Influence of Different Incision Designs on Flap Extension: A Cadaveric Animal Model

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It is well known that wound dehiscence is one of the most frequent complications in guided bone regeneration. The main cause of this complication may be a lack of tension-free and primary wound closure. The aim of this study was to evaluate and compare the effect of periosteal releasing incisions (PRI) on the extension of 3 different flap designs: envelope, triangular, and trapezoidal. Twelve pig mandibles were used to quantify extension of the flap designs. The mandibles were equally and randomly distributed into the 3 flap groups. Each mandible was divided into 2 sides: 1 was subjected to a PRI and the other not. The flap was pulled with a force of 1.08 N, and the extension was recorded. The subgroups without PRI showed an average extension of 5.14 mm with no statistically significant differences among them ($P = .165$). The PRI provided an average extension of 7.37 mm with statistically significant differences among the subgroups ($P < .001$). The releasing incisions significantly increased flap extension in each flap design. The increase in extension of the trapezoidal flap with PRI was significantly greater than in the other subgroups. In cases where primary closure is required, surgeons should consider performing trapezoidal flaps with PRI in order to reduce tension.

Key Words: surgical wound dehiscence, surgical flap, guided bone regeneration, incision design, suture techniques, tension

INTRODUCTION

Since Brånemark originally defined the concept of osseointegration in the 1960s,[1] oral rehabilitation has changed drastically. However, the presence of an adequate bone volume is basic in order to secure optimal results.[2] Several techniques, such as guided bone regeneration (GBR), have been proposed to increase bone volume.[3] These techniques always require complete closure of the wound while stretching the overlying mucosa.[4,5]

Indeed, the success and predictability of GBR are strongly influenced by 4 major factors: (1) primary wound closure, (2) angiogenesis, (3) space creation/maintenance, and (4) stability.[6] Wound closure is of outmost importance since dehiscences are one of the most common complications (6.95%–13.1%). Tension of the flap also leads to deformation of the grafting material and to poor regeneration in the most coronal areas.[7,8] An inadequate flap design, suturing technique or material can also increase the risk of dehiscence due to the presence of tension in the wound.[9–11] This complication may lead to graft or membrane exposure, which jeopardizes bone regeneration, especially when nonresorbable membranes are employed, and may even preclude placing an implant.[10,12,13]

A wide range of surgical techniques have been proposed in the literature to reduce flap tension: the buccal approach,[14] a rotated palatal flap,[15] a palatal advanced flap,[16] or a split-flap approach,[17] among others. One of the most widespread and predictable approaches is the use of a trapezoidal flap with 2 vertical incisions and 1 periosteal releasing incision (PRI) (Rehrmann's technique).[18]

Greenstein et al[10] suggested a graded procedure, depending on the amount of advancement required: (1) minor: triangular or trapezoidal flap with PRI (<3 mm); (2) moderate: trapezoidal flap with PRI and apical detachment (3–6 mm); or (3) major: full-thickness mucoperiosteal flap followed by another 3- to 5-mm incision into the soft tissue coronally to its base[19] or multiple incisions into the periosteum and underlying connective tissue (≥7 mm). However, the authors concluded that the best flap design should balance simplicity and tensionless primary closure because doing so results in lesser morbidity.

On the other hand, vertical releasing incisions (VRI), PRI, and underlying connective tissue incisions might compromise flap integrity and vascularization, leading to soft tissue trauma, greater postoperative inflammation, and delayed healing.[20] Moreover, VRI in triangular flaps should have an inclination of 15° to 30° in order to avoid compromising blood supply.[21]

In an in vitro study, Park et al[5] evaluated the influence of each VRI and PRI on the extension of trapezoidal flaps and pointed to PRI as the key factor for obtaining greater extension, thereby questioning whether posterior VRI is actually necessary. To the best of our knowledge, no data are available on the amount of extension achieved by PRI in different flap designs (envelope, triangular, or trapezoidal). The objective of the present study therefore was to evaluate and compare the effect of PRI on the vertical extension of each of the 3 flap designs:

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envelope, triangular, and trapezoidal. A secondary objective was to identify which flap design affords the most extension.

