

# Open-healing approach to avoid flap mobilization and subsequent morbidity

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## Abstract

### Objective

This retrospective analysis evaluated the outcome of bone regeneration using membranes in an open-healing approach.

### Materials and methods:

In 119 patients with 160 surgical areas, ridge preservation or bone augmentation was performed. Bone defects were filled and covered with a membrane that was left exposed during healing. Outcome parameters were the need to perform an unplanned augmentation and complication rates during wound healing.

### Results

Bone augmentation was performed in 33.1%, ridge preservation in 41.9% and ridge preservation combined with bone augmentation in 13.1% of the surgical areas. In 78.8% of the surgical areas, a native bilayer collagen membrane was used. Healing was uneventful in 90.6% of the surgical areas. Complications occurred in 9.4% of the surgical areas and included premature membrane resorption, hematoma, membrane loosened by tongue, pain, wound dehiscence and fractured bone plate during augmentation surgery. One patient developed an abscess, one lost an implant. The graft was partially lost in 1.9% of the surgical areas.

Implants could be inserted as planned in a two-stage procedure in all but the one surgical area in which the abscess had occurred. In this area, an unplanned re-augmentation was required. In 86.9% of the surgical areas, no re-augmentation was necessary. Secondary augmentation was performed in 12.5% according to the treatment plan.

### Conclusion

Using suitable membranes, open healing may allow uneventful wound healing and sufficient bone formation. This approach may help to avoid soft-tissue problems associated with extensive flap mobilization and tension.

### Keywords

Collagen membrane, open healing, ridge preservation, augmentation.

## Introduction

The aim of implant therapy is to ensure an optimal functional and esthetic outcome as well as good long-term results. The use of regenerative techniques is often necessary to maintain or augment sufficient bone and soft-tissue for implant placement. Among the bone substitutes, a deproteinized bovine bone mineral (DBBM) has been shown to be effective in bone augmentation<sup>1–4</sup> and ridge preservation procedures.<sup>5–8</sup> Studies with long-term follow-ups have shown that the regenerated bone is maintained over time.<sup>9, 10</sup> Histological analyses have indicated that the slow resorption rate of DBBM is responsible for the long-term stability of the augmented bone volume.<sup>11</sup>

DBBM is often used in combination with a semipermeable membrane. According to the principle of guided bone regeneration (GBR), the membrane is used to exclude epithelial cells from the bone defect, thereby allowing bone formation.<sup>12</sup> In the early days of GBR, nonresorbable ePTFE (expanded polytetrafluoroethylene) barriers were successfully used to cover bone defects.<sup>13, 14</sup> However, postoperative wound dehiscence occurred frequently. It was often associated with infections that required early membrane removal and impaired bone regeneration.<sup>15–17</sup> A resorbable native bilayer collagen membrane (NBCM) was shown to reduce the risk of membrane exposure and achieve comparable results to the ePTFE barriers with regard to bone regeneration.<sup>16</sup> If wound dehiscence occurred with the NBCM, healing was uneventful. Other studies have confirmed the promising healing characteristics of this membrane.<sup>18, 19</sup>

In general, it is recommended to achieve complete, but tension-free, primary wound closure over the collagen membrane. However, when bone augmentation procedures are performed, closing the flap without tension may become challenging. Splitting of the periosteum and extensive soft-tissue mobilization may then be necessary. This may increase morbidity, swelling and the rate of wound dehiscence because of impaired blood supply in a thinned flap. In addition, an insufficient vestibular depth, lack of keratinized tissue or scars may compromise the esthetic results and require additional surgical interventions.

A possible approach to avoid flap mobilization is to allow open healing of the membrane. We started to use various collagen membranes and

## Materials and methods

Evaluation included patients from a private practice who were treated between August 2005 and June 2014 using an open-healing approach. Patients underwent implant therapy to replace hopeless or missing teeth. Surgical interventions were performed as well as pre- and postoperative care administered according to our standard procedures. Membranes were applied in ridge preservation and in bone augmentation procedures, which were performed simultaneously with or before implant placement.

