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Technique sensitivity hampers outcomes in periodontal regeneration when performed by less experienced operators: A retrospective analysis

Hamzeh Almashni[1], Ruben Leyton[1], Abdusalam Alrmali[1,2], Yousef Amrou[1], Hom-Lay Wang[1], and Muhammad H. A. Saleh[1]*

[1]Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, Michigan, United States of America

[2]Department of Oral Medicine, Oral Pathology, and Oral & Maxillofacial Surgery, School of Dentistry, University of Tripoli, Tripoli, Libya

Abstract

Flap design is a key factor in the clinical outcomes of periodontal regeneration (PR). This study compares the effectiveness of minimally invasive flap (MIF) to conventional flap (CF) techniques in PR procedures performed by periodontic residents. The study also addresses how technique sensitivity may influence clinical outcomes when performed by less experienced operators. A retrospective study was conducted on patients who underwent PR from January 2012 to January 2023 at the School of Dentistry, University of Michigan. Flap techniques were classified as MIF or CF, and clinical outcomes, including bleeding on probing (BOP), probing depth (PD), clinical attachment level (CAL), gingival recession (GR), changes in keratinized gingiva, and tooth loss, were evaluated. Statistical analysis using generalized estimation equations was performed for the overall sample and separately for each group. The study sample consisted of 40 male (45.5%) and 48 female patients (54.5%), with an average age of 63.1 ± 13.8 years and a mean follow-up of 42 months. No significant differences were found between the MIF and CF groups regarding the reduction in PD or GR. However, the CF group exhibited a superior gain in CAL (p=0.005) and a greater decrease in BOP after adjustment for confounders (odds ratio: 4.44, p=0.0276). Tooth type and defect depth were identified as significant factors affecting clinical outcomes. Both techniques were effective in treating periodontal defects. However, the CF approach demonstrated a greater improvement in CAL and BOP. Given the technique-sensitive nature of MIF, the limited clinical experience of resident operators may have contributed to the diminished performance of MIF observed in this study. Simpler surgical techniques may offer comparable effectiveness to more complex, superior surgical techniques in a university-based setting when performed by less experienced operators.

Keywords: Guided tissue regeneration; Periodontal disease; University-based services; Smoking

***Corresponding author:**
Muhammad H. A. Saleh
(muhsaleh@umich.edu)

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1. Introduction

Periodontal regeneration (PR) is a valuable treatment modality for managing isolated furcation and intrabony defects (IBD).[1,2] Several systemic and localized factors are considered well-evidenced risk factors and predictors of periodontal and peri-implant therapy success.[3-5] In addition, numerous clinical studies have explored the impact of various membranes, bone grafts, and biological agents on PR success.[6-8] Despite these variables, the clinician's skill in several aspects of the procedure—such as case selection, incision and flap design optimization, supra-crestal tissue compartment management, materials selection, membrane manipulation, and type of suturing techniques—directly influences the healing process. Ultimately, these skills impact the outcomes of the PR procedure.[9] Therefore, ongoing refinement of skills and adopting technological innovations are essential for achieving the best possible results for patients.[10]

The conventional flap (CF) technique, involving buccal and lingual/oral flap reflection beyond the limits of IBD,[11] is commonly used due to its convenience and ease of execution.[12,13] However, recognizing the importance of effective access to the interdental blood supply, wound closure, and optimal tissue/bone regeneration, various surgical approaches have been developed.[14] Minimally invasive flap (MIF) techniques aim to limit tissue reflection, thereby reducing surgical trauma and lowering the risk of post-operative complications, the most common of which is membrane exposure.[15-20] Notable examples include the papilla-preserving flap technique introduced by Takei in 1985,[21] its modifications by Cortellini in 1995 and 1999,[15,16] the minimally invasive surgical technique (MIST),[22-24] and its later modification, the modified MIST (M-MIST).[18] In treating deep IBD, using an MIF is crucial to optimize wound stability, maintain flap integrity, and promote primary intention healing in molars.[25,26]

