Role of flap tension in primary wound closure of mucoperiosteal flaps: a prospective cohort study

R. Burkhardt
N. P. Lang

Authors’ affiliation:
R. Burkhardt, N. P. Lang, The University of Hong Kong, Hong Kong

Correspondence to:
Dr Rino Burkhardt
Weinbergstrasse 98
CH-8006 Zurich
Switzerland
Tel.: +41 44 360 50 50
Fax: +41 44 360 50-55
e-mail: rino.burkhardt@bluewin.ch

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Abstract
Aim: To evaluate the role of suture tension in primary wound closure of mucoperiosteal flaps.

Materials and methods: Sixty patients, scheduled for a single implant installation, were recruited. Before suturing, the wound closing forces were measured with an electronic tension device. One week after the surgery, the wounds were inspected with regard to complete closure.

Results: The applied tension varied between 0.01 and 0.4 N. In 72% a tension of 0.01–0.1 N was applied, resulting in few dehiscences (10%). Higher closing forces (>0.1 N) increased the percentage of wound dehiscences significantly (≥40%).

Conclusions: It appears necessary to control flap tension at the time of wound closure to achieve a primary closure.

Regenerative procedures in conjunction with or before implant installation require an undisturbed wound healing guaranteed by primary wound closure [Lang et al. 1994]. Maintaining flap closure and 6 months of undisturbed wound healing resulted in a regenerated bone volume corresponding to 90–100% of the original defect size. However, wound dehiscences resulted in the necessity to remove membranes prematurely. This in turn allowed bone regeneration to occur to a limited amount, corresponding to only 40–60% of the original defect size without the presence of infection. Infected sites, however, failed to present any bone regeneration. Rather, further bone volume was resorbed. Wound dehiscences are commonly encountered complications in regenerative procedures in jaw bone [Fugazotto 1999; Lorenzoni et al. 1999].

It is believed that tension-free adaptation of the flap margins results in primary wound closure. This should be maintained throughout the entire healing phase of the flap.

To achieve such a stable situation of the wound, both the tension applied to the wound margins during suturing and the thickness and mobilization of the flaps may be determining factors. Although in vitro experiments [Burkhardt et al. 2008] have established that trauma to the tissues exerted by suture tension may be reduced by choosing finer suture diameters for tissue closure, the role of suture tension in vivo has not been elucidated so far.

The purpose of the present study is to evaluate the role of suture tension in primary wound closure with regard to the flap thickness, flap design and suture materials chosen.
Material and methods

From the patient pool of a private practice specialized in periodontology and implant dentistry, 60 consecutive patients were recruited. They were all scheduled for implant installation in order to reconstruct a single missing tooth in a gap. Consequently, they were in need of the preparation of a mucoperiosteal flap to gain access to the edentulous ridge.

Before implant surgery, the patients were treated initially to achieve hygienic conditions of their oral cavity [initial or hygienic phase of periodontal therapy]. This resulted in minimal amounts of plaque accumulations and hence optimal oral healing conditions.

After flap elevation, the thickness of the mucoperiosteal flaps was measured in the mesio-distal mid-crestal region using an ultrasonic device (SDM, Krupp Corporation, Essen, Germany).

All implants were placed in a two-stage modality either with or without the simultaneous augmentation of buccal bone dehiscences. The augmentation procedures were performed using a bioresorbable membrane [Bio-Gide®, Geistlich, Wolhusen LU, Switzerland], supported by a scaffolding bone substitute [deproteinized bovine bone mineral; Bio-Oss®, Geistlich, Wolhusen LU, Switzerland].

At the discretion of the surgeon the mucoperiosteal flaps, which had been elevated following a mid-crestal incision, were mobilized with either no or one or two releasing incisions and/or periosteal splitting. Special attention was focussed to the length of the releasing incisions and the amount of splitted flap area in order to achieve primary wound closure. Flap design and preparation are two relevant factors and a prerequisite for passive suturing.

Implants were placed according to the manufacturer’s recommendations with the termination of the implant shoulder flush with the alveolar bone crest. Healing was intended to be in a submerged fashion. Consequently, the mucoperiosteal flaps were adapted to the wound margins and sutured with mattress and/or single sutures of either 5-0 [Ethilon®, Johnson & Johnson, Norderstedt, Germany] or 7-0 [Prolene®, Johnson & Johnson, Norderstedt, Germany] diameter.