In ridge preservation procedures, hopeless teeth were extracted atraumatically. The extraction socket was cleaned and all granulation tissue was removed carefully. A DBBM (Geistlich Bio-Oss, Geistlich Pharma, Wolhusen, Switzerland) was applied into the socket according to the manufacturer's instructions and covered with a membrane. In three-wall defects, that is, if the buccal bone wall was partially or completely missing, and if the defect was narrow and deep, a soft-tissue pond was prepared and the ice-cream cone technique<sup>20</sup> was used.

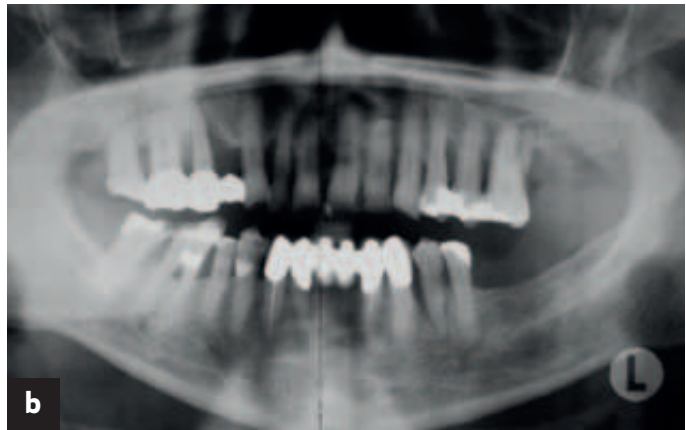
In patients with missing teeth, a reduced full-thickness flap was prepared. If sufficient primary stability could be ensured, implants were placed immediately according to the manufacturers' instructions. Bone augmentation was performed using DBBM or autogenous bone harvested from the drill hole. If the defect was large or if several bone walls were missing, mechanical stability was ensured using a titanium mesh (Synthes, Umkirch, Germany). A membrane was applied overlapping the defect. Membrane margins were placed under the flap and the flap was sutured tension-free, leaving the membrane partially exposed.

The following membrane materials were used:

- Geistlich Bio-Gide (NBCM; Geistlich Pharma)
- Jason membrane (JM; botiss biomaterials, Berlin, Germany)
- Socket Repair Membrane (SRM; Zimmer Biomet, Freiburg, Germany)
- DynaMatrix (DM; Keystone Dental, Alfter, Germany)
- Geistlich Mucograft Seal (CMXs; Geistlich Pharma)
- Histoacryl (HIA; B. Braun Medical, Melsungen, Germany).

Antibiotics were prescribed in accordance with current guidelines, that is, in patients at higher risk, such as valvular heart disease or inflammation due to tooth fracture prior to tooth extraction. Suture removal took place after two weeks. In order to allow maturation of bone and soft tissue, sites were allowed to heal for at least six months before implant placement or secondary augmentation procedures were performed. A typical clinical case is shown in **Figures 1a–m**.

ing complications and membrane type or defect morphology (number of bone walls) was evaluated using the exact chi-squared test or Fisher exact test for general frequency tables at the 5% level of significance. Additionally, a Spearman rank correlation coefficient was calculated for healing complications and defect morphology. The univariate results were confirmed by a multivariate logistic regression using healing complications as the main variable and defect morphology and membrane type as co-variables.



Figs. 1a &amp; b

**Fig. 1**  
Initial (a) clinical and (b) radiographic situation prior to tooth extraction. Owing to periodontal bone loss, teeth in the upper and lower jaws were extracted.

### Evaluation

In many cases, one membrane was used to cover multiple neighboring defects. These sites were defined as one surgical area. The data were retrospectively analyzed for defect morphology (number of remaining bone walls), size of surgical area (number of neighboring sites), indication, complications during healing, loss of graft material, possibility of performing flapless implantation and need for follow-up augmentation procedures (none, planned or unplanned). The primary outcome parameter was the need to perform an unplanned augmentation during the implant procedure. The secondary outcome parameter was complication rate during wound healing. In addition, the data were analyzed to determine whether unfavorable defect morphology might increase the frequency of healing complications and whether the membranes differed with regard to healing complications.