Studies have investigated the outcome of surgical and non-surgical procedures performed by inexperienced clinicians, such as university-based periodontal residents.[27-29] Brayer *et al.*[27] reported that root debridement performed by 2nd-year periodontal residents compared to fully trained American board-certified, experienced level 1 clinicians was less effective. In a retrospective analysis, Kozlovsky *et al.*[28] concluded that the operator's experience level will affect the outcome and the patient's compliance. Similarly, Ozcan *et al.*[29] compared the reported clinical and esthetic results of coronally advanced flap procedures for the treatment of gingival recession (GR). The 6-month results showed that an advanced surgical experience level results in higher percentages of root coverage. In addition, as the experience level increased, the rate of complications and the operative time decreased.

There are currently no reports in the literature assessing the efficacy of technique-sensitive procedures, such as MIF, compared to more straightforward procedures, such as CFs for PR in inexperienced clinicians. Therefore, the study aims to evaluate the outcomes of using MIF incisions compared to CF in PR procedures performed by less experienced periodontal residents while considering systemic risk factors/predictors of included subjects, hypothesizing that MIF should result in more predictable outcomes compared to CF, consistent with the available literature.[15,16]

2. Methodology

2.1. Study population

Patient data of those who underwent periodontal therapy from January 2012 to January 2023 at the School of Dentistry, University of Michigan, in Ann Arbor, Michigan, United States, were retrieved from electronic health records. The research received ethical clearance from the Institutional Review Board of the University of Michigan (IRBMED: HUM00248789).

2.2. Data collection

2.2.1. Inclusion criteria

The inclusion criteria are as follows:

(i) Individuals aged ≥18 years
(ii) Individuals diagnosed with IBD ≥ 5 mm probing depth (PD) of vital anterior, pre-molar, or molar, with or without furcation involvement, treated with PR in the post-graduate periodontics department at the University of Michigan.
(iii) Individuals with baseline and follow-up periodontal charts with complete clinical parameters (clinical attachment level [CAL], PD, bleeding on probing [BOP]) and comprehensive clinical notes describing the PR procedure in detail, indicating the type of flap used and the materials utilized.
(iv) Patients compliant with supportive periodontal therapy following surgeries.

2.2.2. Exclusion criteria

The exclusion criteria are as follows:

(i) Individuals with hopeless teeth (Based on the definition provided by Sanz *et al.*[30]).
(ii) Individuals with systemic conditions that were generally considered to be contraindications to periodontal surgery, but not limited to severe osteoporosis, uncontrolled diabetes, and blood dyscrasias.

(iii) Individuals who were pregnant or lactating.
(iv) Individuals who did not have baseline and/or follow-up complete periodontal charts or clinical notes, especially those not specifying the flap technique used for PR.

2.2.3. Flap technique description

Two flap techniques were investigated in this study: (i) MIF and (ii) CF techniques. MIF technique is a general term describing conservative flap reflection to the bony limits of the defect or to single-flap designs. This study included the modified papilla preservative incision technique,[16] the simplified papilla preservation (SPPF) incision technique,[15] and the entire papilla preservation technique.[18,25,31] Figure 1 illustrates the SPPF technique. Results of subgroup analysis are presented in Table S1. CF technique consists of a buccal and lingual/oral flap reflection beyond the limits of the IBD, usually a horizontal crestal incision with or without vertical releasing incisions to reflect a full-thickness or partial-thickness flap.[11,13] Figure 2 illustrates the CF technique.

Two independent evaluators collected the data retrospectively of two patient cohorts from previously treated PR cases: The experimental group, in which incisions were performed using the MIF designs, and the control group, in which the CF approach was employed. For both groups, a comprehensive review of available clinical records was conducted regarding the specific incision and flap techniques employed, the type of membrane and graft used, the biological agents utilized, and all post-operative complications encountered.

