GUIDED BONE REGENERATION (GBR) has been used recently for the regeneration of bone in conjunction with the placement of dental implants, for augmentation of resorbed alveolar crests, and to treat localized ridge deformities. Twenty-two patients with alveolar crest defects or peri-implant dehiscences participated in this study. Titanium implants were inserted, and the defects were covered with a titanium micromesh, above which was positioned an e-PTFE membrane. After healing, the 2 membranes were removed and a small specimen of the underlying tissues was retrieved with a small trephine. The postoperative healing was mostly uneventful, and only a few dehiscences with membrane exposure were observed. The space under the membranes was, in all patients, filled by a tissue with the macroscopic features of newly formed bone. No residual bone defects were observed and an increase of the alveolar width or height was observed. No untoward effects on bone regeneration were observed in the cases with membrane exposure. Histology showed that the underlying regenerated tissues were composed, in all cases, by newly formed bone. In conclusion, our results show that very satisfactory results concerning GBR techniques can be obtained even without the use of grafts under barrier membranes.

INTRODUCTION

Many techniques are available for the treatment of localized ridge augmentation: different surgical techniques (guided bone regeneration, bone splitting osteotomy, inlay and onlay grafting), different fixation devices (bone screws, pins, titanium mesh), different augmentation materials, and different barrier membranes. Guided bone regeneration (GBR) has been used in recent years for the regeneration of bone in conjunction with the placement of oral implants, for the augmentation of resorbed alveolar crests in man and animals, or to treat localized ridge deformities. An adequate bone volume for complete circumferential coverage of the implants is very important for obtaining long-term success of oral implants. The barrier membrane can be used either in a 2-stage technique, where bone is formed before the implant placement, or directly at the time of implant insertion. Many studies have recently demonstrated that simultaneous insertion of dental implants and barrier membranes produces bone regeneration.
regeneration over the exposed implant surfaces. One of the most important aspects for obtaining results with membranes for ridge augmentation is the creation and maintenance of a secluded space under the membrane, the development of this space is the prime determinant of the amount of newly formed bone. Moreover, membrane stability seems to be very important for wound healing in GBR techniques. The sites for localized ridge augmentation are non-space-making defects because they are not supported by the bone walls and, in these situations, an excessive soft tissue pressure could cause a membrane collapse toward the defect. Possible solutions to avoid membrane collapse and to increase the regenerative capabilities of the bone in non-space-making situations have been the use of reinforced e-PTFE (polytetrafluoroethylene) membranes or the use of miniscrews and pins to support the membrane. Recently, the use of self-reinforced polyglycolide membranes has been advocated. Even with miniscrews, however, it is possible to have a lateral collapse of the membrane and so the use of different types of grafts have been proposed to maintain the space between implant and surrounding defect. Semirigid membranes are especially useful to treat the vertical component of the ridge deformity. It seems, moreover, that maintenance of an unexposed barrier can be extremely important for the regenerative capabilities of bone. The aim of the present study was a clinical and histological evaluation of the use of a titanium mesh for GBR without the use of biomaterials.

**MATERIALS AND METHODS**

Twenty-two patients (14 females and 8 males) with a mean age of 47.5 years (range 20–63) participated in this study. All patients gave their informed consent. In all patients, alveolar crest defects (Figure 1) due to advanced periodontitis, trauma, extractions, or peri-implant dehiscences (Figures 2 and 3) were present.

Titanium implants (Bone System, Milano, Italy) were inserted (Figure 4) and the defects were then covered with a titanium micromesh (Bonesheet, Bone System) (Figures 5 and 6), above which was positioned an e-PTFE (polytetrafluoroethylene) membrane (Fig-
FIGURES 9–16. Figure 9. After 6 months, it is possible to observe a complete bone regeneration; the e-PTFE membrane has been removed. Figure 10. It is possible to observe a high quantity of newly regenerated tissue. Figure 11. After 6 months, it is possible to observe an increase in the quantity of peri-implant mineralized tissues. Figure 12. After 6 months, it is possible to observe a complete bone regeneration. Figure 13. It is possible to observe a small area of exposure of the e-PTFE membrane. Figure 14. The contaminated portion of the e-PTFE membrane has been removed. Figure 15. Postextraction implant (distal implant). Figure 16. After 6 months, it is possible to observe a significant increase in the vertical height around the distal implant.