Material and Methods

An in vitro, randomized, split-mouth study was performed on pig mandibles. Sample size calculation was performed with the Stata 14 statistical package (StataCorp) considering the results obtained by Park et al.[5] A difference of 6.0 mm (SD = 3.0 mm) between the techniques that afforded more and less extension (envelope flap without PRI and trapezoidal flap with PRI) was considered clinically relevant. The alpha error was 0.05, and the statistical power 80%. The necessary sample size was 4 mandibles for each flap design (envelope, triangular, and trapezoidal). We performed PRI on 1 side, while the other side served as control.

Thus, 14 mandibles were used from 8- to 9-month-old miniature pigs (20–30 kg). They were randomly assigned to 3 groups of 4 mandibles each (8 hemiarches): (1) envelope flap, (2) triangular flap, or (3) trapezoidal flap. Both sides of the mandible were randomly assigned to the PRI subgroup (flap combined with PRI) or control group (periosteum left intact). Thus, the split plot design consisted of 6 subgroups of 4hemiarches each. Each mandible was randomly assigned in a group via a randomization system (StataCorp) in a 1:1:1 proportion. Similarly, the test and control hemiarches (with and without PRI) were randomly assigned to each mandible in a 1:1 proportion for both the right and the left hemiarches.

All the mandibles were frozen (−16°C) the day after sacrifice and were thawed 12 hours before the procedure and kept at room temperature. All mandibles were selected according to the following inclusion criteria: (1) intact gingiva and fornix, (2) edentulous section of $\geq$17 mm, (3) $\geq$2 mm of attached gingiva, and (4) $\geq$8 mm of alveolar mucosa.

Flaps were prepared by an experienced surgeon (O.C.-F.). Incisions were made under ×2.8 magnification (Galilean HD, ExamVision ApS) with a headlight (Focus LED 6000K, Exam-Vision) using a no. 15 blade. A 15-mm envelope flap was made with 2 1.5-mm incisions perpendicular to the crestal one on each side in the palatal aspect. These allowed us to slightly detach the lingual gingiva to be able to place an implant bur without interfering flap traction (Figure 1). Group 1 (envelope flap) had 2 buccal incisions done in exactly the same way as the lingual ones, thus conforming an "H," simulating an envelope flap (Figure 2a and b). Group 2 (triangular flap) had a 6-mm-long VRI on the buccal side at the mesial end of the envelope flap at an angle of 105° with the envelope flap. In addition, a 1.5-mm incision was placed buccal at the distal extreme (Figure 2c and d). Finally, group 3 (trapezoidal flap) had 2 6-mm-long buccal VRI placed at both ends of the envelope flap (Figure 2e and f). Then a full-thickness flap was raised using a Freer periosteal elevator in all groups, extending the flap 6 mm in the apical direction. In the test hemiarches, a 1-mm-deep PRI was performed from the distal to the mesial end and below the mucogingival junction.[22] The surgical blade was replaced for each mandible, and PRI was also done using a new blade.[23] Finally, a silk suture was placed in the middle of the flap (7.5 mm away from both extremes) at a distance of 2 mm away from the incision line (silk suture 3/0, Silkam, B. Braun). A pulling force of 110 g (1.08 N) was applied to a flap employing a pulley system and a counterweight previously calibrated with a dynamometer (25 kg ± 10 g, Digitale Weegschaal).

Figure 1. Lingual view of envelope flap under traction. The flap is pulled along a calibrated implant bur to help measure flap extension.

A 2-mm calibrated implant bur was placed 8 mm inside of the crestal bone (drill Ø2 8–16 TPR, Nobel Biocare, Danaher Corp). The bur was used as a calibrated method for later measurements (Figure 1). Flap extensions were photographed with a camera using a tripod always set at the same distance, angulation, and height (Nikon D5100m AF-S Micro, 85 mm, 1:35 G, Nikon, Nikon Corp), allowing us to determine the extension achieved using the calibrated bur marks (Figure 2). All measurements were calibrated and performed using Image J software (ImageJ 1.51k, Wayne Rasband, National Institutes of Health) by the same investigator (B.T.-G.). Flap extension was measured in millimeters in the mesial and distal areas, and the mean was calculated. This was done because the triangular flap had an asymmetrical extension (Figure 2c and d). As suggested by Park et al,[5] flap extension was measured from the crestal bone surface, not from the gingival surface.