Primary wound closure was achieved in all sites. At the time of wound closure, the tension exerted on the flap margins with the respective sutures was measured using a highly sensitive electronic tension/pressure device (Flap Tension Meter®, Imedico GmbH, Zurich ZH, Switzerland) [Fig. 1]. Tension was read to an accuracy of 0.001 N (0.1 g).

The patients were asked to rinse with chlorhexidine digluconate for a period of 2 weeks starting on the day of surgery. Oral hygiene practices were resumed after 7 days of healing applying an ultrasonic brush (Curaprox® CS Surgical, Kriens LU, Switzerland) soaked in chlorhexidine for the wounded area, while regular oral hygiene was performed in the remainder of the dentition.

One week after implant installation, the patients were recalled for suture removal. At this time, the wound was inspected with regard to complete closure. Adverse healing events were registered. In case of a wound dehiscence after 1 week, further inspections of the wound were performed at weekly intervals. Between 2 and 6 months following implant installation, prosthetic abutments were connected using a minor surgical incision over the covering screw of the implant.

Prosthetic reconstruction was performed 2–4 weeks after abutment connection.

Data collection and statistical analysis

The primary outcome variable was flap closure or dehiscence at the time of suture removal [7 days] registered in a dichotomous way. The tension under which the flap margins were approached was measured continuously in increments of 0.001 N (0.1 g). Likewise, the thickness of the elevated flap was assessed in increments of 0.1 mm using the ultrasonic device described. The remaining parameters such as periosteal splitting, buccal releasing incisions, application of membranes and augmentations as well as the application of connective tissue grafts were evaluated in a dichotomous way.

For the statistical analysis the sites were grouped in increments of 0.05 N (0.01–0.05, 0.06–0.10, 0.11–0.15, 0.16–0.20, 0.21–0.25, 0.26–0.30, 0.31–0.35 and 0.36–0.40 N, respectively). The proportion of dehiscences after 1 week was calculated for each of the cohorts.

The statistical analysis represents a patient-based evaluation, because every patient contributed to the study with only one procedure.

The Shapiro–Francia test for normality revealed a normal distribution of the tension variables. Consequently, multiple linear regression was performed.

Results

A total of 60 patients consecutively recruited over a period of 2 years were included in the study. They all received a submerged implant installation predominantly in the area of esthetic priority. The patient cohort is characterized in Table 1. Twenty percent presented as smokers. The characteristics of the sites are depicted in Table 2.

The thickness of the elevated flaps in relation to the tension applied is depicted in Fig. 2. In 25 sites [40%] a tension of 0.01–0.05 N was applied. In 20 sites [32%] the applied tension varied between 0.05 and

Table 1. Baseline patient-related characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [mean ± SD (years)]</td>
<td>54 ± 8.8</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>26 (43%)</td>
</tr>
<tr>
<td>Smoking patients</td>
<td>12 (20%)</td>
</tr>
<tr>
<td>Cigarette pack/year</td>
<td>0.9 ± 2.4</td>
</tr>
<tr>
<td>FMPS [mean ± SD (%)]</td>
<td>10.5 ± 6</td>
</tr>
<tr>
<td>FMBS [mean ± SD (%)]</td>
<td>6.9 ± 3.8</td>
</tr>
<tr>
<td>Tooth type</td>
<td></td>
</tr>
<tr>
<td>Central incisor</td>
<td>21 (35%)</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>11 (18%)</td>
</tr>
<tr>
<td>Canine</td>
<td>10 (17%)</td>
</tr>
<tr>
<td>First premolar</td>
<td>6 (10%)</td>
</tr>
<tr>
<td>Second premolar</td>
<td>4 (7%)</td>
</tr>
<tr>
<td>First molar</td>
<td>8 (13%)</td>
</tr>
</tbody>
</table>

Fig. 1. Flap Tension Meter®. Handpiece with tension measurement unit [strain gauge].
Ten sites (16%) yielded a flap tension varying between 0.11 and 0.15 N, while only three sites (3%) were under a flap tension of 0.15–0.20 N. Single sites belonged to the categories under flap tension higher than 0.20 N (n = 6, 9%).