### Statistics

Explorative analysis of the data was performed using R (Version 3.2.2; R Foundation Vienna, Austria). A possible correlation between heal-

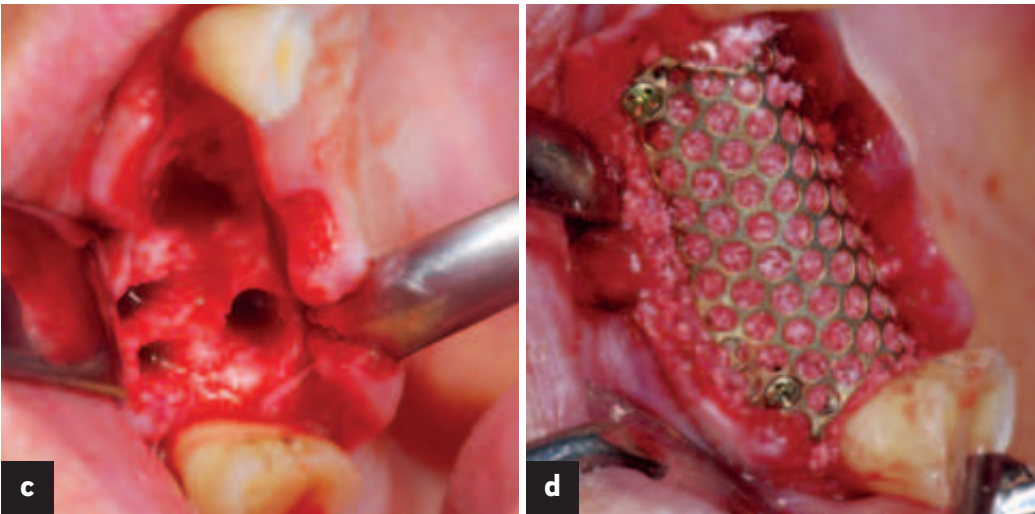
### Results

During the observation period, a total of 127 patients with 171 surgical areas were treated using the open-healing approach. Eight patients were lost to follow-up because they did not show up for implant placement. Therefore, the analysis included 160 surgical areas in 119 patients. Of the patients, 49.6% were male and 50.4% female. Mean patient age was  $54.3 \pm 13.0$  years (aged 29–88 years). The maximum number of surgical areas per patient was four. A surgical area contained  $1.89 \pm 1.26$  sites on average (**Table 1**). The number of missing bone walls per surgical area is shown in **Table 2**.

DBBM was used in 98.1% and autogenous bone in 1.9% of the surgical areas. In 78.8% of the surgical areas, NBCM was used (**Table 3**). A titanium mesh was additionally applied in 11.3% of the surgical areas. Of these surgical areas, 88.9% were covered with NBCM, 5.55% with JM and 5.55% with DM.

Bone augmentation procedures were performed in 33.1% of the surgical areas. They included bone splitting, horizontal, and/or vertical bone augmentation and sinus floor elevation. Ridge preservation alone was performed in 41.9%