The statistical analysis was performed using the Stata 14 statistical package (StataCorp). The normal distribution of continuous quantitative variables was assessed using the Shapiro-Wilk test ($P > .10$) and visual analysis of the normal P-P plot and box plots. Considering that the distributions were normal, a descriptive analysis was conducted based on the mean and SD, and a bivariate analysis was made using parametric tests (Student *t* test for paired data; 1-factor analysis of variance for independent data with Bonferroni correction for multiple comparisons). Fulfillment of the assumptions was ensured through tests of normality and homogeneity of variances (ie, Shapiro-Wilk and Levene tests, respectively). Statistical significance was considered for $P \leq .05$. The intraclass correlation coefficient (ICC) was used to assess consistency of the measurements. Accordingly, 6 randomly selected hemi-

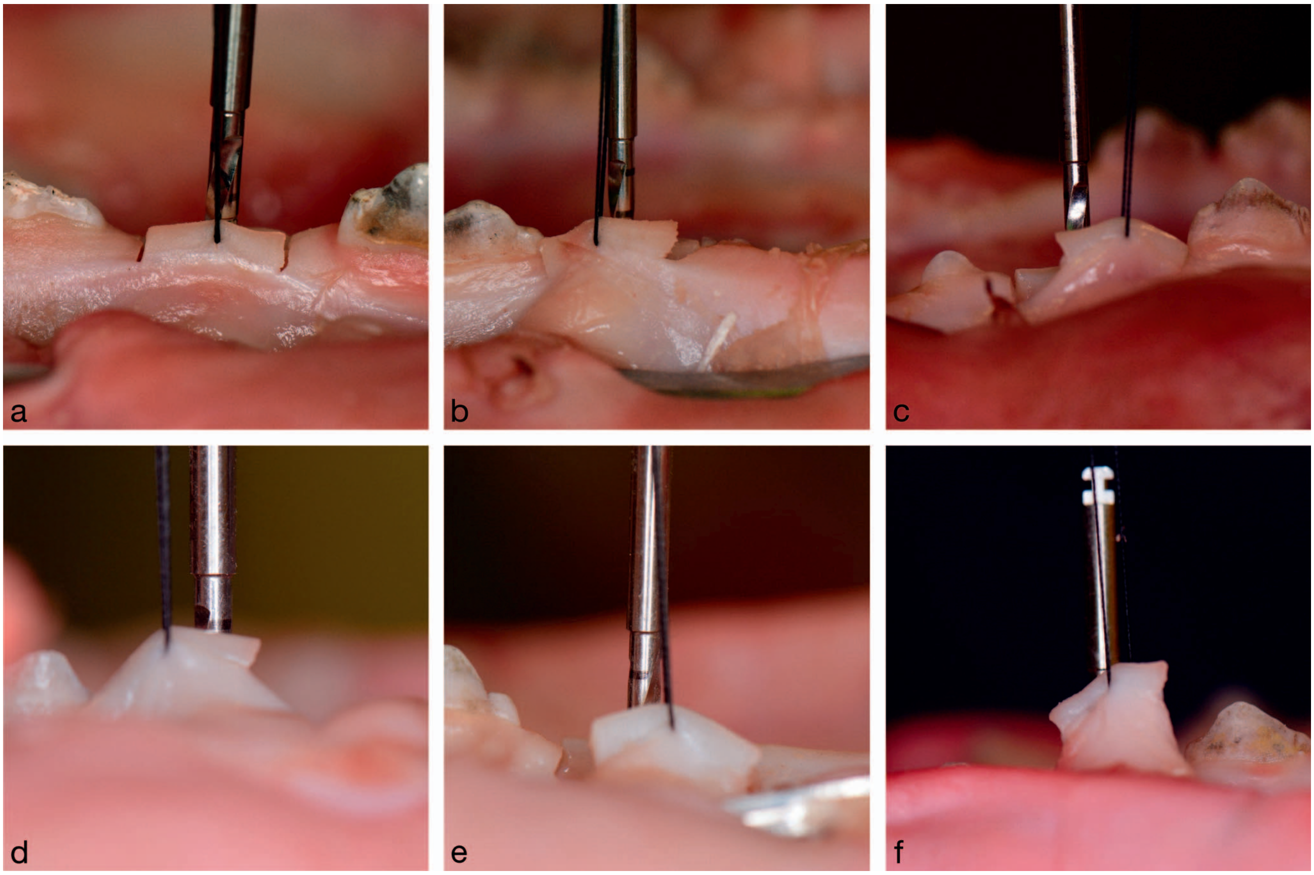

Figure 2. Photographic registry of each flap extension. (a) Envelope flap without periosteal-releasing incision (PRI). (b) Envelope flap with PRI. (c) Triangular flap without PRI. (d) Triangular flap with PRI. (e) Trapezoidal flap without PRI. (f) Trapezoidal flap with PRI.

arches were subjected to repeated measurement with Image J software, and the ICC between the first and the second measurements of these 6 hemiarches was calculated. The ICC was 0.993 (95% CI: 0.950–0.999; $P < .001$), affording excellent agreement and intraexaminer consistency.

The methodology was reviewed was reviewed by an independent statistician.