Flap dehiscences after 1 week were registered exclusively if flap tension at the time of surgery was >0.05 N. The percentage of sites with dehiscences in the cohort with 0.06–0.10 N of tension corresponded to 10%. It increased significantly (P<0.05) to 40% in the cohort with an original flap tension of 0.11–0.15 N. The small cohort (n = 3) with a flap tension of 0.16–0.20 N presented with 67% of sites with dehiscences. Collapsing all sites exposed to flap tensions of at least 0.20 N (n = 6) revealed 50% of the sites with dehiscences after 1 week. When all the sites exposed to flap tensions of at least 0.16 N were collapsed (n = 9), 55% of the sites yielded dehiscences after 1 week.

Plotting the cohorts of flap tension <0.05 N, 0.05–0.10 N, 0.10–0.15 N and >0.15 N against two categories of flap thicknesses (Figs 3a and b) again reveals that no dehiscences occur at flap tensions of <0.05 N irrespective of the thickness of the flap. Also, in the cohort of 0.05–0.10 N, the incidence of dehiscences was 10% not influenced by flap thickness. However, with flap tensions above 0.10 N there was a tendency for thin flaps (≤1 mm) to yield higher percentages of dehiscences. When flap tensions reached >0.15 N significantly higher proportions of dehiscences occurred in the thin flaps compared with flaps of a thickness of >1 mm.

Analysis of various flap thicknesses in increments of 0.1 mm revealed that most of the flaps yielded a thickness of up to 0.7 mm with no concomitant dehiscences arising in the two cohorts with very low flap tension (<0.10 N).

Smoking had no effect on the incidence of flap dehiscences after 1 week. Likewise, the flap design in terms of releasing incisions and/or periosteal splitting influenced the outcome to a very minor degree.

Moreover, no significant effects on the incidence of dehiscences could be documented for augmented vs. non-augmented sites. Likewise, the application of connective tissue grafts did not influence the incidence of dehiscences.

Discussion

In the present prospective cohort study, patients in need of implant installations were evaluated with respect to the dimensions of the flap thickness and the tension applied to the sutures during wound closure. All the procedures were performed as two-stage installations. This, in turn, means that an abutment connection procedure involving a small incision on top of the cover of the implant was performed between 3 and 6 months after implant installation. However, the primary outcome variable in the present study is related to primary wound closure at the first-stage surgery [implant installation], rather than the second-stage abutment connection.

The present study revealed that primary wound closure after 1 week of healing was achieved in 100% of the sites when flap tension

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**Table 2. Baseline defect and treatment related characteristics**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sites</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented sites</td>
<td>31</td>
<td>52%</td>
</tr>
<tr>
<td>Resorbable membrane</td>
<td>26</td>
<td>43%</td>
</tr>
<tr>
<td>Non-resorbable membrane</td>
<td>5</td>
<td>9%</td>
</tr>
<tr>
<td>Connective tissue grafts</td>
<td>18</td>
<td>30%</td>
</tr>
<tr>
<td>Releasing incisions</td>
<td>27</td>
<td>45%</td>
</tr>
<tr>
<td>One incision</td>
<td>24</td>
<td>40%</td>
</tr>
<tr>
<td>Two incisions</td>
<td>3</td>
<td>5%</td>
</tr>
<tr>
<td>Periosteal incisions</td>
<td>48</td>
<td>80%</td>
</tr>
</tbody>
</table>

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![Fig. 2](image_url) Distribution pattern of sites with or without dehiscence, related to flap thickness and applied closing forces.