Figs. 1c & d



Figs. 1e & f

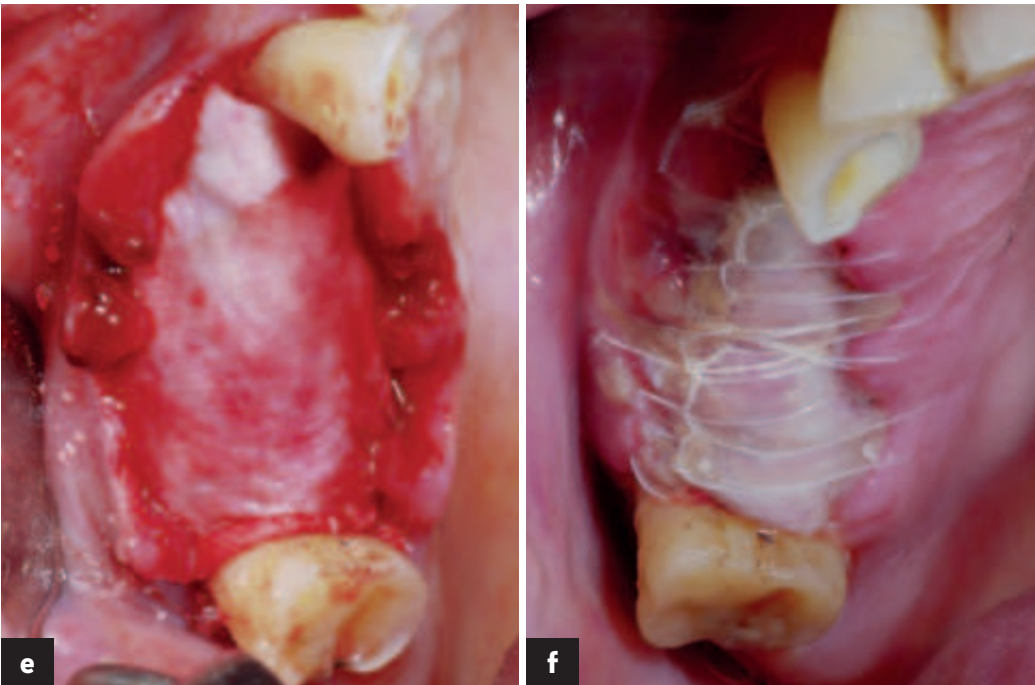


Fig. 1g



**Fig. 1**  
**Intraoperative view:**  
**(c)** Ridge situation after atraumatic extraction and reduced flap elevation.  
**(d)** The extraction sites were filled with DBBM, and titanium nets were placed bilaterally to stabilize the augmented volume (first quadrant is shown here).  
**(e)** Placement of a native bilayer collagen membrane (NBCM) over the titanium mesh. The flap was sutured without tension, leaving the NBCM exposed.  
**(f)** Clinical situation two days after surgery.  
**(g)** Radiographic situation two weeks after surgery.

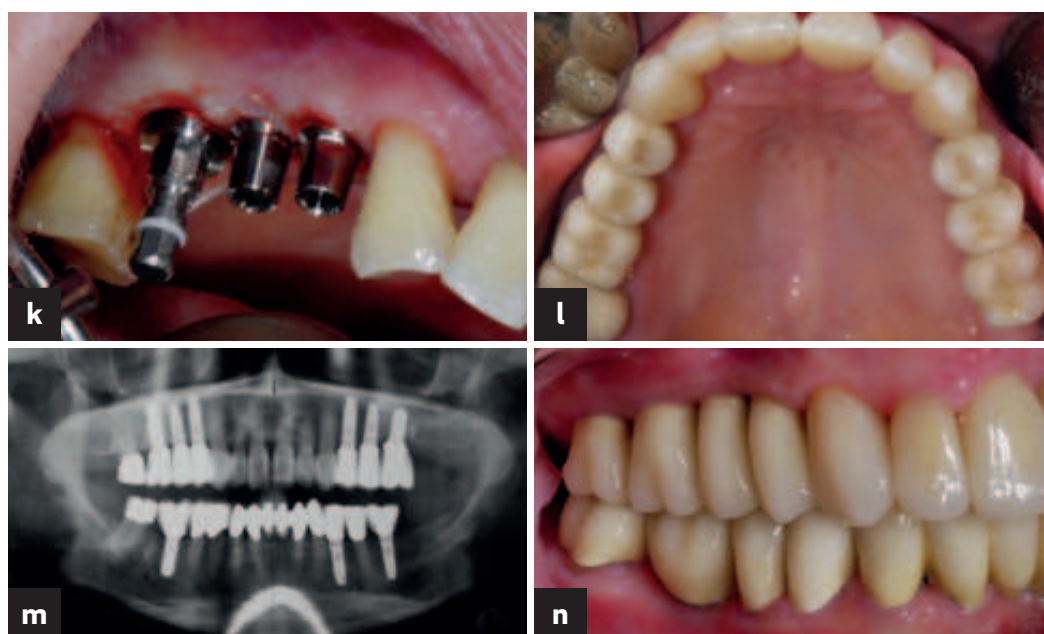




Figs. 1h & i

Fig. 1j

**Fig. 1**  
**During healing:**  
(h) Nine days and (i) three weeks after surgery. The membrane had resorbed and the titanium mesh was visible. (j) After three months, the titanium mesh was removed.  
**After healing:**  
(k) Six months after surgery, implants were placed using minimally invasive surgery. (l) Final restoration and (m) radiographic view after 15 months. (n) Stable clinical situation five years after augmentation.



