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HUMAN RANDOMIZED CONTROLLED TRIAL

Flap versus flapless alveolar ridge preservation: A clinical and histological single-blinded, randomized controlled trial

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Abstract

Background: The aim of this randomized clinical trial was to compare a flapless technique of alveolar ridge preservation (ARP) to a flap technique to determine if preserving the periosteal blood supply would limit loss of crestal ridge width and height.

Methods: Twenty-four patients were randomly assigned to receive ARP using either a flapless or flap technique. Sockets were grafted with demineralized bone matrix and mineralized particulate allograft then covered with a barrier in both groups. Re-entry was performed at 4 months to obtain samples for histological analysis and subsequent implant placement.

Results: Ridge width of the flapless group at the crest decreased from 8.3 ± 1.3 mm to 7.0 ± 1.9 mm for a mean loss of 1.3 ± 0.9 mm ($p < 0.05$), whereas the flap group decreased from 8.5 ± 1.5 mm to 7.5 ± 1.5 mm for a mean loss of 1.0 ± 1.1 mm ($p < 0.05$). The mean midbuccal vertical change for the flap group was a loss of 0.9 ± 1.3 mm ($p < 0.05$) versus 0.5 ± 0.9 mm ($p < 0.05$) for the flapless group. There was no statistically significant difference between the groups. Histologically, flapless ARP revealed more vital mineralized tissue (44 ± 10%) compared to the flap group ($p>0.05$). In the flapless group, the occlusal soft tissue was significantly thicker than in the flap group at the 4-month re-entry ($p< 0.05$).

Conclusions: Crestal ridge width, height, and percentage of vital mineralized bone following treatment with a flapless ARP technique, was not significantly different from a flap technique.

KEYWORDS
alveolar ridge augmentation, clinical trial, dental implant, tooth extraction, tooth socket

Trever L. Siu and Himabindu Dukka contributed equally to the manuscript.

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1 | INTRODUCTION

Alveolar ridge preservation (ARP) is a procedure designed to attenuate postextraction osseous ridge dimension changes. Most studies on postextraction dimensional changes show that following extraction of single teeth, the horizontal dimension is most affected by loss, while the vertical dimension undergoes only slight change.[1,2] Extraction studies, in general, show that there is substantial loss of horizontal ridge width that increases with time. "Thus, studies with 12-month observational periods demonstrate more loss than 6-month follow-up studies, which show more loss than 4-month follow-up studies."[3–5]

Reflection of a mucoperiosteal flap has been shown to cause loss of crestal alveolar bone.[6] These studies were performed with the tooth present, when the crestal bone had a dual blood supply from both the periosteum as well as the periodontal ligament and when it was not possible to determine an effect on ridge width.[7] Crestal bone loss may have been at least in part due to the disruption of blood supply derived from the periosteum. The thin nature of the crestal bone and its minimal vascular supply make it prone to resorption leading to loss of crestal width.[8] Hence, it may seem advantageous to avoid flap reflection and preserve the remaining blood supply from the periosteum.

However, there is still conflicting evidence regarding significant benefit, or lack thereof, associated with a flapless surgical procedure compared to traditional flap reflection as it relates to postextraction bone loss and subsequent ARP procedures. Animal studies have not demonstrated a significant difference in alveolar bone loss between full-thickness flap and flapless or partial thickness flap elevation.[9,10] Similarly, no histological or histomorphometric differences were reported between the flap and flapless approaches for tooth extraction and socket grafting procedures in humans.[11] In contrast, in a human study by Barone et al. and a canine model by Fickl et al., it was shown that more bone resorption occurred with a full-thickness flap in postextraction sockets.[12,13] As indicated by the recent systematic reviews, there is a need for clinical studies investigating ARP that allow for direct comparison between surgical variables, such as flap reflection, among others.[3,14]

Hence, the primary aim of this randomized controlled single-blinded clinical trial was to compare a flapless technique of ARP versus a conventional flap technique. We hypothesize that preserving the periosteal blood supply may minimize loss of crestal ridge width and height.