At the patient level, demographics captured included patient sex and age, while general health data encompassed the presence of diabetes mellitus at the onset of PR therapy and smoking history categorized as non-smoker, former smoker, or current smoker (along with daily cigarette consumption). Each patient's periodontal status was classified using the staging and grading system for periodontitis, which includes stage (1–4), grade (A, B, and C), and extent (localized, generalized), as defined immediately before PR treatment.[32] In addition, the analysis considered the duration of each patient's follow-up as well as the frequency of maintenance visits after the procedure.

At the tooth level, tooth-specific clinical parameters, such as PD, CAL (formerly calculated and recorded in the chart as the difference between PD and the distance from the free gingival margin to the cementoenamel junction), BOP, and tooth mobility, were assessed alongside the width of keratinized tissue. Furcation involvement was examined for the molar tooth.[33] Two time points were considered

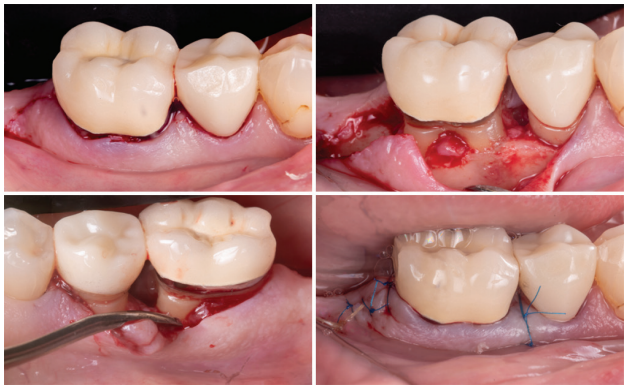

Figure 1. Representation of the simplified papilla preservation flap performed by a periodontics resident

Figure 2. Representation of the conventional flap technique performed by a periodontics resident

in data collection: T0, indicating the baseline period before surgical intervention, and T1, representing the past follow-up chart, at least 12 months after the procedure. Intra-operative details specifically focused on the dimensions and morphology of the periodontal defects, the bone graft used, and the type of membrane used in the PR procedure, if any. Any biological agents deployed, antibiotics prescribed, and post-operative complications, including infections or membrane exposures, were collected.

For operators, their levels were determined by the year of the procedure and the corresponding resident level. R1 was designated as 1st-year residents, R2 as 2nd-year residents, and R3 as 3rd-year residents.

2.3. Statistical analysis

Statistical analysis was conducted using the Statistical Package for Social Sciences software (version 22.0, IBM, United States). The following clinical parameters were considered primary outcomes: BOP, PD reduction, CAL gain, keratinized gingiva (KT) change, GR at T1, and

tooth loss due to periodontal reasons (TLP).[34] At the tooth level, multilevel binary logistic regression with generalized estimation equations was used to relate the independent factors and covariates to the binary outcomes (e.g., TLP, BOP at T1). Raw odds ratio (OR) and 95% confidence intervals (CI) were obtained from the Wald's χ^2 statistic. Then, multiple models were estimated to adjust by potential confounding factors (at patient's level, such as age, sex, smoking, diabetes mellitus, periodontitis diagnosis, number of maintenance visits, and duration of follow-up, as well as clinical data, including the number of walls, antibiotic use, the type of membrane applied, furcation involvement, number of walls of the defect, defect dimensions, and the type of grafting material). Quantitative outcomes (e.g., CAL gain, PD reduction, KT change, and GR at T1) were analyzed using linear regression models estimated with generalized estimation equations to control the within-subject dependence of teeth. Beta coefficients and 95% CIs were reported. As previously mentioned, multiple models were estimated. The significance level used in the analysis was 5% ($\alpha = 0.05$).

To ensure sufficient statistical power to detect a clinically valuable difference between the MIF and CF groups, a power analysis using a *post hoc* estimation was performed. A sample size of 99 independent teeth provides 72.3% power at a 95% confidence level to detect an OR of 3 as significant using a logistic regression model (an OR of 3 is equivalent to comparing rates of 50% and 25%, for example, for BOP rates). However, since teeth were not independent observations, the power was adjusted to account for the two-level structure of the data. Each patient provided an average of 1.13 teeth. Assuming a moderate within-subject correlation of 0.5, a correcting coefficient of 1.06 was obtained. Therefore, a sample of 99 dependent teeth was equivalent to 93 independent observations, yielding an estimated power of 70.0% under the same previous conditions.