Figs. 1k & l

Figs. 1m & n

of the surgical areas. In 13.1%, ridge preservation was combined with bone augmentation. The ice-cream cone technique was used in 14% of the surgical areas (26% of all areas undergoing ridge preservation). In 1.25% of the surgical areas, bone defects were treated owing to implant removal.

A total of 32.5% of the surgical areas included an extraction site in which immediate implant placement was performed. In 10.6% of the surgical areas, implants were placed into healed bone simultaneously with the augmentation procedure.

Healing was uneventful in 90.6% of the surgical areas. Complications during healing occurred in 15 areas (9.4%; **Table 4**). Five of these areas had undergone ridge preservation, three areas ridge preservation combined with bone augmentation and seven areas augmentation procedures. The complications included premature membrane resorption (five areas: four covered with NBCM; one covered with JM), hematoma (three areas: two covered with NBCM; one covered with JM) and membrane loosened by tongue (one area covered with NBCM). One patient developed an abscess (area covered with JM), one implant was lost (area covered with NBCM) and another patient complained about pain six weeks after surgery (area covered with NBCM). The patient was successfully treated with antibiotics. Other complications were an exposed titanium mesh (one area covered with NBCM), wound dehiscence (one area covered with NBCM) and a fractured bone plate during the augmentation surgery (one area covered with NBCM). The graft was partially lost in three surgical areas (1.9%; one area covered with JM; two areas covered with NBCM).

The number of complications per defect morphology type is given in **Table 5**. The number of morphology categories was too large to test for a correlation between the number of present bone walls and frequency of healing complications. When only the two most frequent defect morphologies, that is, three- and four-wall defects, were compared with each other, no clear indication of a correlation was found. In both morphology types, the percentage of healing problems was very similar. When defect morphology was coded as a figure (e.g., 2–3 was 2.5), a rank correlation of -0.052 was calculated. This indicated that defects with a higher number of bone walls slightly tended to have fewer healing complications. Healing complications occurred in 9.52% of the surgical areas covered with NBCM and in 8.82% of the areas covered with a different membrane type. The data did not indi-

cate any correlation between membrane type and healing complications.

#### Implantation or secondary augmentation

The average healing phase until implantation and/or secondary augmentation was  $5.2 \pm 8.1$  months (0–58 months). Implants could be inserted as planned in a two-stage procedure in all but one surgical area. Flapless implantation was possible in 58.8% of the surgical areas.

In 86.88% of the surgical areas, no secondary augmentation was necessary (**Table 6**). Secondary augmentation procedures were performed according to the treatment plan in 12.5% of the surgical areas. They ranged from minor to extensive interventions and included sinus floor augmentation in nine surgical areas (three internal sinus lifts), bone spreading in three and bone splitting in two. There was only one surgical area in which an abscess required an unplanned re-augmentation and implant insertion was therefore not possible as planned.

### **Discussion**

In this analysis, different collagen membranes and matrices, as well as tissue glue, were used in ridge preservation and augmentation procedures in an open-healing approach in a variety of indications and defect types. The clinical outcomes were evaluated retrospectively. The primary outcome parameter was the necessity to perform unplanned augmentation since this was regarded to be a partial failure of the regenerative treatment. The treatment was judged to be successful if no re-augmentation had to be performed or if an additional bone augmentation could be performed as planned at the time point of the first intervention. There was just one case in which an unplanned re-augmentation had to be performed owing to an abscess. Therefore, the surgical approach using open healing was successful according to the criterion of no unplanned re-augmentation being required in 99.4% of the surgical areas.