As a secondary objective, the histological composition of the newly formed bone that occupies the extraction socket was evaluated to determine vital bone percentage. It was hypothesized that the increased vascularity provided by the intact periosteum lining the facial and lingual bone may promote more rapid vascularization of the graft, resulting in greater formation of vital bone and faster resorption of nonvital/residual graft particles.

2 | MATERIALS AND METHODS

2.1 | Ethical approval and registration

This randomized, single-blinded controlled clinical trial reports on patients presenting to the Graduate Periodontology Clinic at the University of Louisville, Kentucky, and requiring ARP for the purpose of implant placement. This study was conducted in accordance with the Helsinki Declaration for the ethical principles for medical research involving human subjects, as revised in 2013. The study was approved by the institutional review board (IRB) of University of Louisville, Kentucky, protocol #047.06. The study was registered at the US National Library of Medicine (ClinicalTrials.gov: NCT01901783). The present study complies with the Consolidated Standards of Reporting Trials (CONSORT) guidelines.[15]

2.2 | Study design and population

Twenty-four patients participated in this randomized controlled, single-blinded clinical trial with two parallel study groups, conducted at a single center. This study was conducted at the University of Louisville School of Dentistry, Department of Periodontics. By random selection, using a coin toss, patients were assigned either to the test or control group. Twelve control patients were selected to receive an intrasocket graft composed of demineralized bone matrix allograft* mixed with a corticocancellous mineralized particulate allograft† and covered by a calcium sulfate barrier‡ using a full-thickness flap technique. Twelve test patients received the same intrasocket allograft mixture covered by a calcium sulfate barrier using a flapless technique. All clinicians and examiners participating in the trial were calibrated before the surgeries and the measurements.

2.3 | Inclusion criteria

The following inclusion criteria were applied: (1) had one nonmolar tooth treatment planned for extraction and replacement with a dental implant where at least one adja-

* Grafton Matrix Plug, BioHorizons, Birmingham, Alabama.
† MinerOss, BioHorizons, Birmingham, Alabama.
‡ CalForma, Lifecore Biomedical, Inc., Chaska, Minnesota.

cent tooth was present and (2) the study subjects were at least 18 years old and had signed an informed consent.

2.4 | Exclusion criteria

The following exclusion criteria were applied: (1) had a debilitating systemic disease or a disease that affected the periodontium, (2) had an allergy to any material or medication used in the study, (3) required prophylactic antibiotics, (4) had previous head and neck radiation therapy, (5) had chemotherapy in the previous 12 months, (6) were taking long term nonsteroidal anti-inflammatory drugs or steroid therapy, and (7) smoked more than one pack of cigarettes per day.

2.5 | Surgical treatment

For the flap group, a papilla preservation incision was utilized to raise a full-thickness mucoperiosteal flap on the facial and palatal/lingual bone to expose the alveolar ridge (Figure 1a-A, B). The flap was reflected past the mucogingival junction, beyond 5 mm from the crest. Teeth were elevated and extracted with periotomes, elevators, and forceps. For the flapless group, the same extraction technique was utilized without flap reflection (Figure 1b, A, B). The extraction socket was then curetted to remove all granulation tissue. Both the demineralized bone matrix and the mineralized corticocancellous particulate allograft were hydrated in sterile water for about 10 minutes. For both the flap and flapless groups, 0.5 cc of mineralized particulate allograft was thoroughly mixed with one package of demineralized bone matrix. The mixture was placed into the socket to the level of the socket crest. A crisscross suture was placed over the bone graft in both groups to provide retention for the calcium sulfate barrier. The calcium sulfate barrier was mixed and placed over the bone graft and was contained by the buccal and palatal/lingual flaps. A second crisscross suture was placed over the barrier after it had completely set. In the flap group, the flaps were replaced and sutured with 5-0 monofilament polyglyconate sutures[§]. At 4 months, papilla preservation incisions were utilized, and a full-thickness flap was elevated for both the flap and flapless groups. Core biopsies were taken using trephine burs. Following that, osteotomy for implant placement was performed according to the manufacturer recommendation and implants were placed.

