Chapter 17

Complications in guided bone regeneration

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Introduction

The development of guided bone regeneration (GBR) in the last decades has extended the use of endosseous implants to jaw bone areas with insufficient bone volume. Nowadays, a deficiency bone volume can be managed by by an experienced clinician almost as a routine clinical situation thanks to the increased predictability and efficacy of the GBR procedure.

GBR is based on the pioneering studies of compartmentalized wound healing developed by Nyman, Gottlow, and Karring in the 1980s [1–4]. It has been shown in animal and human studies [5–7] that when a membrane is placed over a bone defect, it inhibits epithelial and connective tissue from entering the wound and improves the rate and quality of the regenerated bone.

A wide range of membrane devices have been proposed in experimental and clinical studies for GBR. They are generally divided in two groups: resorbable and nonresorbable. Nonresorbable materials includes expanded polytetrafluoroethylene (e-PTFE), dense polytetrafluoroethylene (d-PTFE), and titanium mesh. Resorbable materials include collagen (native or cross-linked), pericardium, dura mater, polylactic acid, polyglycolic acid, polyurethane, and cortical foil.

Resorbable membranes demonstrate some advantages over nonresorbable devices: there is no need for membrane removal, the surgical procedure is simpler, there are fewer complications with reduced patient morbidity, and they are less expensive. However, when defects are not self space-making, bone regeneration by means of resorbable materials has dramatically reduced effectiveness. In these "critical" bone defects, nonresorbable devices were found to have better abilities to achieve successful regeneration thanks to membrane stiffness, controlled time of barrier function, and lack of resorption process of the device. Today, the increased evidence of the effectiveness of bioresorbable materials has limited the use of PTFE membrane and titanium grids; however, the latter have specific indications in large horizontal defects and in supracrestal areas.

Despite the scientific evidence demonstrating that GBR with a PTFE membrane and titanium mesh is a successful and predictable technique for horizontal and vertical regeneration [8–10], the use of a barrier has several potential drawbacks. The most common complication is the premature exposure of the device to the oral environment and its sequelae. However, other complications have been reported.

Verardi and Simion [11], discussing the treatment options for e-PTFE membranes that become exposed, suggested a division of the exposures into class I and class II categories. Class I was defined as a small soft tissue fenestration (≤3 mm), and class II as a wider opening (>3 mm).

Fontana *et al.* [12] proposed a classification of complications in the use of e-PTFE membranes with the intent to provide a treatment regime for managing these clinical situations. Depending on the amount of membrane exposure and/or the presence of infection, the authors identified four different clinical situations: small membrane exposure (≤ 3 mm) without purulent exudation (class I); large membrane exposure (>3 mm) without purulent exudation (class II); membrane exposure with purulent exudation (class III); and abscess formation without membrane exposure (class IV).

On the basis of the evidence emerging from clinical practice, a possible classification of complications in GBR with non-absorbable devices can be suggested:

- Exposure and infection:
  - class I: small device exposure (≤3 mm) without purulent exudation

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  - class II: large device exposure (>3 mm) without purulent exudation
  - class III: device exposure with purulent exudation
  - class IV(a,b): abscess formation without device exposure.
- Lesions associated with periosteal releasing incision.

Literature review

The incidence of membrane exposure varies depending on the study and on the clinical use of the barrier technique. When e-PTFE membranes were introduced in the early 1990s to laterally augment the alveolar ridge, a 41% incidence of exposure was reported [13]. This number has been drastically reduced in recent years due to the improvement in the surgical technique. Today, thanks to these improvements, GBR is considered to be a highly predictable technique to regenerate bone.

In a systematic review by Rocchietta *et al.* [8], the use of e-PTFE nonresorbable membranes for vertical ridge augmentation in a GBR setting was assessed and its complications reported. A prevalence of complications varing from 0% to 45.5% was published. Complications varied from a minor situation, such as soft tissue dehiscence requiring no treatment or treatment with chlorhexidine and/or systemic antibiotics, to major problems, such as treatment failure, implant/graft loss and suffering for the patient.