![Fig. 3](image_url) (a) Percentages of wound dehiscences for thin flaps (≤1 mm), related to the applied closing forces. (b) Percentages of wound dehiscences for thick flaps (>1 mm), related to the applied closing forces.
tension was minimal (<0.05 N). If more tension was applied to the wound margins, but still in a low range of 0.05–0.10 N, a small proportion of 10% exhibited wound dehiscences. Exceeding the 0.10 N tension limit, the incidence of dehiscences increased dramatically to 40–100%. Especially the application of higher flap tension (>0.15 N) resulted in unacceptably high proportions of wound dehiscences. Although the numbers of sites incorporated into the cohorts with higher flap tensions were small (n = 2–3), it is evident that 100% flap dehiscences were encountered with tensions >0.25 N, irrespective of the thickness of the flap. Also, for cohorts of lower tensions, flap thickness did not influence the incidence of dehiscences. When minimal flap tension was applied (<0.05 N), no dehiscences were encountered, although a variety of flap thicknesses resulted from the procedures.

From a clinical point of view, it appears necessary to control flap tension at the time of wound closure and maintain it below 0.10 N if primary wound closure is to be achieved. This goal can only be achieved by use of a thin suture thread and an appropriate flap elevation including a minimally traumatic flap preparation for a tight adaptation of the sharply dissected wound margins.

Flap tension has also been studied in a previous clinical experiment with the goal to evaluate outcomes of recession coverage over denuded root surfaces [Pini Prato et al. 2000]. In a split-mouth design, eleven patients with bilateral Miller Class-I recessions were treated using coronally advanced flap procedures. By means of a dynamometer the residual tensions of the flaps were measured at the time of suturing. The test sites yielded higher tension, varying from 0.04 to 0.11 N [mean 0.065 N], while the control sites displayed very small to no tension [mean 0.004 N]. The test sites with tensions comparable to the cohort with a flap tension of 0.05–0.10 N in the present study demonstrated a mean root coverage of 78% ± 15% and 18% of the teeth with complete coverage. On the other hand, the control sites without any noticeable flap tension revealed a mean root coverage of 87% ± 13% and 45% of the teeth with complete coverage. From this study which is the only one assessing flap tension in the oral environment, it had to be concluded that the less the tension applied, the better the treatment outcomes. In this respect, the results of the present study corroborated by and large those of the study mentioned on root coverage. In addition, a threshold tension value of 0.05 N was identified in the present study, below which wound dehiscences were completely absent. Between 0.05 and 0.10 N, a clinically acceptable risk with 10% dehiscences resulted. However, above the tension of 0.10 N the incidence of dehiscences increased to a level that may no longer be acceptable for optimal treatment outcomes in the areas of esthetic priority, especially in combination with regenerative procedures.

Flap thickness affected the clinical outcome only when higher flap tensions (>0.10 N) were applied, indicating that flap tension was a more crucial risk for complete wound stability than flap thickness. Moreover, it has to be realized that, in the present study, thin flaps never presented with a wound dehiscence after 1 week, most likely due to the fact that no substantial tension could be applied in such delicate tissues.

Tensile strength, histological and immunohistochemical parameters of the healing of the full-thickness flap were investigated at various time points following surgery in a dog study [Werfully et al. 2002]. Flaps were either replaced to dentine or alveolar bone. The histological results revealed a substantial reduction in inflammatory cells after 3 days of healing with both flap attachment modalities. However, the inflammatory cell count was consistently higher at dentine/flap interfaces compared with bone/flap interfaces. Fibroblast densities peaked at 7–14 days irrespective of the flap interfaces studied. The synthesis of type III collagen peaked during the first week of healing. These results, in turn, support the necessity of flap stabilization during the first week of healing. With respect to the present study, the outcome of flap closure after 1 week, therefore, represents a relevant observational period of healing.

The present study assessed wound closure in conjunction with two-stage implant installations as opposed to the study mentioned before [Pini Prato et al. 2000], in which root surface coverage was evaluated as the primary outcome. It is clear that wound healing over the avascular root surface cannot be directly compared with the situation in the present study and yet, the basic notion of low tensions to be applied for optimal treatment outcome holds true in both situations.

Consequently, efforts have to be made to minimize flap tension in plastic periodontal and implant surgical procedures. This may be achieved by the choice of appropriate suturing material. In a recent study [Burkhardt et al. 2008], it was established that tissue trauma may be reduced by finer suture diameters (6-0, 7-0), because thinner sutures would lead to tissue breakage rather than tissue tearing and breakage. The present study used exclusively 5-0 and 7-0 sutures and hence represented close to optimal circumstances for minimally traumatic wound closure.


References


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