Each patient received a postsurgical regimen of oral antibiotics (doxycycline hyclate 50 mg daily for 2 weeks), anti-inflammatories (naproxen sodium 375 mg for 1 week), 0.12% chlorhexidine gluconate rinse twice daily, and analgesics as needed. Patients also received detailed oral hygiene instructions.

At 4 months post surgery, a 2.7×6-mm trephine core was taken from the center of the grafted socket immediately prior to implant placement. The core was placed in 10% buffered formalin and submitted for histological preparation. The osteotomy site was then fully prepared and a dental implant placed.

2.6 | Outcome measurements

2.6.1 | Clinical indices and parameters

Each patient received a diagnostic work-up including standardized periapical radiographs, study models, clinical photographs, and a clinical examination to record attachment level, probing depth, recession, and mobility of teeth adjacent to the extraction sites. A customized acrylic occlusal stent was fabricated on the study models to serve as a fixed reference guide for the vertical measurements.[12]

Presurgical baseline data consisting of measurements on the site to be treated included: (1) keratinized tissue and (2) soft tissue thickness measured using the dedicated tissue thickness meter[**].[16–18]

After tooth extraction, the following measurements were recorded: (1) horizontal ridge width at the crest and 5 mm apical to the crest using a digital caliper[††] and (2) vertical height of the ridge relative to an acrylic stent customized to fit on neighboring teeth.[12] All height measurements were done at midbuccal, midlingual, mesial, and distal; all of them were measured at the crest using a custom stent (Figure 2). For the flapless group, a 2-mm soft tissue plug was removed at the ridge crest using a trephine to create access for the digital caliper. The measurement 5 mm apical to the crest was not performed for the flapless group.

At 4 months, another standardized radiograph was taken. All baseline indices and measurements were repeated. A blinded examiner performed all clinical measurements for both the initial and final data collection points.

2.6.2 | Histological analysis

Trephine cores (2.7×6 mm) were decalcified, sectioned, and prepared for histological analysis using hematoxylin

[§] Maxon, Kendall Healthcare, Mansfield, Massachusetts.

[**] SDM gingival thickness meter, Austenal Medizintechnik, Cologne, Germany.

[††] Mitutoyo, Tokyo, Japan.