Simion *et al.* [14] reported an incidence of complications of 18% combining an e-PTFE membrane with a one-to-one auto/xenograft, while Merli *et al.* [15], in a clinical trial to compare two different techniques for vertical ridge augmentation, reported one major complication with 11 non-absorbable membranes. When vertical ridge augmentation was performed in conjunction with sinus elevation, Simion and coworkers [16] reported a 12.5% incidence of membrane exposure.

In a prospective study comparing allogenous bone matrix versus autograft for vertical augmentation of alveolar ridges, Fontana *et al.* [12] reported one membrane exposure in 10 surgically treated sites. Once exposed to the oral environment, microorganisms can invade the surface and pass through the membrane as reported by Simion *et al.* [17]. In this study the authors concluded that bone regeneration under an e-PTFE membrane stops 2–3 mm from the contaminated surface of the membrane. Further experimental and clinical results by Simion *et al.* [18] noted that bacterial penetration is delayed by the low porosity of the e-PTFE membrane due to its texture. According to this study, colonization of the regenerating tissue starts 3–4 weeks after exposure. This period can be taken to be the critical time for membrane removal to avoid infection to the deeper tissues.

Chlorhexidine has been proposed to reduce bacterial contamination of exposed membranes. In an *in vitro* study [19], topical application twice a day of a 0.2% chlorhexidine gel proved to be effective in reducing the amount of bacteria and inflammation to the surrounding soft tissues. Nevertheless, the use of chlorhexidine in this study did not influence the rapidity of bacterial penetration through the thickness of the membrane.

Almost all the information present in the literature regarding the predictability, effectiveness, and behavior of nonresorbable membranes for bone regeneration is related to the use of e-PTFE, but in the last few years e-PTFE membranes have been discontinued from the dental market. An alternative is the d-PTFE membrane with micron (<0.3 μm) porosity size, which was originally tested in postextraction sockets without primary soft tissue closure [20–22]. Scientific evidence of the efficacy of d-PTFE in GBR is still missing but short-term data are promising.

Recently, a prospective randomized controlled clinical trial to compare expanded versus dense PTFE membranes in vertical ridge augmentation provided encouraging results [23]. The authors concluded that no clinical or histological differences in vertical bone gain around implants could be observed while performing GBR procedures with either e-PTFE or d-PTFE membranes. Similar results were reported in a prospective case series by Urban *et al.* [24] using d-PTFE membrane in vertical ridge augmentation in 19 patients.

Similar complication rates have been reported when a titanium grid is used for GBR [8, 25–27]. Artzi *et al.* [25] reported 20% incidence of complications when titanium mesh was used in association to deproteinized bovine bone for vertical ridge augmentation in both mandibular and maxillary sites. In a retrospective study to evaluate 56 implants placed in alveolar ridges augmented using autogenous bone and titanium micromeshes, Corinaldesi *et al.* [26] encountered 4 premature exposures out of 27 micromeshes (complication rate, 14.8%). The titanium meshes were removed before the intended time with consequent incomplete bone regeneration.

Von Arx *et al.* [28] described 50% premature exposure when a a titanium mesh was used, but a low incidence of inflammation of the underlying regenerating tissue.

In a systematic review on the use of titanium grids in association or not with biomaterials for reconstructive surgery, Ricci *et al.* [10] assessed the success rate of the procedure and the survival and success rates of implants. Out of the 72 articles found in the literature, six studies met the inclusion criteria for the systematic review. In terms of complications of the surgical technique, they showed that titanium grid exposure occurred in 22.78% of patients; early removal of the device was necessary in

half of these cases. The consequences of wound healing dehiscence ranged from minor discomfort to total failure of the augmentation process.

Prevention of complications: surgical technique

Vertical and horizontal ridge augmentation by means of GBR with nonresorbable membranes is believed to be the most technically sensitive of all GBR procedures. Proper surgical technique combined with the technical skill of the surgeon are essential for a successful and predictable outcome (Figs. 17.1–17.26).

