Guided bone regeneration with titanium membranes: a clinical study

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SUMMARY Guided bone regeneration using barrier membranes is useful in bone augmentation. Because the commonly used polytetrafluoroethylene (PTFE, Gore-Tex®, WL Gore, Flagstaff, AZ, USA) membranes or resorbable membranes tend to collapse, more stable membranes are desirable. A titanium membrane (FRIOS® BoneShield, Friatec, Mannheim, Germany) was evaluated in a clinical study of 52 patients. Most of them had particulate bone grafts or phycogene hydroxyapatite (Algipore®, Friatec, Mannheim, Germany) or both stabilized with titanium membranes. In 78 procedures, 23 membranes (29%) became exposed, but only seven of these (9%) led to failure of the graft with a considerable loss of augmented material. The time interval between operation and possibly exposure was responsible for the result. Early exposures (within a few weeks) led to poor formation of new bone within the grafts, whereas if exposure was later, results were as good as in procedures in which the membranes did not become exposed.

INTRODUCTION

An adequate supply of bone is one of the prerequisites of good long-term prognosis in implant dentistry. The volume of bone is often not sufficient because of trauma, advanced periodontal disease, or atrophy of the alveolar ridge.2 Bone grafts, augmentation of the maxillary sinus floor, and guided bone regeneration have been used to ensure sufficient bone at the implant sites. Biological principles of guided tissue regeneration to gain new bone have been tested in experimental animal studies,2–4 and the principle of guided bone regeneration is the creation and maintenance of secluded spaces.5,6 The ingrowth of osteo-genetic cells is therefore undisturbed by competing non-osteogenetic soft tissue cells. Dahlin et al.7 published a controlled clinical study in which fixture fenestrations treated with guided bone regeneration showed significantly more new bone formation than control sites of fenestration defects. As well as the coverage of exposed implant surfaces by newly formed bone,7–10 the goal was to increase the volume of bone on the alveolar ridge.7 In the first studies of guided bone regeneration, flexible membranes were applied. But the creation and maintenance of sufficient space underneath the barrier is an important factor for a successful result.5,11 Therefore titanium-reinforced12 polytetrafluoroethylene membranes (PTFE, Gore-Tex, WL Gore, Flagstaff, AZ, USA) and titanium membranes11,13 were introduced to increase the stability of barrier membranes. The aim of this study is to present first clinical results of a microperforated titanium membrane used for guided bone regeneration and to evaluate the results of different augmentation techniques.

MATERIALS AND PATIENTS

Since 1995, we have used titanium membranes with microperforations (FRIOS® BoneShield, Friatec, Mannheim, Germany) for guided bone regeneration. The membranes are either triangular or oval (Fig. 1). The mechanical properties of the membrane prevent collapse of the membrane and provide a constant volume underneath it and areas of microporosity that are small enough to prevent soft tissue penetration through the membrane permit diffusion of interstitial fluid. The membrane has to be preshaped according to the size of the defect. Lateral slits allow fixation with titanium pins to the bone surrounding the defect and make the membrane able to be molded. It can therefore be adapted to fit passively according to the shape of the augmented site.

Fig. 1 – Various titanium membranes.
Fifty-two patients (35 women and 18 men, mean age 51 years, range 19–75) have been treated with titanium membranes.

The mean time that the membranes were left in place was 4.6 months (range 2–9). A total of 112 membranes were used for coverage with different augmentation techniques (Table 1).

The membranes were used to cover the lateral wall of the maxillary sinus after elevation and grafting of the floor. In horseshoe-LeFort I osteotomy sandwich procedures, contour irregularities between local bone and monocortical bone transplants were grafted with a mixture of Algipore and cancellous bone. Titanium membranes covered and stabilized this mixture. Cavernous defects were filled with Aligipore and covered with titanium membranes. Peri-implant bone deficiencies were filled with Aligipore® or particulate bone harvested from the oral cavity, and the augmented material was kept in place with titanium membranes. Onlay grafts (Figs 2 & 3), which are often harvested from donor sites such as the region of the chin and mandibular angles, were also covered with titanium membranes. In some patients, the membranes were used for two different augmentation techniques, so they are listed twice in Table 1.

RESULTS

Five unilateral perforations and one bilateral perforation developed in bilateral sinus grafts and the membranes were removed between nine weeks and five months postoperatively. One of these patients, a heavy smoker with a unilateral exposed membrane two weeks postoperatively, lost part of the augmented material on the affected side. When the membrane was removed, it was found that the augmented material had not been adequately stabilized by newly formed bone. In all the other patients, even in those in whom the membranes became exposed six weeks to five months postoperatively, a stable layer of newly formed bone had developed underneath the membrane.

Three unilateral sinus grafts developed exposed membranes one week to three months postoperatively. The patient who had the shortest interval before the membrane was exposed had insufficient new bone and part of the augmented material was lost. The remainder had good results. In the horseshoe-LeFort I osteotomy group, the membrane was exposed in one patient after two months. In this case, the loss of augmented material was minimal and, after removal of the membrane, the exposed bone was covered by local mucosa within a few weeks. All the other patients had excellent results.

