissue graft.⁴

The effectiveness of CAF has been reviewed.^{2,5,6} The primary clinical outcome is the percentage of coverage of the previously exposed root surface. However, due to diverse study designs and techniques, there is a wide range of results. A well-controlled randomized clinical trial with adequate power is considered the ideal study design that contributes to objective results. Unfortunately, only limited studies are performed in such a manner. Therefore, a meta-analysis, a collection of quality literature according to selected criteria, ranked the study independently, weighted the data correspondingly, and has been accepted as the consensus while discussing the predictability of the procedure. Based on the meta-analyses,^{5,6} for the CAF, the average root coverage ranged from 75% to 82.7%, with 24% to 95% of sites achieving complete root coverage. Conclusions from these articles also confirmed that there were many factors that could influence the outcomes.

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Various studies have examined factors that can be classified as anatomical, patient, and surgical/technical factors. Anatomical factors were adjacent bone height,⁷ adjacent papilla dimension,⁸ defect size,⁹⁻¹⁴ flap thickness,¹⁵ and the location of the tooth.¹⁰ Patient factors, such as smoking, showed negative influences on the clinical results.^{11,16-18} Surgical factors, such as the surgeon's clinical experience,^{19,20} flap tension,²¹ and root surface preparation techniques,^{2,22-24} demonstrated different levels of impact. However, none of the studies investigated the factors that were most associated with successful outcomes. Hence, the purpose of this study was to analyze and identify the factors that affect the outcomes of CAF root coverage procedures.

MATERIALS AND METHODS

Study Design

This study was reviewed and approved by the University of Michigan Institutional Review Board committee. Twenty-three patients were recruited from the patient population of the University of Michigan School of Dentistry from January 2, 2003 to February 28, 2004. The inclusion criteria were as follows: 1) systemically healthy; 2) non-smokers; 3) patients who were willing to give informed consent; 4) ≥ 18 years old; 5) ability to maintain good oral hygiene (O'Leary plaque score²⁵ $\leq 20\%$); 6) maxillary or mandibular incisors, canines, or premolars with Miller's Class I facial mucogingival defects⁷; and 7) width of keratinized gingiva ≥ 1 mm. The exclusion criteria were as follows: 1) previous mucogingival surgery at the defect; 2) long-term (>2 weeks) use of antibiotics in the past 3 months; 3) known allergies to the materials used; 4) with compromised healing potential; 5) with active infectious diseases (hepatitis, tuberculosis, HIV, etc.); 6) taking steroids or medications known to cause gingival enlargement; and 7) pregnant or attempting to get pregnant.

Presurgical treatments included oral hygiene instructions, scaling and root planing, polishing, or occlusal adjustment as indicated. Subjects were required to complete baseline examinations. All surgical procedures were performed by one surgeon. A masked examiner recorded all clinical parameters, i.e., plaque index (PI), gingival index (GI), probing depth (PD), clinical attachment level (CAL), width of keratinized tissue (WKT), recession depth (RD), recession width (RW), and gingival tissue thickness, at baseline and at 3- and 6-month postoperative visits. The wound healing index (WHI) was recorded at 10 to 14 days and 1, 3, and 6 months after the surgery.

Clinical Parameters

Measuring stents were made from self-curing orthodontic acrylic resin. Clinically reproducible mea-

suring points were marked on the stent at the mesio-buccal, mid-buccal, and disto-buccal as standardized reference points.

1. PD was measured from the free gingival margin to the most apical part of the sulcus at mesio-buccal, mid-buccal, disto-buccal points on the stent to the nearest 0.5 mm with a University of North Carolina (UNC) probe.

2. CAL was measured from the cemento-enamel junction (CEJ) to the most apical part of the sulcus at the same reference points on the stent with the UNC probe.

3. WKT was measured at the mid-buccal point from the mucogingival junction (MGJ) to the free gingival margin by a Boley gauge.

4. RD was measured by a Boley gauge at the mid-buccal point. The calculation was the distance from the stent to the most apical point of free gingival margin subtracted from the distance from the stent to CEJ, which remained as a constant for each case throughout the study.

5. RW was measured at 1 mm apical to the CEJ by a Boley gauge.

6. Gingival thickness (GT) was measured at the mid-buccal 2 mm apical to the free gingival margin by penetrating a UNC probe into the tissue and recorded to the nearest 0.5 mm.

7. PI was recorded according to Silness and L oe.²⁶

8. GI was recorded according to L oe.²⁷

9. WHI was recorded after surgery using the following criteria: score 1 = uneventful healing with no gingival edema, erythema, suppuration, patient discomfort, or flap dehiscence; score 2 = uneventful healing with slight gingival edema, erythema, patient discomfort, or flap dehiscence, but no suppuration; and score 3 = poor wound healing with significant gingival edema, erythema, patient discomfort, flap dehiscence, or any suppuration.