Results

Table 1 displays the outcomes of flap extension according to the different flap designs used. When PRI was not performed, the mean flap extension was 5.14 mm, with no significant differences among the 3 groups (95% CI: 4.27–6.00 mm; $P =$ .165). In contrast, when PRI was performed, the mean flap extension was 7.37 mm, with significant differences among the 3 groups (95 CI%: 5.57–9.17 mm; $P < .001$). The results are graphically displayed in Figure 3.

Periosteal-releasing incisions significantly increased flap extension in the envelope flap (0.57 mm; 95% CI: 0.37–0.77 mm; $P =$ .003) and trapezoidal flap groups (4.93 mm; 95% CI: 1.87–7.99 mm; $P =$ .014). The results are graphically displayed in Figure 3.

Finally, all possible comparisons among the 6 subgroups of the study were made (Tables 2 and 3). Both absolute and

Table 1

Means (SD) of the 6 subgroups*

	Envelope	Triangular	Trapezoidal	Total Mean (95% CI)
No PRI	4.26 (0.94)	5.06 (0.68)	6.08 (1.78)	5.14 (4.27–6.00) $P =$ .165†
PRI	4.84 (0.94)	6.24 (0.63)	11.02 (0.33)	7.37 (5.57–9.17) $P <$ .001†§
Total mean (95% CI)	0.57 (0.37–0.77) $P =$ .003‡§	1.18 (−0.05–2.41) $P =$ .055‡	4.93 (1.87–7.99) $P =$ 0.014‡§	

*PRI indicates periosteal releasing incisions.
†Analysis of variance for independent data.
‡*t* test for paired data.
§Statistically significant ($P \leq .05$).

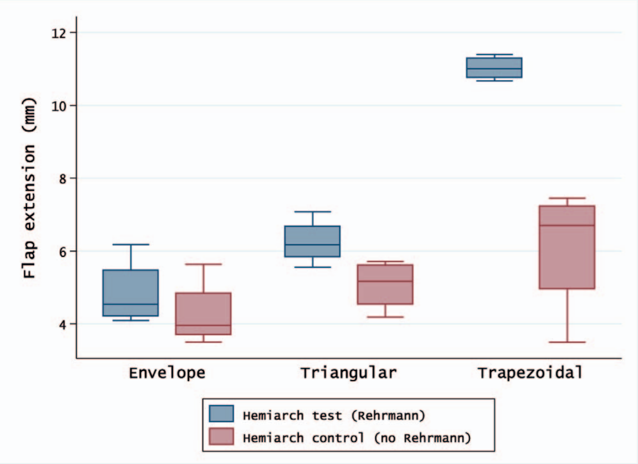

Figure 3. Box plot displaying flap extension of the 6 subgroups (in mm).

relative extensions were significantly greater in the group with PRI.