In the group of donor site and other cavernous defects, there was one perforation after a week, and

<table>
<thead>
<tr>
<th>Technique</th>
<th>No. of procedures</th>
<th>No. of membranes</th>
<th>Complications</th>
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</thead>
<tbody>
<tr>
<td>Bilateral elevation of sinus floor</td>
<td>28</td>
<td>44</td>
<td>7 (25.0%)</td>
</tr>
<tr>
<td>Unilateral elevation of sinus floor</td>
<td>11</td>
<td>16</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Horseshoe-LeFort I osteotomy</td>
<td>5</td>
<td>10</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Cavernous defects</td>
<td>9</td>
<td>12</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Peri-implant defects</td>
<td>10</td>
<td>10</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Onlay grafts</td>
<td>14</td>
<td>20</td>
<td>8 (4%)</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>112</td>
<td>23 (30%)</td>
</tr>
</tbody>
</table>

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the procedure failed. The membrane was exposed and most of the graft material had disappeared five months postoperatively.

In the group of peri-implant defects there were three exposed membranes (two weeks to five months after surgery), and one of them failed. Peri-implantitis had been treated by curettage and grafting with Algipore and a titanium membrane was used to cover it.

There were most problems in the onlay graft group, eight membranes were exposed one week to five months postoperatively. In three cases (exposed at 2–4 weeks) there was considerable loss of the grafted material, and in one of these patients a fixture applied at the same time was lost. The remaining patients had satisfactory results.

DISCUSSION

Routinely used non-absorbable PTFE membranes or resorbable membranes (Bio Gide®, Geistlich Biomaterials, Wolhusen, Switzerland) tend to collapse, which narrows the space for new bone to form, so autogenous bone harvested from intraoral sites, demineralized freeze-dried bone, or hydroxyapatite have been used to support the membrane. Graft material stimulates the formation of new bone by osteoconduction, and Algipore, the phycogene hydroxyapatite that we used, reduces the number of bone grafts necessary. The texture of Algipore serves as an osteoconductive scaffold for osteoblastic cells and stimulates deposition of the matrix. Particles are osseointegrated and resorbed biomaterial is slowly replaced by newly formed bone. However, the graft material consists of particulate material that has no particular dimensional stability unless bone blocks are used and stabilized by osteosynthesis. New bone may not form in particulate graft material (particulate bone grafts or hydroxyapatite, or both) because the graft material is not sufficiently stable during the healing period.

To overcome this problem, we used titanium membranes as barriers and the rigidity of the titanium membrane makes the barrier able to maintain space. In a recent study, Lundgren et al. compared guided bone regeneration by PTFE membranes with that of titanium foils. They created bilateral non-space-making defects in the maxillae of 22 rabbits, which were devided into three groups. PTFE barriers were placed over the defects and compared with totally occlusive or perforated titanium foils; the third group was not covered and acted as controls. After four weeks of healing, the amount of regenerated bone tissue underneath the collapsed PTFE membrane was about the same as in the controls. The most regeneration was seen in defects underneath the titanium foils, particularly if they had perforations. The authors suggested the possibility that cells and fluids necessary for nourishment had passed through the perforated foils and aided regeneration.

FRIOS BoneShield is a titanium membrane with microperforations that follows the same principles as reported in the studies by Lundgren et al.

In our clinical series, we found sufficient new bone formation underneath the titanium membranes, unless there was early exposure or dislocation of the membrane. The quality of the newly formed bone was excellent for the positioning of dental implants. When flexible membranes, either resorbable or non-absorbable, were used, the results were less predictable. Even when the membranes were not exposed until we uncovered them, new bone did not always form within the particulate graft material. At the time that it was uncovered, the grafted particulate material was still mobile without any evidence of inflammation, and we suppose that inadequate stability was the reason. However, the rigidity of the titanium membranes leads to an increase in the number of exposures because of mucosal perforation. Similar problems have been reported with titanium-reinforced PTFE membranes that have been applied in vertical augmentations. The number of exposed membranes was more than in the conventional PTFE membranes, obviously because of local irritation of the soft tissue adjacent to the more rigid membranes. One of the most critical points that we noticed was the time between operation and possible exposure of the membrane. If the interval was more than 4–6 weeks, the grafted material was sufficiently stabilized by newly formed bone, so the loss of grafted material was minimal. The barrier should be left in place for up to six months, as that is the optimal time for bone regeneration.

The membrane should, however, be shortened if soft tissue is damaged by sharp edges. Local application of antiseptics and meticulous oral hygiene is essential to prevent inflammation. However, if the membrane does become exposed after only a few days or weeks, the result of the augmentation procedure is in doubt. Contact between saliva and the grafted material, as well as bacterial contamination, are thought to prevent formation of new bone within the graft. When membranes were removed, even months after exposure and despite careful local treatment, the augmented particulate material was often insufficiently stable. Titanium membranes are more difficult to insert than flexible membranes, because it is important to have a smooth junction between local bone and the membrane, otherwise the sharp edges of the membrane may cut through the mucosa. In onlay grafts, it is essential to insert the membrane carefully to avoid it crumpling, when the surgeon is trying to bend it around two axes. Bending it around one axis is intolerable and the smooth surface is preserved.

Careful soft tissue management is essential to prevent wound dehiscence. The blood supply of mucoperiosteal flaps has to be considered as well as the closure of the wound without tension. The patients should not be allowed to smoke postoperatively. When we had learned about these problems, we considerably reduced the number of exposed membranes.
References


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