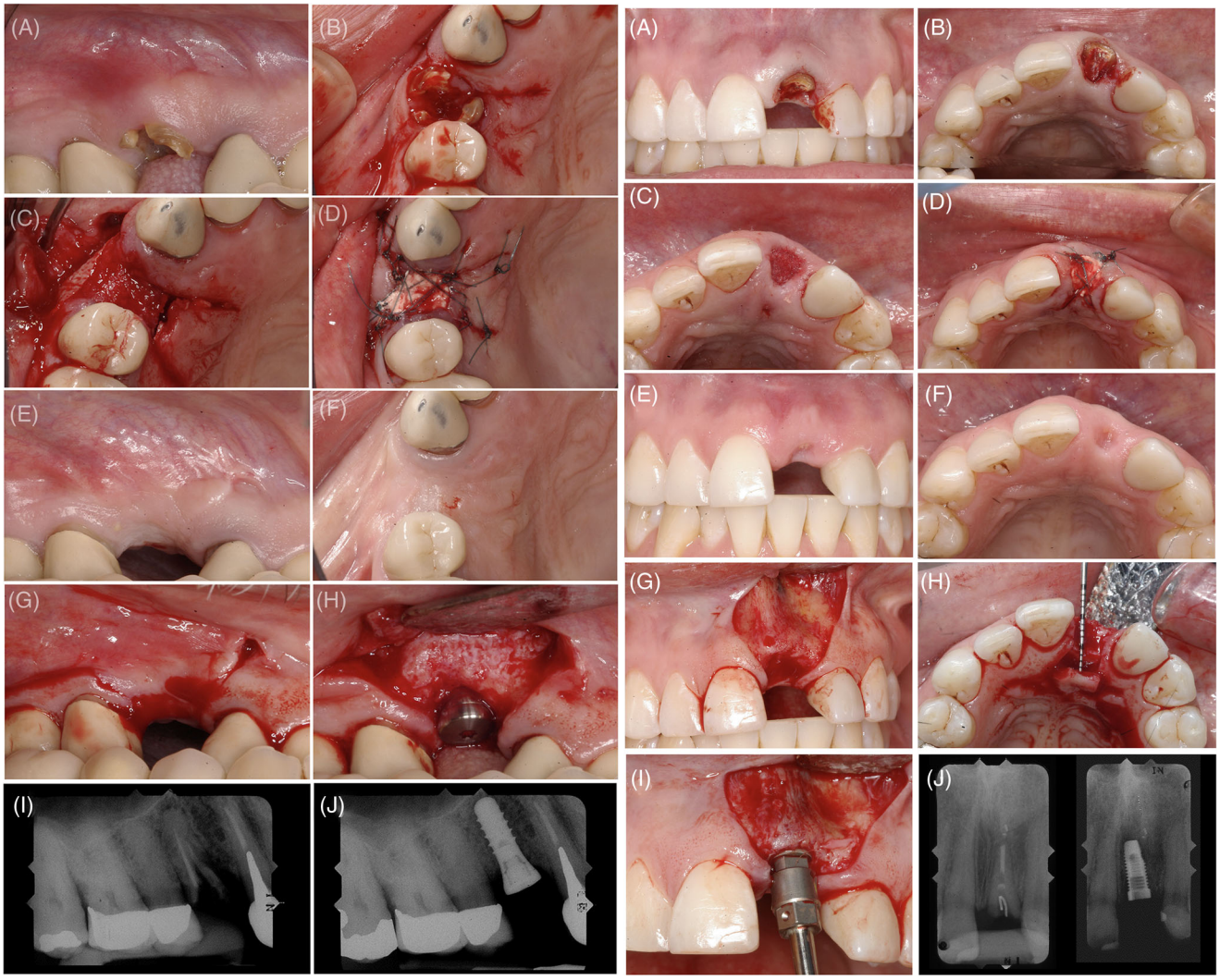

FIGURE 1 (**a, Left**) Flap procedure. (**A**) Tooth site before extraction showing a premolar with vertical root fracture. (**B**) Trapezoidal papilla preservation incisions buccally and lingually. (**C**) Tooth was extracted, and mineralized particulate allograft plus demineralized bone matrix was packed to the bone crest. (**D**) Crisscross sutures placed over the bone graft in both groups to provide retention for the calcium sulfate barrier. (**E, F**) Healed site 4 months after ARP. (**G**) Trapezoidal papilla preservation incisions buccally and lingually to facilitate clinical measurements. (**H**) A tissue-level implant placed in a single stage approach. (**I, J**) Pre- and post-periapical radiographs. (**b, Right**) Flapless procedure. (**A, B**) Tooth site before extraction. (**C**) Tooth was extracted, and mineralized particulate allograft plus demineralized bone matrix was packed filling the socket to the bone crest. (**D**) Crisscross sutures placed over the bone graft in both groups to provide retention for the calcium sulfate barrier. (**E, F**) Healed site 4 months after ARP. (**G**) Trapezoidal papilla preservation incisions buccally and lingually. (**H**) Horizontal ridge width demonstrated clinically after 4 months (note that the measurements were taken using a digital caliper). (**I**) Implant placement showing adequate buccal bone. (**J**) Pre- and post-periapical radiographs. ARP, alveolar ridge preservation

and eosin staining. Twelve- to 15-step serial sections were taken from the center of each longitudinally sectioned trephine core. Six randomly selected fields, one per slide, if possible, were used to obtain percentage of vital bone, remaining graft particles, and trabecular space using a light microscope[‡‡] at 150×, with a 10× objective and Nikon 15× reticle eyepieces[§§].

[‡‡] American Optics light microscope, New York.
[§§] Nikon, Tokyo, Japan.