3. Results

3.1. Characteristics of the study population

There were 40 males (45.5%) and 48 females (54.5%), with an average age of 63.1 ± 13.8 years, ranging from 30 to 87 years at baseline. Each patient contributed, on average, 1.13 teeth to the database, resulting in a total sample of 99 teeth (40 in the MIF group and 59 in the CF group) treated by 84 post-graduate residents. Table 1 summarizes the demographic characteristics of both groups, the type and location of tooth, and the operator level.

The sample included 88 patients who underwent either MIF (n = 36, consisting of 30% SPPF incision technique, 47.5% modified papillary preservation incision technique, and 22.5% papillary preservation incision technique) or CF (n = 52) procedures. The mean follow-up period after treatment was 42.0 ± 30.1 months, ranging from 2 to 163 months (median: 34; interquartile range: 19–57).

In terms of group homogeneity, no significant differences were found between the groups regarding patient-level covariates, such as sex, age, diabetes mellitus, smoking, and periodontitis diagnosis (staging and grading), as well as the number of follow-up visits (p>0.05). Group homogeneity information is presented in Table S2.

No significant difference was found in the treating residents' level, with 2nd-year residents predominately contributing to both groups (MIF: 47.6%, CF: 52.3%).

3.2. Analysis of changes in clinical outcomes

3.2.1. Effect of procedure complexity on clinical outcomes

The mean CAL gain was found to be 2.17 ± 2.18 mm for the CF group, in contrast to only 0.59 ± 3.43 mm for the MIF group (Figure 3). Significant differences in CAL gain remained between the groups even after adjusting

Table 1. Demographic characteristics of both groups, the type and location of the tooth, and the operator level

Demographic characteristics	Total	CF	MIF
Number of patients	88	52	36
Age, mean (years)	63.1±13.8	63.16	63.45
Sex (M/F)	40/48	25/28	15/20
Follow-up time, mean (months)	42.0±30.1	44.85	38.5
Number of teeth	99	59	40
Type of the tooth (%) (M/P/C/I)	65.7/19.2/4.0/11.1	86.4/6.8/5.1/1.7	35.0/37.5/2.50/25.0
Arch (%) (Max/Man)	44.3/55.6	62.5/37.5	32.2/67.8
Operator level (R1, R2, R3)	13, 42, 29	9, 22, 19	4, 20, 10

Note: R1, R2, and R3 refer to 1st-year residents, 2nd-year residents, and 3rd-year residents, respectively.
Abbreviations: CF: Conventional flap; M/F: Male/female; M/P/C/I: Molar/premolar/canine/incisor; Max/Man: Maxilla/mandible; MIF: Minimally invasive flap.