Preoperative and postoperative care

The surgical procedure is performed in a surgical operation in a private office with strict hygienic conditions. Presurgical preparation of the patient consists of use of a chlorhexidine digluconate 0.2% mouthrinse (Corsodyl; GlaxoSmithKline) for 2 minutes and an extraoral scrub with a povidone–iodine solution (Betadine; Viatris). A sedative premedication with diazepam (20–30 gtt, Valium-2; Roche) is administered before the surgery. Local anesthesia consists of administration of articaine 4% with epinephrine 1:100 000 (Citocartin 100; Molteni Dental).

The patient is prescribed antibiotics (amoxicillin 875 mg and clavulanic acid 125 mg; Augmentin; GlaxoSmithKline) starting 1 day prior to surgery and then twice a day for one week. The patient also receives a nonsteroid anti-inflammatory agent starting 1 hour before surgery and twice a day for one week. Local plaque control is essential and chlorhexidine 0.12% mouthrinses are prescribed for use twice a day, in order to reduce bacterial contamination of the wound. The patient is recalled once a month. Radiographic examination is done at the end of the surgery and at the time of membrane removal.

Flap design and recipient site preparation

Meticulous preparation of the recipient site is one of the key points for a successful outcome (Figs. 17.1–17.8). Surgery starts with a crestal incision down to the bone within the keratinized mucosa of the edentulous ridge. The incision extends intrasulcularly to include one or two distally and mesially adjacent teeth. Two vertical releasing incisions are made buccally at the distal and mesial termination of the crestal incision. Buccal and palatal full-thickness flaps are elevated to obtain a wide access for membrane and eventual implant placement. A continuous releasing periosteal incision is made at the base of the buccal flap, connecting the mesial and distal vertical incisions to help obtain a completely tension-free closure.

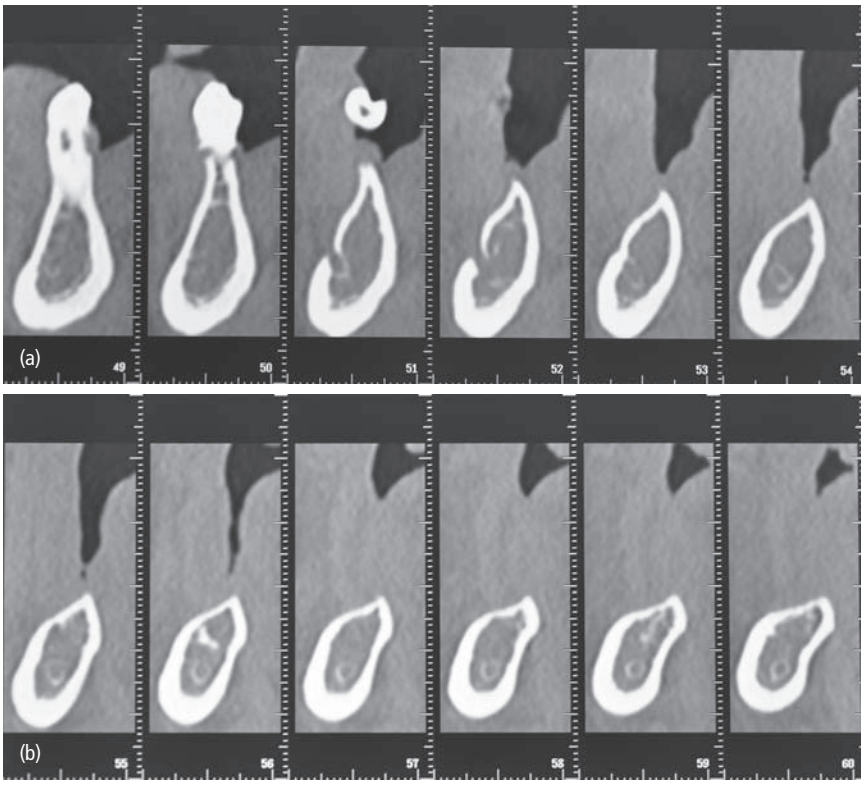


Fig. 17.1 (a, b) Computed tomography (CT) scan showing area of advanced atrophy.