10. The percentage of root coverage (RC) was calculated as $([RD \text{ preoperative} - RD \text{ postoperative}] / RD \text{ preoperative}) \times 100\%$.

Surgical Protocol

After achieving profound local anesthesia, sulcular incisions were made using 15C blades on the buccal side. The incisions at the papillae were made following their outline. The distance between the tip of the papillae and the incisions was the recession depth plus 1 mm or more. Two vertical incisions were made at the line angle of adjacent teeth and extended into the mucosa. A full-thickness flap was elevated. A releasing incision through the periosteum was made to allow the flap to be coronally positioned to cover the defect and CEJ without tension. Deepithelialization was performed at the papilla to provide the connective tissue bed for flap adaptation. The exposed root

surface was thoroughly planed by periodontal curets, high-speed fine carbide burs, and low-speed fine diamond burs to obtain a smooth and hard surface. After all procedures were finished, the flap was coronally advanced to cover the exposed root and sutured with 5-0 polyglactin 910.[‡] Gentle pressure was applied to achieve hemostasis and a close adaptation of the flap to the underlying surface. No surgical dressing was used.

Postoperative instructions were provided in oral and written forms. Analgesics (non-steroidal anti-inflammatory drugs [NSAIDs]) were prescribed to control postoperative discomfort. No antibiotic was prescribed. Patients were informed not to brush or floss the surgical sites for 3 to 4 weeks. Instead, they were instructed to alternate rinsing with salt water and 0.12% chlorhexidine gluconate rinse. Sutures were removed 10 to 14 days after the surgery. Oral hygiene instructions and professional cleaning were performed at each follow-up visit when indicated.

Statistical Analysis

Data were reported as mean \pm standard deviation. A statistical software program was used.[§] The Wilcoxon signed rank test was used to analyze parameters before and after treatment. The Mann-Whitney test was performed to evaluate the relationships of the specific factors and prediction of complete root coverage. A restricted/residual maximal likelihood (REML)-based mixed effect model was used for multivariate regression analysis of the factors that may influence the outcomes. All tests were two-sided, and differences were considered statistically significant when $P < 0.05$.

RESULTS

Demographic Results

Twenty-three patients were treated. The mean age of these patients was 43.8 ± 11.9 years (ranging from 24 to 63 years). There were 17 females and six males. Nineteen maxillary (11 canines and eight premolars) and four mandibular (two incisors and two premolars) teeth were treated.

Clinical Parameters

The average baseline RD was 2.9 ± 0.4 mm (range: 2.5 to 4 mm); RW, 3.4 ± 0.6 mm (range: 2 to 4.2 mm); WKT, 2.7 ± 1.3 mm (range: 1 to 5.8 mm); and GT, 1.1 ± 0.3 mm (range: 0.5 to 2 mm). At mid-buccal, the mean PD was 1.7 ± 0.8 mm (range: 1 to 4 mm) and CAL, 4.5 ± 0.8 mm (range: 3.5 to 6.5 mm). PI and GI ranged between 0 and 2.

At the 6-month follow-up, the average RC was $82.3\% \pm 24.7\%$ (range: 20% to 100%); RD, 0.5 ± 0.7 mm (range: 0 to 2 mm); RW, 0.4 ± 0.9 mm (range: 0 to 2.5 mm); WKT, 3.2 ± 0.9 mm (range: 2 to 6 mm); and GT, 1.5 ± 0.5 mm (range: 1 to 2.5 mm). At mid-buccal, the mean PD was 1.3 ± 0.6 mm (range:

1 to 3 mm) and CAL, 1.8 ± 1.1 mm (range: 0 to 4 mm). The mean WHI at the 2-week follow-up was 1.2 ± 0.4 . After 1 month, the WHI was 1 for each case. From baseline to the 6-month follow-up, the changes of RC, RD, RW, WKT, GT, and CAL at mid-buccal point showed statistical significance ($P < 0.05$). PI and GI were higher after the surgical procedure; however, they gradually returned to baseline with the resumption of oral hygiene routines.