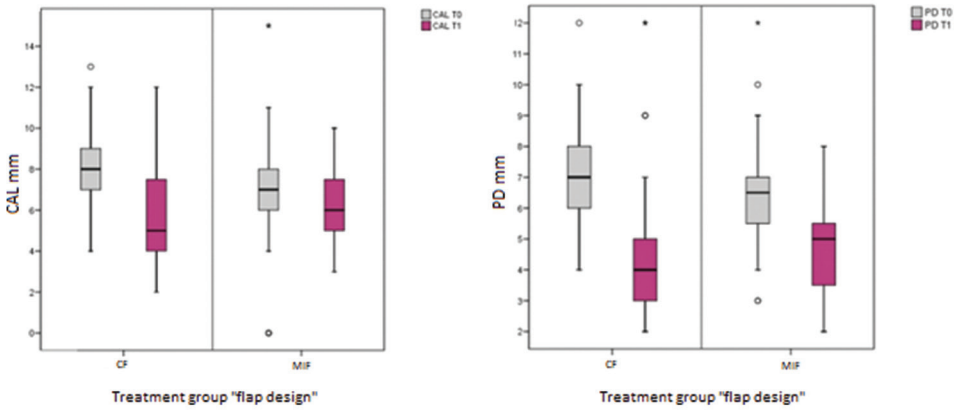

Figure 3. CAL gain and PD reduction for MIF and CF at T0 and T1. (A) CAL gain; (B) PD reduction. The mean CAL gain decreased by 2.17 ± 2.18 mm from T0 to T1 for the CF group, in contrast to only 0.59 ± 3.43 mm for the MIF group. T0 and T1 refer to the 1st and 2nd time points, respectively
Abbreviations: CAL: Clinical attachment level; CF: Conventional flap; MIF: Minimally invasive flap; PD: Probing depth.

for confounding factors (p<0.001), indicating a greater CAL gain for the MIF group (Tables 2 and S3). Both the MIF and the CF groups showed improvements in PD and BOP at the follow-up. However, no significant differences were observed between the two groups in PD reduction (p=0.218) (Table 3). BOP was slightly higher in the MIF group at T1 (p=0.047) (Figure 4). Similarly, for GR, no statistically significant difference was found between the CF and MIF groups (p=0.073) (Tables S4-S7).

3.2.2. Effect of covariates on clinical outcomes

The depth of the defect was a critical factor, as it negatively impacted the CAL gain outcome (p=0.003) (Table 2). Teeth in the Stage 3 or 4 patients resulted in higher PD reductions compared to Stage 1 patients (p=0.003, Table S8). Deeper and larger defects were correlated to less PD reductions (p=0.001 and p=0.020, respectively) (Tables 3 and S8).

3.3. Analysis of tooth loss due to periodontitis

MIF and CF showed the same TLP rate (p=0.521). A more significant occurrence of TLP was noted in teeth with furcation involvement, regardless of the flap design (OR: 4.3, p=0.035).

4. Discussion

The study investigated the effectiveness of two flap designs, MIF and CF, in treating isolated intra-bony and furcation defects within a periodontics residency program. Both techniques were effective in treating periodontal defects. No statistically significant differences were found between the two groups regarding PD, GR, or TLP. Nonetheless, notable differences emerged between the MIF and CF groups in terms of CAL gain and BOP reduction.

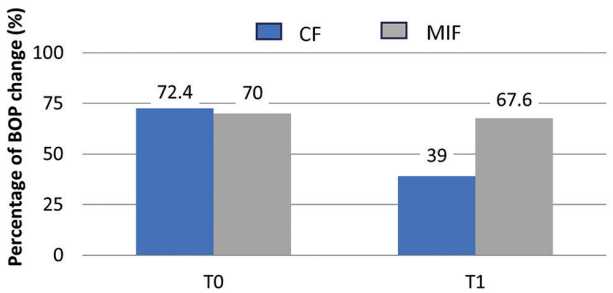

Figure 4. Percentage of BOP changes by group. The CF group demonstrated improved BOP changes compared to the MIF group from T0 to T1. A total of 41.4% of teeth reported an improved BOP status in the CF group, but only 17.6% in the MIF group. T0 and T1 refer to the 1st and 2nd time points, respectively.
Abbreviations: BOP: Bleeding on probing; CF: Conventional flap; MIF: Minimally invasive flap.

Considering the CAL gain, several factors contributed to the superior gain in the CF group compared to the MIF group. The insufficient gingival phenotype (keratinized width and thickness) that was found to be significantly lower in the MIF group can negatively impact the results. According to Tonetti *et al.*[3,35] and a recent review by Levine *et al.*,[3,35] a thin gingival phenotype appears to be at greater risk of exhibiting GR in response to regenerative procedures than a thick phenotype. The keratinized tissue width appears to play a role in flap stability and flap micromotion prevention, affecting healing. De Ry *et al.*[36] presented 10-year follow-up results of PR with enamel matrix derivatives, reporting that maxillary molars were correlated with an increased risk for CAL loss. This aligns with the findings in our cohort, with the CF group mostly in the mandibular arch compared to the MIF group.