2.7 | Data analysis

Means and standard deviations were calculated for all parameters. The data were analyzed using a paired *t* test to determine the statistical significance of the differences between baseline and follow-up data, and an unpaired *t* test was used to evaluate statistical differences between the test and control groups. A predetermined sample size of 12 gave 83% statistical power to detect a difference of 1-mm ridge width between the groups with a standard

TABLE 1 Clinical indices for flap and flapless sites (mean ± SD)

		Baseline (index units)	4 months (index units)	Change (index units)
Mean plaque index	Flap	0.1 ± 0.2	0.2 ± 0.2	−0.1 ± 0.2
	Flapless	0.1 ± 0.2	0.0 ± 0.1	0.1 ± 0.2
Mean gingival index	Flap	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1
	Flapless	0.1 ± 0.2	0.0 ± 0.1	0.1 ± 0.2
Mean bleeding on probing	Flap	0.2 ± 0.2	0.1 ± 0.2	0.1 ± 0.3
	Flapless	0.2 ± 0.3	0.1 ± 0.2	0.1 ± 0.2

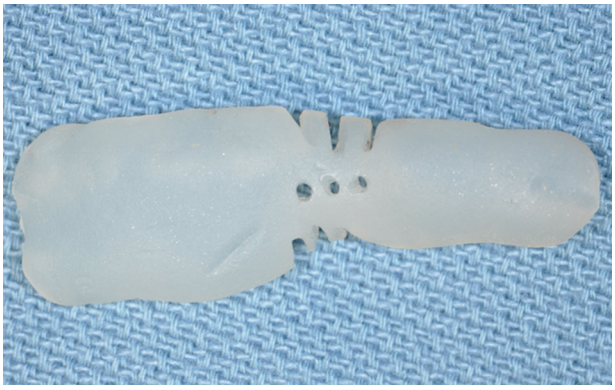

FIGURE 2 Custom surgical stent fabricated before each case. Channels in these stents guide the North Carolina periodontal probe placement for intrasurgical and re-entry measurements

deviation of 0.8 mm. The mean and standard deviation used for the power calculation was based on data from previous studies.[19,20] The histomorphometric analysis was performed using an independent *t* test. In all tests, statistical significance was set at a *P* value of .05. All data analyses were conducted using a commercially available software[***].

3 | RESULTS

3.1 | Sample characteristics

A total of 16 females and 8 males with a mean age of 55.0 ± 14.4 years, ranging from 26 to 78 years, were enrolled. Patients were equally distributed between the two study groups, with 12 patients per group and no dropouts. Recruitment stopped after required sample size was reached in both groups. No difference was noted in terms of early postoperative healing between the two groups (Table 1), and implants were successfully placed at all treated sites for the flapless group. Implant placement was delayed at two sites in the flap group; one site needed sinus augmentation prior to implant placement, while the other required restorative work on adjacent teeth prior to implant placement, and placement was delayed by 4 and 1 months, respectively.

3.2 | Alveolar ridge width at the crest

Flap cases had a mean initial width at the crest of 8.5 ± 1.5 mm, which decreased to 7.5 ± 1.5 mm at the 4-month re-entry for a mean loss of 1.0 ± 1.1 mm ($p < 0.05$, Table 2). Flapless cases presented with a mean initial width at the crest of 8.3 ± 1.3 mm, which decreased to 7.0 ± 1.9 mm at the 4-month re-entry for a mean loss of 1.3 ± 1.0 mm ($p < 0.05$). There were no statistically significant differences between the flap and flapless groups ($p > 0.05$, Table 2a).

3.3 | Alveolar ridge width 5 mm apical to the crest

Flap cases presented with a mean loss of 0.6 ± 1.0 mm ($p > 0.05$). For the flapless group, there were no ridge width measurements 5 mm apical to the crest at baseline. At the 4-month re-entry, the flap and flapless cases had a similar mean width of 8.6 ± 1.4 mm and 8.0 ± 1.6 mm, respectively. There were no statistically significant differences between the flap and flapless groups at 5 mm apical to the crest ($p > 0.05$, Table 2a).