Factors Associated With Complete Root Coverage

After 6 months, there were 14 patients who achieved 100% RC. The data was stratified into two groups: complete and partial coverage. The average RC in the partial coverage group was $54.8\% \pm 16.8\%$ (range: 20% to 79.3%). Analysis was performed based on factors such as patient age, tooth location (maxillary versus mandibular), GT, initial RD, initial RW, and surgeon experience (Table 1) and revealed that an initial GT thicker than 1.2 ± 0.3 mm was greatly associated with complete root coverage at the 6-month follow-up ($P < 0.05$). The mean initial GT of the partial coverage group was 1.0 ± 0.3 mm. The surgeon experience, patient age, tooth type, initial RD, and initial RW were not critical factors related to complete root coverage ($P > 0.05$).

Multiple Regression Analysis

The 6-month post-surgical RD reduction and RC was investigated by multiple regression analysis to explore the impact of specific factors, for example, patient age, tooth location (maxillary versus mandibular), initial GT, initial RD, initial RW, the surgeon experience, and the WHI at the 2-week post-operative follow-up. Overall, the tooth location showed a statistically significant relation to predicting RD reduction (Table 2) and RC (Table 3) ($P < 0.05$). The mandibular teeth decreased the RD reduction by 0.9 mm and RC by 35.4%. The patient's age presented only a marginally statistically significant relation to RC ($P > 0.05$). Each 1-year increase in age decreased the RC by 0.7%. Excluding the outlier, RC 20%, the initial GT and WHI at the 2-week follow-up showed a statistically significant relation to RD reduction (Table 4) and RC (Table 5) ($P < 0.05$).

DISCUSSION

Factors that influenced the final outcomes were analyzed. Initial GT was the most critical factor associated with complete root coverage in the CAF root coverage procedure. Based on this study, if initial GT was $>1.2 \pm 0.3$ mm, then the chance of achieving 100% RC was higher than those GT <1.2 mm that were not. This was in agreement with another study that reported

[‡] Vicryl, Ethicon, Somerville, NJ.

[§] SPSS 12, SPSS, Chicago, IL.

Table 1.
Factors Associated With Complete Root Coverage at the 6-Month Follow-Up

Factors	RC (%)	N	Mean Value*	P Value†
Age (years)	100	14	41.8 ± 12.6	NS
	<100	9	46.9 ± 10.6	
Tooth location (maxillary/mandibular)	100	14	13/1	NS
	<100	9	6/3	
Gingival thickness (mm)	100	14	1.2 ± 0.3	0.049‡
	<100	9	1.0 ± 0.3	
Initial recession depth (mm)	100	14	2.9 ± 0.4	NS
	<100	9	2.8 ± 0.2	
Initial recession width	100	14	3.3 ± 0.6	NS
	<100	9	3.5 ± 0.6	
Surgeon experience (days)§	100	14	121.7 ± 62.8	NS
	<100	9	128.6 ± 60.5	

* Mean ± standard deviation.

† P value was based on the Mann-Whitney test.

‡ Statistical significance ($P < 0.05$).

§ Surgeon experience was calculated as the days after the first patient was treated.

NS = not statistically significant.

Table 2.
Overall Multiple Regression Analysis for Recession Depth Reduction

Variable	Coefficient	Standard Error	t	P Value
β_0 (constant)	-0.97	1.04	-0.93	0.364
β_1 (arch)	-0.88	0.33	-2.67	0.015*
β_2 (RD)	1.22	0.36	3.43	0.003*

The dependent variable was recession depth reduction. The predictor variables were tooth location (arch) and initial recession depth (RD). Model: recession depth reduction = $\beta_0 + \beta_1$ arch + β_2 RD + ϵ ($P < 0.05^*$). $R^2 = 0.55$. Arch: maxillary = 0; mandibular = 1.

* Statistical significance.

Table 3.
Overall Multiple Regression Analysis for Root Coverage at 6-Month Follow-Up

Variable	Coefficient	Standard Error	t	P Value
β_0 (constant)	119.77	16.37	7.317	0.000*
β_1 (arch)	-35.43	10.94	-3.24	0.004*
β_2 (age)	-0.72	0.36	-2.00	0.59

The dependent variable was percentage of root coverage. The predictor variables were tooth location (arch) and age. Model: root coverage = $\beta_0 + \beta_1$ arch + β_2 age + ϵ ($P < 0.05^*$). $R^2 = 0.41$. Arch: maxillary = 0; mandibular = 1.

* Statistical significance.

that complete root coverage was related to tissue thicker than 0.8 mm.¹⁵ The difference of thickness was due to the different measuring techniques. Baldi et al.¹⁵ measured within the mucosa by an Iwanson gauge. In our study, GT was recorded at 2 mm apical to the gingival margin by bone sounding using a UNC probe, which measured the keratinized gingiva that would be attached to the exposed root surface after surgery.