However, owing to the retrospective and uncontrolled nature of this study, it is not known whether a closed-healing approach might have resulted in improved bone regeneration or might have reduced the extent of a planned secondary augmentation. Exposure of resorbable membranes may be associated with premature mem-

**Table 1**

Size and number of surgical areas.

**Table 2**

Defect morphology of surgical areas.

**Table 3**

Types of membranes used to treat surgical areas.

**Table 4**

Type of complication and types of membranes used per surgical area in which a complication was recorded (surgical areas with complications  $n=15$ ).

Sites per surgical area	Number of surgical areas (%)
1	85 (53.13)
2	33 (20.63)
3	33 (20.63)
4	6 (3.75)
5	1 (0.63)
6	1 (0.63)
12	1 (0.63)

Table 1

Number of bone walls surrounding defects	Number of surgical areas (%)
1–4 <sup>†</sup>	1 (0.63)
2	14 (8.75)
2–3 <sup>‡</sup>	10 (6.25)
3	67 (41.88)
3–4 <sup>§</sup>	9 (5.63)
4	59 (36.88)

Table 2

<sup>†</sup> Surgical area contained sites with one, two, three and four bone wall defects.

<sup>‡</sup> Surgical area contained sites with two and three bone wall defects.

<sup>§</sup> Surgical area contained sites with three and four bone wall defects.

Membrane type	Number of surgical areas treated (%)
NBCM	126 (78.8)
HIA	19 (11.9)
DM	8 (5.0)
SRM	3 (1.9)
JM	2 (1.3)
CMXs	1 (0.6)
Not documented	1 (0.6)

Table 3

Type of complication	Number of surgical areas (%)	Membrane type used per surgical area in which complication developed
Premature membrane resorption	5 (3.1)	NBCM ( $n = 4$ ) JM ( $n = 1$ )
Hematoma	3 (1.9)	NBCM ( $n = 2$ ) JM ( $n = 1$ )
Membrane loosened by tongue	1 (0.6)	JM ( $n = 1$ )
Abscess	1 (0.6)	JM ( $n = 1$ )
Implant loss	1 (0.6)	NBCM ( $n = 1$ )
Patient complained about pain	1 (0.6)	NBCM ( $n = 1$ )
Exposed titanium mesh	1 (0.6)	NBCM ( $n = 1$ )
Wound dehiscence	1 (0.6)	NBCM ( $n = 1$ )
Fractured bone plate during augmentation surgery	1 (0.6)	NBCM ( $n = 1$ )

Table 4

Table 5

Defect morphology (number of bone walls present)	No complication (%)	Complication (%)	Membrane type used per surgical area in which complication developed
1–4	1 (100.0)	0 (0.0)	–
2	12 (85.7)	2 (14.3)	NBCM ( <i>n</i> = 2)
2–3	8 (80.0)	2 (20.0)	NBCM ( <i>n</i> = 2)
3	62 (92.5)	5 (7.5)	JM ( <i>n</i> = 2) NBCM ( <i>n</i> = 3)
3–4	8 (88.9)	1 (11.0)	NBCM ( <i>n</i> = 1)
4	54 (91.5)	5 (8.5)	DM ( <i>n</i> = 1) NBCM ( <i>n</i> = 4)

Table 5

Number of complications per defect morphology and types of membranes used per surgical area with complications.

Table 6

Number of secondary augmentations performed after healing.

Table 6

Secondary augmentations	Number of surgical areas (%)
Not necessary	139 (86.88)
Planned	20 (12.50)
Unplanned†	1 (0.63)

† Re-augmentation.