3.4 | Changes in vertical ridge height

Over a period of 4 months, the flap group showed a statistically significant decrease in the mean facial height of 0.9 ± 1.3 mm ($p < 0.05$). In the flapless group, there was a statistically significant mean loss of facial height of 0.5 ± 0.9 mm ($p < 0.05$). There were no statistically significant differences between groups in terms of vertical change ($p > 0.05$). Vertical ridge height changes are reported in Table 2b.

[***] Microsoft Excel for Windows version 16.0, Microsoft Corporation, Redmond, Washington.

TABLE 2a Horizontal crestal ridge width changes (in mm) for flap and flapless sites (mean ± SD)

		n	Baseline (mm)	4 months (mm)	Change (mm)	Range (mm)
Horizontal crestal ridge width						
At crest	Flap	12	8.5 ± 1.5	7.5 ± 1.5	−1.0 ± 1.1*	−2.5 to -0.9
	Flapless		8.3 ± 1.3	7.0 ± 1.9	−1.3 ± 1.0*	−2.7 to +0.5
At 5 mm	Flap	12	9.2 ± 1.6	8.6 ± 1.4	−0.6 ± 1.0	−2.5 to 1.5
	Flapless			8.0 ± 1.6		

*$p < 0.05$ between initial and 4-month values.

TABLE 2b Vertical ridge height change for flap and flapless sites (mean ± SD)

Location	Flap	Flapless	Flap	Flapless
	Mean change (in mm)		Range (in mm)	
Midbuccal	−0.9 ± 1.3*	−0.5 ± 0.9*	−2.5 to 2.5	−2.0 to 1.0
Midlingual	−0.9 ± 1.3*	−0.7 ± 1.1*	−2.5 to 1.0	−2.5 to 1.5
Mesial	−0.8 ± 0.8*	−0.2 ± 0.5*	−2.2 to 0.5	−1.0 to 0.7
Distal	−0.9 ± 0.7*	−0.3 ± 0.7*	−1.8 to 0.2	−1.8 to 1.0

*$p < 0.05$ between initial and 4-month values.

TABLE 2c Soft tissue thickness changes (in mm) for flap and flapless sites (mean ± SD)

	n	Baseline (mm)	4 months (mm)	Change (mm)	Range (mm)
Soft tissue thickness changes					
Flap	12				
Buccal		1.1 ± 0.5	1.3 ± 0.6	0.2 ± 0.7	−1.2 ± 1.4
Lingual		2.0 ± 1.0	2.3 ± 1.3	0.3 ± 0.7*	−1.4 ± 1.6
Occlusal			1.7 ± 0.5		1.2 ± 2.9
Flapless	12				
Buccal		0.9 ± 0.4	1.0 ± 0.4	0.1 ± 0.3	−0.4 ± 0.6
Lingual		2.3 ± 0.5	2.7 ± 0.5	0.4 ± 0.5*	−.0.6 ± 1.3
Occlusal			2.3 ± 0.8**		0.8 ± 3.1

*$p < 0.05$ between initial and 4-month values; **$p < 0.05$ between flap and flapless groups.

3.5 | Histological evaluation

A high percentage of vital bone was found in both groups (Table 3). Histological analysis revealed that flap sites healed with 35 ± 15% vital bone, 19 ± 12% remaining graft particles, 46 ± 17% trabecular space. The flapless sites healed with 44 ± 10% vital bone, 17 ± 13% remaining graft particles, and 39 ± 9% trabecular space. There were no statistically significant differences between the flap and flapless groups ($p > 0.05$) (Table 3; see also Figure S1 in the online version of the *Journal of Periodontology*).

3.6 | Bone quality

Bone quality was assessed subjectively as type I through IV for all sites.[21] The flap group comprised one type I site, two type II sites, eight type III sites, and one type IV site. The flapless group consisted of one type I site, seven type II sites, three type III sites, and one type IV site (Figure 3).