Table 2. Multiple linear regression using generalized estimation equation model estimation of clinical attachment level gain (T0–T1) by independent factors and covariates

Factors	β	95% confidence interval	*p*-value
Group			
CF	0	-	-
MIF	−1.65	−2.48–−0.82	<0.001***
Stage			0.069
2	0	-	-
3	−1.47	−2.81–−0.14	0.031*
4	−1.90	−3.57–−0.22	0.027*
Position			0.010*
Anterior	0		
Premolar	1.07	−0CF.09–2.04	0.032*
Molar	−0.47	−1.35–0.41	0.291
Arch			
Maxilla	0	-	-
Mandible	−0.45	−1.13–0.22	0.188
No. of walls			0.305
1	0	-	-
2	−0.74	−1.86–0.39	0.198
3	0.23	−0.92–1.37	0.701
Defect depth	−0.24	−0.39–−0.08	0.003**
Antibiotics			
No	0	-	-
Yes	−0.31	−1.11–0.49	0.451
CAL T0	0.67	0.53–0.81	<0.001***
KT T0			
No	0	-	-
Yes	−0.14	−0.96–0.67	0.733

Notes: Statistical significance determined at *p<0.05, ** p<0.01, and ***p<0.001. T0 refers to the 1st time point.
Abbreviations: CAL: Clinical attachment level; CF: Conventional flap; KT: Keratinized gingiva; MIF: Minimally invasive flap.

Table 3. PD reduction (T0–T1) by independent factors and covariates

Factors	β	95% confidence interval	*p*-value
Group			
CF	0	-	-
MIF	−0.41	−1.07–0.24	0.218
Stage			0.730[a]
2	0	-	-
3	0.34	−0.62–1.31	0.484
4	0.58	−1.04–2.20	0.483
Position			0.014*
Anterior	0	-	-
Premolar	0.05	−0.74 – 0.85	0.896
Molar	−0.77	−1.55–0.02	0.056
Arch			
Maxilla	0	-	-
Mandible	0.28	−0.29–0.85	0.331
No. of walls			0.843
1	0	-	-
2	−0.23	−1.08–0.63	0.608
3	0.03	−0.79–0.85	0.331
Defect depth	−0.25	−0.39–−0.11	<0.001***
Defect width	0.00	−0.14–0.14	0.997
Antibiotics			
No	0	-	-
Yes	−0.31	−0.92–0.31	0.331
No. of furcation			
0	0	-	-
≥1	−0.44	−1.17–0.29	0.241
PD T0	0.65	0.47–0.83	<0.001***
KT T0			
No	0	-	-
Yes	−0.39	−1.05–0.27	0.245

Notes: Statistical significance determined at *p<0.05, **p<0.01, and ***p<0.001. T0 refers to the 1st time point.
Abbreviations: CAL: Clinical attachment level; CF: Conventional flap; KT: Keratinized gingiva; MIF: Minimally invasive flap; PD: Probing depth.

The technique sensitivity of the MIF procedures, which requires a more experienced operator and proper magnification, might contribute to less CAL gain in this group, assuming it was sub-optimally executed by training residents, therefore leading to less favorable outcomes. The initial defect depth was found to affect CAL gain outcome significantly, aligning with the findings of Tonetti *et al.*[37] However, no significant difference was found in the initial defect depth between the groups.

Regarding the PD reduction, there was no significant difference between the CF and MIF groups, with molar teeth showing less improvement compared to pre-molar and anterior teeth. Nibali *et al.*[26] stated that papilla preservation flaps yield superior outcomes and should be regarded as an essential surgical step in any regenerative procedure that aims to achieve better PD results. Our finding of no difference in PD reduction is aligned with a study by Windisch *et al.*,[38] which also reported no differences in resulting PD reduction irrespective of the employed surgical technique for IBDs treatment with enamel matrix derivatives.