brane degradation and a shortened barrier function.<sup>19</sup> Various studies have shown controversial results regarding the effect of secondary wound dehiscence occurring during healing. Moses et al. evaluated bone healing of buccal periimplant bone dehiscence defects with or without membrane exposure.<sup>21</sup> Using NBCM, they found a mean defect reduction of 95% in the case of uneventful healing, while defect resolution was significantly reduced to 53% when the membrane was exposed. In a dog study, a significant negative effect of membrane exposure on defect fill was found too.<sup>22</sup> In contrast, other studies demonstrated only a slight, nonsignificant reduction in defect fill if exposed membrane sites were compared to nonexposed ones.<sup>16, 19</sup> In ridge preservation, positive results using the membrane in an open-healing approach have been described before. Filipek et al. compared open and closed healing in extraction sites in 40 patients.<sup>23</sup> When analyzing the dimensions of the alveolar ridge six months after tooth extraction, they did not find any significant difference between open and closed healing. In another study, Cardaropoli et al. achieved good results using open healing with regard to ridge dimension.<sup>8</sup>

However, the control treatment was spontaneous extraction socket healing and there was no control treatment with closed healing.

Owing to its retrospective nature and the lack of a control group, the current analysis does not allow drawing of clear conclusions on whether open healing may have a certain negative effect on the outcome of the regenerative procedure. The positive result regarding the low necessity of re-augmentation indicates that open healing may be a suitable clinical procedure. However, prospective studies should compare the outcome of open and closed healing under standardized clinical conditions.

In this study, the second outcome parameter was the incidence of complications during healing. Healing was uneventful in 90.6% of the surgical areas. In 2.5% of the surgical areas, the complications were associated with the surgical intervention (hematoma and one broken bone plate). In 6.9% of the areas, the complications may have been related to the open-healing approach. These complications were premature resorption, membrane loosening by tongue, exposed titanium mesh and wound dehiscence. A certain rate of healing complications has been



reported with closed healing too. In a study using NBCM in periimplant defects, Zitzmann et al. found wound dehiscences in 16% of the defects at the time point of suture removal.<sup>16</sup> Von Arx and Buser reported a complication rate of 9.5% during healing in horizontal ridge augmentation.<sup>1</sup> The sites re-epithelized spontaneously within two to four weeks and the authors concluded that the membrane did not cause infections when exposed.

Moses et al. found wound dehiscences in 39% of patients treated with cross-linked collagen membranes.<sup>21</sup> In a multicenter randomized, controlled clinical trial, bone augmentation procedures using DBBM and NBCM were applied in 90% of 208 patients undergoing immediate implant placement with transmucosal healing.<sup>24</sup> After one week, flap dehiscences were noted in 12% of the cases. After two weeks, the percentage had decreased to 6.0% and after six weeks to 1.5%, indicating proper secondary healing even in the case of membrane exposure. In the retrospective analysis presented here, the overall complication rate of 9.4% indicates that open healing is not associated with an increased risk of healing complications compared with closed healing. Studies have indicated that native collagen membranes may facilitate angiogenesis.<sup>25</sup> and allow for less compromised wound healing in comparison with cross-linked collagen materials.<sup>19</sup> Therefore, native collagen may promote uneventful soft-tissue healing under open-healing conditions too. Apart from material-related wound dehiscence, iatrogenic factors like suture technique may play an even more important role, but to our knowledge, no study has reported on the rate and effect of tensionless wound closure compared with flaps under tension. However, further studies are needed to investigate wound healing when the flap is not closed over the membrane.

Owing to the large variety of defect morphologies, no clear correlation could be found between defect morphology and healing complications, although there was a small trend for a higher complication rate in defects with a higher number of missing bone walls. However, the positive outcomes for all defect morphologies indicate that open healing is not limited to a certain defect type.

While NBCM was applied in most of the areas, a few other materials were used too. The number was too small to draw a clear conclusion on possible differences in healing between these different membrane types. Further studies

are necessary to compare the suitability of various membranes for open healing.

## Conclusion

The retrospective analysis of patients treated in a private practice indicates that open healing using suitable membrane materials allows uneventful healing and sufficient bone formation. Thereby, soft-tissue problems associated with extensive flap mobilization and tension may be avoided. There was no control group and the data set included different indications, defect morphologies and defect sizes. While this limits the power of the study, it reflects the situation in private practice. Furthermore, if open healing allows for achieving good results in a nonuniform patient group, one may conclude that it could have the potential to become a general clinical option. Prospective studies with control groups are needed to further investigate this surgical approach.

## Competing interests

The author declares that he has no competing interests.

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