FIGURES 17–18. Figure 17. Mature newly formed bone with small marrow spaces. Acid fuchsin and toluidine blue ×30. Figure 18. In the central portion of the defect, it was possible to observe newly formed bone with wide osteocyte lacunae. Many osteoblasts (arrows) are present. Acid fuchsin and toluidine blue ×100.

RESULTS
The postoperative healing was mostly uneventful in all patients and only 4 dehiscences of the soft tissues with membrane exposure were observed af-
AUGMENTATION USING TITANIUM MICROMESH

One of the main problems in using occlusive membranes is their lack of stiffness, which can produce a collapse of the barrier toward the bone defect, reducing in such a way the space needed for the bone regeneration.13,19,24 This problem can be, in part, overcome with the use of grafts beneath the membrane, but the influence of the overlying soft tissues in collapsing the membrane could still be present. Von Arx and Kurt1 used a titanium micromesh to protect and preserve densely packed bone grafted in the defects without the use of a barrier membrane, and they demonstrated that there was no invasion or displacement of the graft by the soft tissues overlying the titanium mesh. To avoid the possibility of a collapse of the membrane, we decided to use a titanium micromesh in patients with deficient ridges in the lateral and vertical dimensions in order to try to eliminate in a more complete way the negative influence of the soft tissues.

A striking result in this series of patients was that we didn’t find the soft tissue layer that has been found underneath e-PTFE membranes used alone.7 This fact could be due, probably, to an effect of the titanium membrane in avoiding the stress and micromovements in the membrane/tissue interface that could be implicated in the genesis of this soft tissue layer.17 These considerations are supported also by the study of Lundgren et al,15 where, with the use of a completely occlusive titanium barrier, no presence of connective tissue was found under the membrane.

Zellin et al24 found that, in a histological comparison of 10 different types of membranes in rats, a 50-μm membrane made of titanium foil had less tendency to collapse, while, on the contrary, problems were present concerning the adaptability of the material. The higher the stiffness of a material, the less the tendency to collapse, but we should take into consideration also the possibility of adapting a barrier to the bone contours.24 Von Arx and Kurt1 found that, even if the titanium mesh presented a degree of stiffness, the perforations of the mesh allowed 3-dimensional adaptation into the residual ridge.

We didn’t find any difficulties in placing the titanium membrane, and, in all our patients, the titanium micromesh was easy to handle, was very ductile, and appeared to have excellent space-making capabilities; few inconveniences (dehiscences) were observed in the healing of the soft tissues. This could be due to the excellent biocompatibility of the titanium membrane, which presents a low risk of infection after mesh exposure.1

To the contrary, Celletti et al,23 in an experimental study in dogs using titanium membranes, found that, at 3 weeks, all these membranes were slightly exposed. These different results could be due to the fact that our barrier was a micromesh with pores where the surrounding tissue could grow, while Celletti et al23 used membranes with no holes. No inflammatory response, as that observed by Paquay et al20 using a titanium fiber mesh in animals, was seen in our patients. The high biocompatibility of the titanium micromesh used is attested to by the presence, in some specimens, of newly formed bone in close and tight contact with the metal. In our patients, we observed a large amount of bone regeneration in non-space-making defects without the use of grafts under the mesh and the membrane. Moreover, no differences were observed between sites with membrane exposure and membrane submerged. Similar results have been reported recently by Machtei et al27 and Murphy.28

CONCLUSIONS

The clinical and histological results of the present study show that most certainly the space for the bone regeneration is one of the most critical factors in the success of the regenerative techniques,4 that the primary closure of the mucoperiosteal flap has a relevant role in the protection of the blood clot and in the prevention of infection,4,10 that even without the use of grafts under the occlusive membrane, very satisfactory results concerning GBR techniques can be obtained, and that the early removal of the e-PTFE membrane but not of the titanium membrane had few effects on the bone regeneration capabilities.
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