Both groups demonstrated improvements in BOP, with significantly greater reduction in BOP in the CF group

than the MIF group at T1, as reported by the multiple regression model. This indicates a higher level of persistent inflammation in the MIF group in our cohort, which is mainly located in the maxil.[39] This aligns with a previous study by De Ry *et al.*,[36] which reported that maxillary molars are more prone to complications than mandibular molars.

GR improvement was observed in both groups, with the CF group showing slightly better, but insignificant, improvement compared to the MIF group at T1. This might be attributed to the difference in gingival phenotype discussed earlier. Some relapse might also be expected over the follow-up period. In our cohort, longer follow-up periods were associated with a higher incidence of GR.

The robustness of our investigation lies in its comprehensive examination of the effectiveness of surgical methodologies in facilitating PR, juxtaposed with the operator's proficiency level. All patients in this study were compliant with supportive periodontal therapy. In addition, our analysis encompassed consideration of various systemic and localized variables pertinent to the procedure. However, the retrospective nature of the study limits our ability to establish a causal relationship between flap design and treatment outcomes. Prospective, randomized controlled trials would provide more substantial evidence, especially when considering novel techniques for gingival augmentation, as well as cell technologies, collagen matrices, mucoderm, mucograft, gene therapy, and gene-activated materials.[40,41] Furthermore, the majority of the teeth involved were molars. Nevertheless, there were no differences attributable to technique between different tooth locations or between furcation and non-furcation teeth. In addition, the study's reliance on a university-based environment may introduce selection bias, potentially affecting the generalizability of the findings. Despite attempts to adjust for confounding variables, other unmeasured factors may influence treatment outcomes, oral hygiene habits, and systemic health conditions. The variability in follow-up duration, ranging from 12 to 163 months, may introduce bias and affect the interpretation of long-term treatment outcomes. The study observed a varied distribution of flap techniques intraorally, which may introduce heterogeneity in treatment outcomes. Standardization of treatment protocols could enhance the reliability of comparisons between groups. While the study evaluated several clinical parameters, other important factors, such as patient-reported outcomes and radiographic assessments, were not included due to the lack of systematic collection of such data. This limited the comprehensiveness of the analysis.

Our study was conducted in a university-level setting, where the procedures were executed by residents under the supervision of a faculty member, potentially affecting the results. Lizio *et al.*[42] concluded that the level of the operator's expertise is relevant in conditioning the final results. Yet, the study provides valuable insights into PR efficacy, particularly for those in training or with limited experience. Both MIF and CF techniques were effective in treating periodontal defects. These findings can guide periodontists in selecting the most appropriate surgical techniques based on individual patient needs and clinical goals, ultimately enhancing overall outcomes.

Studies with more standardized protocols of higher sample sizes might be needed to further evaluate the efficacy of MIF techniques compared to CF on PR outcomes, especially in treating posterior multirooted teeth.

5. Conclusion

Both MIF and CF techniques conducted by periodontic graduate residents within a university-based setting effectively treated periodontal defects. However, the CF approach demonstrated superior improvements in CAL and BOP. In addition, simpler flap designs can offer comparable outcomes to more complex techniques conducted by less experienced operators in less-than-ideal clinical situations.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Hamzeh Almashni, Abdusalam Alrmali
Investigation: Hamzeh Almashni, Ruben Leyton, Yousef Amrou
Methodology: Hamzeh Almashni, Abdusalam Alrmali, Muhammad H. A. Saleh
Project administration: Hamzeh Almashni
Writing – original draft: Hamzeh Almashni, Ruben Leyton, Abdusalam Alrmali
Writing – review & editing: Muhammad H. A. Saleh, Hom-Lay Wang

Ethics approval and consent to participate

The Institutional Review Board (IRB) for the Medical Sciences at the University of Michigan, Ann Arbor, MI, reviewed and approved this study before enrollment of participants began (IRBMED: HUM00248789). Informed consent was obtained from all participants before participation in the study.

Consent for publication

Participants consented to the publication of their data.

Availability of data

The original raw data collected are available from the corresponding author upon reasonable request.

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