3.7 | Soft tissue thickness

Soft tissue thickness increased from 0.1 to 0.4 mm on the facial and lingual surfaces for both the flap and flapless groups (Table 2c). This increase was statistically significant only on the lingual bone for both groups ($p< 0.05$). In the flapless group, the occlusal soft tissue was significantly thicker than in the flap group at the 4-month re-entry ($p< 0.05$).

4 | DISCUSSION

In this 4-month randomized controlled clinical study of ARP, a flapless surgical technique was compared to a flap

TABLE 3 Histological data at implant placement for flap and flapless sites (mean percentage ± SD)

Study group	Time point	n	VMT (%)	NVMT (%)	% Trabecular bone
Flap	4 months	12	35 ± 15	19 ± 12	46 ± 17
Flapless	4 months	12	44 ± 10	17 ± 13	39 ± 9

Abbreviations: NVMT, non-vital mineralized tissue; VMT, vital mineralized tissue.

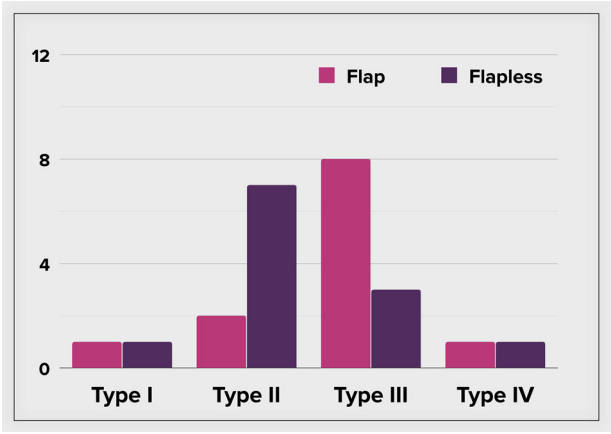

FIGURE 3 Bone quality as subjectively assessed as type I through IV for both flap and flapless techniques based on the Lekholm and Zarb classification[21]

reflection technique. While there are a number of preclinical and clinical studies comparing the two surgical techniques for implant placement, this is one of the very few human studies investigating ridge alterations as it relates to ARP.[22–24] For both groups, the socket was grafted using a demineralized bone matrix allograft mixed with a mineralized particulate allograft and then capped with a calcium sulfate barrier in the socket opening to contain the graft. There were no statistically significant differences in ridge dimension changes between groups in this study (Figure 1a C and D, Figure 1b C and D). These findings are in agreement with the results demonstrated by Araujo and Lindhe and Filipek et al. in that there is no statistically significant difference in hard tissue loss between the two surgical approaches.[9,25] Araujo and Lindhe examined the ridge dimension changes in an animal model following tooth extraction with and without flap reflection, while Filipek et al. did a hard and soft tissue comparative analysis between flap and flapless tooth extractions in humans.[9,25] Furthermore, the current findings also confirmed that bone loss cannot be prevented completely irrespective of the surgical approach used, which concurred with the results of several other studies.[9,12,19] However, our findings differed from the conclusions of Fickl et al. and Barone et al.,[12,13] who evaluate healing socket sites at earlier time intervals. Fickl et al. examined the tissue alterations following tooth extraction in flap and flapless groups at 2- and 4-month time intervals.[13] Their canine study showed increased soft and hard tissue loss in the flap group, but the experimental model did not distinctly distinguish between hard and soft tissue components. The human study conducted by Barone et al., examining the socket healing in flap versus flapless procedures after 3 months of healing, showed statistically significant differences in buccolingual width and vertical ridge height between the two groups.[12] The flapless group showed more loss in the ridge height compared to the flap group. They investigated soft and hard tissue changes in extraction sockets grafted with corticocancellous porcine bone and a collagen membrane after 3 months. The teeth included in their analysis were molars and premolars. The differences in tooth type, graft materials, and healing time period may have contributed to the difference in results.