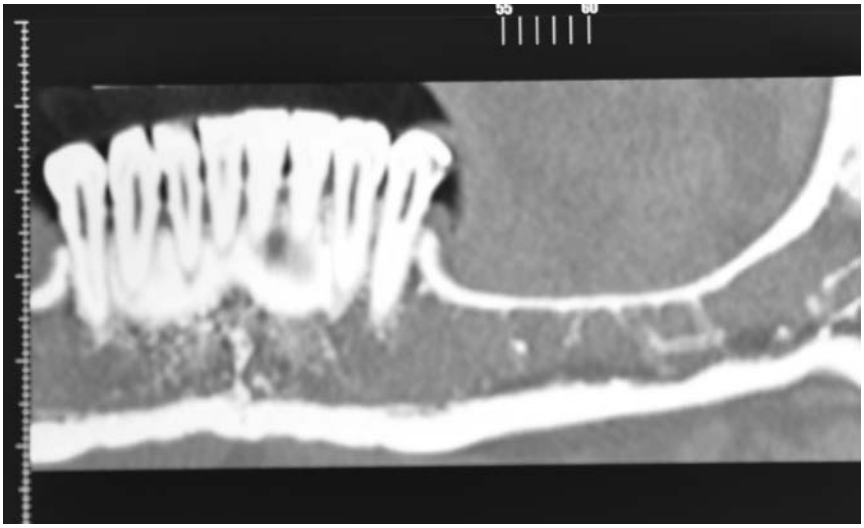


Fig. 17.2 Panoramic CT scan of the area to be regenerated by means of guided bone regeneration.

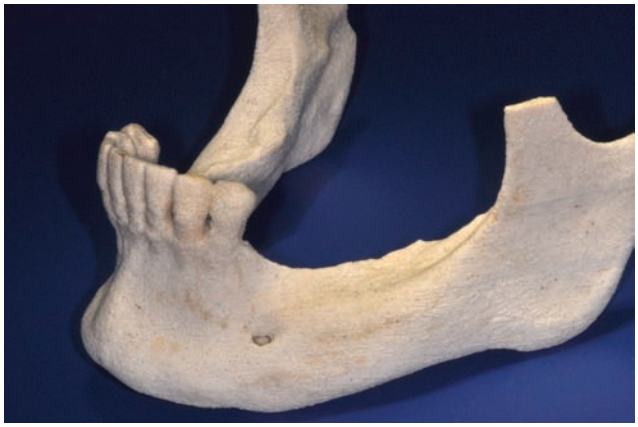


Fig. 17.3 Prototyping of the entire mandible showing the vertical and horizontal defect.

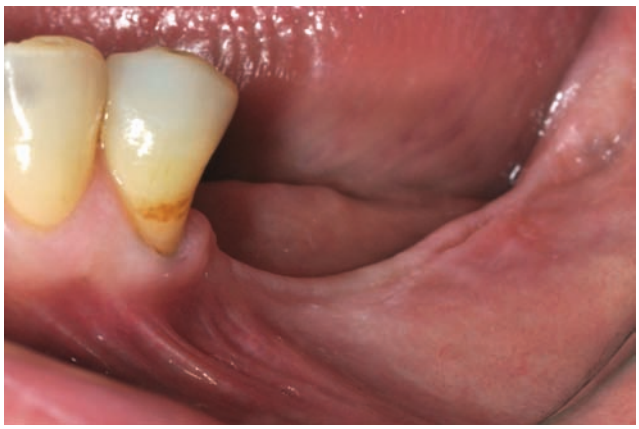


Fig. 17.4 Lateral view of the defect in the posterior left mandible.

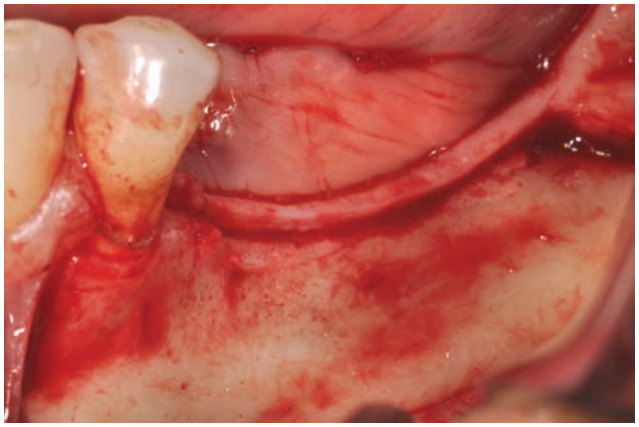


Fig. 17.5 After buccal and lingual flaps are gently elevated, the bone defect is curetted and prepared for the regenerating procedure.