Discussion

The present study shows that trapezoidal flaps with PRI resulted in 159% more extension compared with a standard envelope flap (without PRI) (Table 3). This figure is very similar to that reported by Park et al[5] (171.3%) despite the methodological differences between the 2 studies, such as the reference point employed, which in our case was the crestal bone instead of the base of the flap. This might explain the greater extension of the triangular and trapezoidal flaps without PRI in the study of Park et al[5] (113.4% vs 18.7% and 124% vs 42.8%, respectively). However, the results referred to the trapezoidal flap with PRI in both studies were very similar despite the fact that the reference point differed. It would be plausible to assume that this similarity could be explained by the differences in traction force (5 g in the study of Park et al[5] vs 110 g in the present study). Thus, it seems that PRI greatly increases sensitivity to traction changes. The histological features (essentially fibrous tissue, nerve, and vascular structures) and width of the periosteum (about 0.375 mm) could explain these results. In addition, the attached gingival tissue has few elastic fibers, which is not the case with the alveolar submucosa.[6,10] Hence, considering the results obtained, PRI seems to be paramount for securing tensionless primary closure in GBR treatments.

Although some authors, such as Kleinheinz et al,[21] discourage the use of posterior VRI, our results underscore that it is needed with a PRI when a small or moderate extension is required (3–6 mm)[10] (Table 3). In addition, PRI should not be deeper than 1 mm since a greater depth could compromise the blood supply to the underlying area.[5]

The differences between trapezoidal flaps without PRI and triangular flaps with PRI were almost nonexistent (Table 3). Considering the vascular supply, which is described to be posteroanterior,[21] when a short extension is required, a triangular flap with anterior VRI and PRI would be preferable to a trapezoidal flap. Triangular flaps, however, extend better next to the VRI, and the clinical situation might dictate the choice of 1 flap or the other.[23]

Another aspect that must be considered is that in envelope flaps with PRI, horizontal extension was common despite the scarce vertical extension. Similar alternatives have been described in the literature that might be useful for horizontal GBR.[24]

It should be pointed out that calculation of the sample size

Table 2

Multiple comparisons in absolute numbers (mm)*

	Envelope Without PRI	Envelope With PRI	Triangular Without PRI	Triangular With PRI	Trapezoidal Without PRI	Trapezoidal With PRI
Envelope without PRI						
Envelope with PRI	0.57 mm (0.27–0.88 mm) $P = .008$†§					
Triangular without PRI	0.80 mm (−1.49–3.09 mm) $P = .977$‡	0.22 mm (−2.07–2.52 mm) $P = 1.000$‡				
Triangular with PRI	1.98 mm (−0.31–4.27 mm) $P = .127$‡	1.41 mm (−0.89–3.70 mm) $P = .526$‡	1.18 mm (−0.68–3.05 mm) $P = .157$†			
Trapezoidal without PRI	1.82 mm (−0.47–4.12 mm) $P = .197$‡	1.25 mm (−1.04–3.54 mm) $P = .684$‡	1.03 mm (−1.27–3.32 mm) $P = .878$‡	−0.16 mm (−2.45–2.14 mm) $P = 1.000$‡		
Trapezoidal with PRI	6.76 mm (4.47–9.05 mm) $P < .001$‡§	6.18 mm (3.89–8.48 mm) $P < .001$‡§	5.96 mm (3.67–8.25 mm) $P < .001$‡§	4.78 mm (2.49–7.07 mm) $P < .001$‡§	4.93 mm (0.30–9.57 mm) $P = .042$†§	

*Fifteen comparisons were made among the 6 subgroups, obtaining the extension differences (mm). Means (SD), 95% CI, and a statistical significance level of $P < .05$ were applied. PRI indicates periosteal releasing incisions.

†*t* test for paired data.

‡1-factor analysis of variance for independent data.

§Statistically significant.