The flapless group showed a loss of 1.3 mm in crestal ridge width, which was slightly greater than in the flap group with a loss of 1.0 mm (Table 2a). Both groups lost ridge height at all locations (midbuccal, midlingual, mesial, and distal). Although these changes were not statistically significant between groups, the flapless group showed less loss of ridge height than the flap group. The flap group showed a loss of ridge height of 0.8–0.9 mm at all locations. The flapless group showed the greatest loss of 0.7 mm at the midlingual site and the least loss of 0.2 mm at the mesial site (Table 2b), which was comparable to 0.9 ±0.9 mm (lingual) and 0.2 ±0.7mm (mesial) vertical dimension loss in a flapless ridge preservation study by Barone et al.[11]

Whether raising a flap would negatively influence the outcomes of ARP is controversial, but what we know is that the extent of facial bone loss after extraction depends on several unrelated factors. The ones that seem to stand out most prominently are facial bone thickness and tooth angulation.[26] In a landmark computed tomography study, teeth with facial bone thickness ≤1 mm had a median vertical bone loss of 7.5 mm (62% of facial height) after just 8 weeks of flapless extraction.[27] Interestingly, in 90% of cases in the anterior maxilla, facial bone thickness is <1 mm, and <0.5 mm in roughly 50% of cases.[28–30] On the other hand, patients with a facial wall thickness of >1 mm exhibited only a median vertical bone loss of 1.1 mm[27]. What

literature shows and this study confirms is that short-term hard tissue changes following ARP with either a flapped or flapless approach are very similar.[31]

Trephine cores were taken from the center of the grafted socket at 4 months for histological analysis (Figure S1). There was approximately 40% vital bone and 18% nonvital residual graft particles in each group, with no statistically significant differences between groups. This was consistent with previous reports of the 3- to 6-month histological composition of the ridge following placement of mineralized particulate allograft into sockets.[11,19] However, the percentage of vital bone was higher in the current study compared to Barone et al., who showed 22.5%.[11] Perhaps the higher percentage of vital bone at 4 months is the reason why the flapless group had relatively denser bone at the time of implant placement (Figure 3).

This study evaluated loss of crestal ridge width in extraction sites with at least one adjacent tooth. Eighteen of the 24 sites had two adjacent teeth. Loss of crestal width may be greater when there are no adjacent teeth, when a terminal tooth is extracted, and especially when all teeth in an arch are being removed. This observation was in agreement with the findings of Chen et al., and Schropp et al.[32,33] Thus, the means and ranges reported in this study may not be generalizable and should be limited in application to bounded single-tooth sites.

Overall, changes in the crestal ridge dimensions did not show any statistically significant differences between the flap and flapless ARP techniques. The observation made in our study is largely in agreement with that presented by Araujo and Lindhe[9] in that a similar amount of bone loss was noted with both techniques, and while the latter was an animal study, the present study was performed in humans. Within the limitations of this study, a flap could be used with minimal compromise to the bone when necessary for an ARP procedure. As with most procedures, there are indications and contraindications for use of the flapless technique. It is yet to be determined if the difference in crestal ridge alterations between flap and flapless techniques is significant enough to impact the outcome of implant placement or has a long-lasting detrimental effect on the final ridge dimensions. The results from this study did not indicate the aforementioned.

5 | CONCLUSION

In conclusion, postextraction dimensional changes of the alveolar ridge were statistically comparable between the flap and flapless surgical techniques. Similarly, the percentage of vital bone and remaining graft particles was comparable between the two surgical approaches. However, the flapless technique may result in an increased tissue thickness at the occlusal aspect.

CONFLICT OF INTEREST

The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

AUTHOR CONTRIBUTIONS

Trever L. Siu and Ziad Dib performed the surgeries. Henry Greenwell, Trever L. Siu, and Ziad Dib contributed to the conception and design of the work. Trever L. Siu, Ziad Dib, and Himabindu Dukka collected and analyzed the data. Muhammad H. A. Saleh, Mustafa Tattan, Trever L. Siu, and Ziad Dib contributed to the manuscript preparation. Hom-Lay Wang, Mauricio G. Araujo, and Muhammad H. A. Saleh made critical changes and gave final approval to the manuscript. All authors gave their final approval and agreed to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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