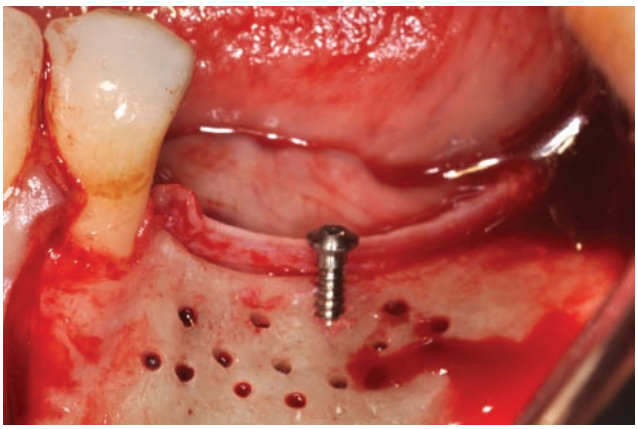


Fig. 17.6 A tent screw is positioned and several drillings of the cortical bone done to promote bleeding necessary for bone formation.

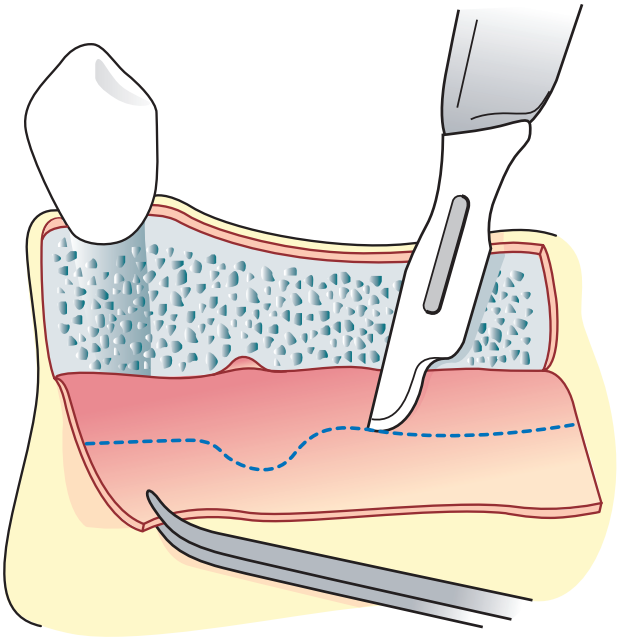
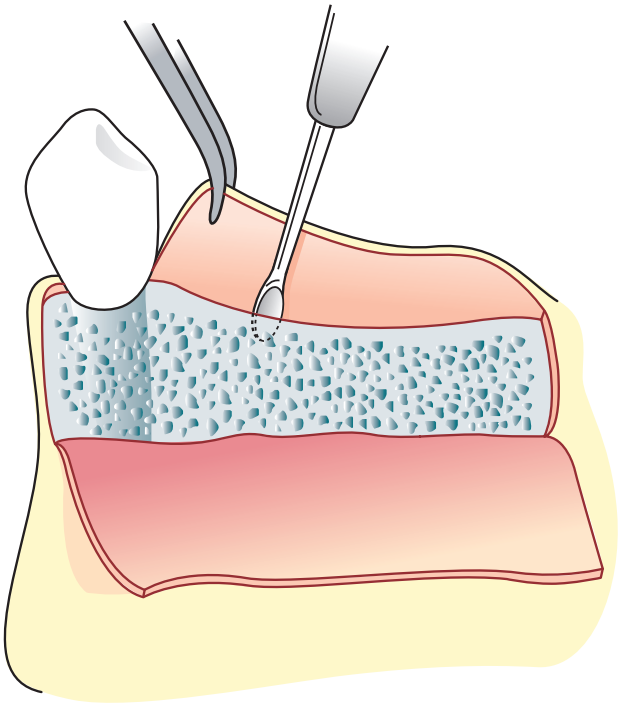


Fig. 17.7 Illustration showing the periosteal incision releasing the buccal flap.