Other anatomical factors have been proposed as essential factors to obtain complete root coverage. The level of adjacent periodontal tissue, i.e., interdental papilla⁸ and alveolar bone,⁷ showed direct impact to the final results. Based on the Miller's classification, complete root coverage is more predictable in Class I and II defects than Class

III or IV, in which cases lost adjacent alveolar bone height.⁷ Also, complete root coverage was significantly more frequent in sites with lower height adjacent papilla.⁸ Wider recession defects were considered more challenged than narrower ones.⁹ According to our study, the mean RW was greater in the partial coverage group. However, the difference did not reach statistical significance. On the other hand, the effect of initial RD on the amount of root coverage remains controversial regarding the effect of initial RD. However, this study demonstrated similar initial RD between the partial and complete covered cases. Some studies found that increased initial RD was associated with decreased complete root coverage or percentage of root coverage.^{13,14} Others observed a greater reduction of RD in deep recession defects.¹⁰⁻¹² The location of the tooth was investigated. Although it was not statistically significant, the trend was that maxillary teeth more predictably achieved complete root coverage than mandibular teeth. Among the teeth treated, mandibular premolars were found to be the most challenged (mean RC, 32.2% ± 17.3%). This finding was in agreement with the previous study.¹⁰

Other factors examined were patient age and surgeon's experience, which were not well documented in the literature. The mean patient age showed no statistically significant difference between groups; however, the mean age was younger in the complete root coverage group. The clinician learning curve did not show any effect on the final outcomes in this study. However, the surgeon's clinical experience may be a potential factor influencing judgments, case

Table 4.
Multiple Regression Analysis for Recession Depth Reduction (excluding outlier)

Variable	Coefficient	Standard Error	t	P Value
β_0 (constant)	-2.46	0.95	-2.59	0.019*
β_1 (GT)	0.90	0.33	2.69	0.015*
β_2 (WHI)	0.76	0.29	2.65	0.016*
β_3 (RD)	1.31	0.31	4.26	0.000*

The dependent variable was recession depth reduction. The predictor variables were initial gingival thickness (GT), wound healing index at the 2-week follow-up (WHI), and initial recession depth (RD). Model: recession depth reduction = $\beta_0 + \beta_1$ GT + β_2 WHI + β_3 RD + ϵ ($P < 0.05^*$). $R^2 = 0.62$. WHI 2 = 1; WHI 1 = 0

* Statistical significance.

Table 5.
Multiple Regression Analysis for Root Coverage at the 6-Month Follow-Up (excluding outlier)

Variable	Coefficient	Standard Error	t	P Value
β_0 (constant)	45.26	14.76	3.07	0.006*
β_1 (GT)	31.35	12.12	2.59	0.018*
β_2 (WHI)	24.96	10.30	2.42	0.025*

The dependent variable was percentage of root coverage. The predictor variables were initial gingival thickness (GT) and wound healing index at the 2-week follow-up (WHI). Model: root coverage = $\beta_0 + \beta_1$ GT + β_2 WHI + ϵ ($P < 0.05^*$). $R^2 = 0.35$. WHI 2 = 1; WHI 1 = 0.

* Statistical significance.

selection, and surgical skills. Comparing various root surface preparation techniques, either mechanical or chemical, showed no impressive clinical benefits in controlled human studies.^{22,28-31} The only factor showing positive impact during the surgery is flap tension.²¹ Based on this particular study, in the CAF root coverage procedure, flap with greater tension resulted in less root coverage, which was avoided in our surgical protocol.

Multiple regression analyses were performed to weigh the influence of specific predictor variables, such as patient age, tooth location, initial GT, initial RD, initial RW, surgeon experience, and the WHI at the 2-week postoperative follow-up. The dependent variable was the reduction of RD and RC. The RD reduction was positively correlated to initial RD and maxillary teeth. Excluding the outlier (RC = 20%) in the data, the RD reduction was positively correlated to initial RD, initial GT, and WHI at the 2-week operative follow-up. This suggested that mild postoperative complications, e.g., redness or swelling, did not

jeopardize the final clinical outcomes. The RC gain was associated with maxillary teeth. After excluding the outlier, the RC gain was associated with initial GT and WHI at the 2-week operative follow-up.

CAF is a predictable procedure to achieve root coverage in Miller's Class I mucogingival defects. However, several factors may contribute to various results. Based on the results of this study, the initial gingival thickness ($\geq 1.2 \pm 0.3$ mm) was the most decisive factor regarding the accomplishment of complete root coverage. To predict the percentage of root coverage or recession depth reduction 6 months after treatment, tooth location, initial gingival thickness, and initial recession depth should be taken into consideration. In addition, better outcomes can be expected in defects with thicker gingival tissue and located in the maxillary arch.

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