TABLE 3

Multiple comparisons in relative numbers (percentages)*

	Envelope Without PRI	Envelope With PRI	Triangular Without PRI	Triangular With PRI	Trapezoidal Without PRI	Trapezoidal With PRI
Envelope without PRI						
Envelope with PRI	13.47% (4.67–31.79%) $P = .008$†§					
Triangular without PRI	18.73% (−25.94–111.85%) $P = .977$‡	4.64% (−32.70–75.23%) $P = 1.000$‡				
Triangular with PRI	46.46% (−5.44–154.59%) $P = .127$‡	29.07% (−14.02–110.54%) $P = .526$‡	23.35% (−11.14–76.62%) $P = .157$†			
Trapezoidal without PRI	42. 80% (−8.14–148.96%) $P = .197$‡	25.85% (−16.49–105.89%) $P = .684$‡	20.27% (−20.63–83.44%) $P = .684$‡	−2.49% (−33.80–40.80%) $P = 1.000$‡		
Trapezoidal with PRI	158.58% (77.53–327.47%) $P < .001$‡§	127.89% (61.52–253.34%) $P < .001$‡§	117.78% (59.70–207.49%) $P < .001$‡§	76.56% (34.31–134.99%) $P < .001$‡§	81.08% (3.34–294.38%) $P = .042$†§	

*Fifteen comparisons were made among the 6 subgroups, obtaining the extension differences (%). Means (SD), 95% CI, and a statistical significance level of $P < .05$ were applied. PRI indicates periosteal releasing incisions.

†*t* test for paired data.

‡1-factor analysis of variance for independent data.

§Statistically significant.

was made considering the 2 most extreme comparisons (envelope flap without PRI and trapezoidal flap with PRI). Consequently, the statistical power was too low to detect differences between the envelope flap and triangular flap or between the triangular flap with and without PRI. A larger sample size could be required in order to detect differences in these comparisons.

Membrane exposure may result in a 5- to 6-fold decrease in hard tissue formation or even lead to total failure in GBR treatments.[25] Thus, tension-free primary closure is a key factor for preventing such problems.[9,10] Burkhardt and Lang[9] reported a 10% incidence of dehiscences when the suture tensile strength was <10 g. Dehiscence risk increased dramatically from 40% to 100% on exceeding 10 g of suture tension and 100% when tension exceeded 25.5 g. The suture technique used can reduce suture tension.[11,26] González-Barnadas et al[11] observed that the suture technique, materials, and diameters strongly influence tensile strength resistance. A combination of simple suture and horizontal mattress suture and expanded-polytetrafluoroethylene 4-0 resists greater traction without untying or rupture compared with all other studied materials, thus preventing wound dehiscence. De Stavola and Tunkel[27] reported that a suspended external-internal suture reduces tension on the margins of the flap (mean 28.5 g; 95% CI: −48 to −16 g; $P < .001$) where a second tension-free suture can be performed with a mean strain of 4.1 g (SD = 1.5).

Other, more complex surgical techniques can help reduce tension in mucoperiosteal flaps. Bichat fat pad flaps,[28] buccinator musculomucosal flaps,[29] or periosteal expansion before regeneration treatment[30] are among them. However, it was beyond the scope of our study to investigate the effect of these techniques on surgical wound closure.

The present study used thawed material from pigs, which might slightly compromise the applicability of these results to an actual clinical scenario. Despite these differences, however, some studies suggest that thawed porcine tissue has similar characteristics to fresh tissue up to 4 to 12 weeks.[31,32] Finally, the traction force was 110 g since this was previously shown to be the minimal traction required to achieve the greatest extension without damaging the tissues.

CONCLUSIONS

According to the results of the present study, PRI significantly improves flap extension. Trapezoidal flaps with PRI seem to be the most suitable option to reduce tension when suturing since this approach allows a longer flap extension in comparison with crestal flaps or triangular flaps (with or without PRI). Due to the limitation of the model employed (animal mandibles), further clinical research is needed to confirm these observations.

ABBREVIATIONS

CI:	confidence interval
GBR:	guided bone regeneration
ICC:	intraclass correlation coefficient
PRI:	periosteal-releasing incision
SD:	standard deviation
VRI:	vertical incisions

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Note

The authors declare that they have no conflicts of interest related to this study.

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