Fig, 17.8 Illustration showing the releasing of the lingual flap.

In the lower jaw, particular care must be taken to avoid any damage to the mental nerve and the vascular plexa of the floor of the mouth. Moreover, the lingual flap must be reflected beyond the mylohyoid insertion of the omohyoid muscle in order to allow coronal advancement of the flap. No periosteal incision is performed with the palatal flap in the upper jaw. The flaps must be carefully managed to avoid any soft tissue trauma or perforation that could lead to membrane exposure during the healing period. After the flaps have been released, curettage of the bone surface is essential to remove all remaining connective tissue and periosteum which could interfere with the regenerative procedure.

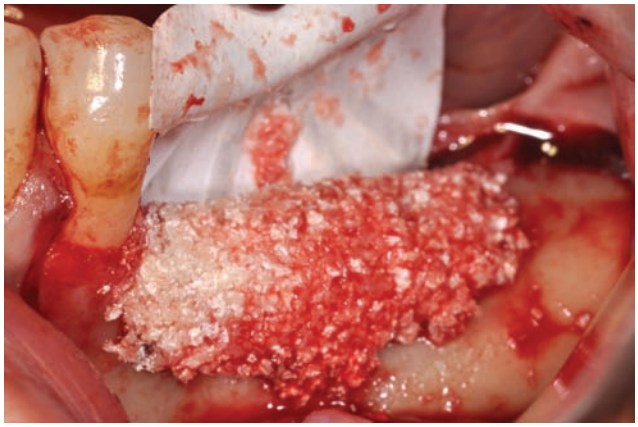


Fig. 17.9 A titanium-reinforced d-PTFE membrane is fixed lingually with mini-screws and the bone graft is packed into the defect.

Membrane positioning

When a large volume of bone is to be regenerated with the GBR technique, a titanium-reinforced d-PTFE membrane (Cytoplast; Osteogenics Biomedical) or a titanium mesh is recommended (Fig. 17.9). Better results are achieved with non-absorbable materials than with absorbable ones because of their better space-maintaining abilities, controlled timing of barrier function, and lack of a resorption process. The device is contoured and trimmed to adapt to the ridge and to a predetermined width and height of the area to be augmented. To avoid any interference during the healing process, the device should not touch the periodontal ligament of the adjacent teeth and should overlap the residual crestal bone by a minimum of 3–4 mm.

Stainless steel mini-screws (6–12 mm in length; Omnia) are used as "poles" to support the membrane/mesh (Fig. 17.10). They are positioned in the residual bone and left to protrude for the required height and/or width. However, when the residual bone height is at least 6 mm and primary implant stability can be achieved, the implants may be inserted simultaneously with membrane positioning. For vertical augmentation, implants are left to protrude from the cortical bone and act as mini-screws. Several drill holes must be made in the cortical bone to ensure the bleeding necessary to promote the required blood clot formation [29].

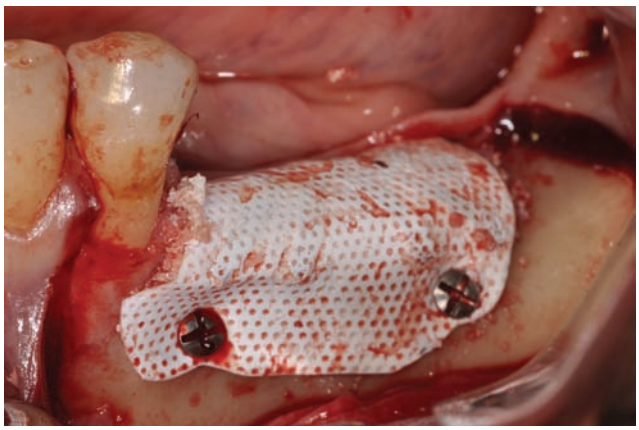


Fig. 17.10 The membrane is gently pulled and fixed buccally with two mini-screws.

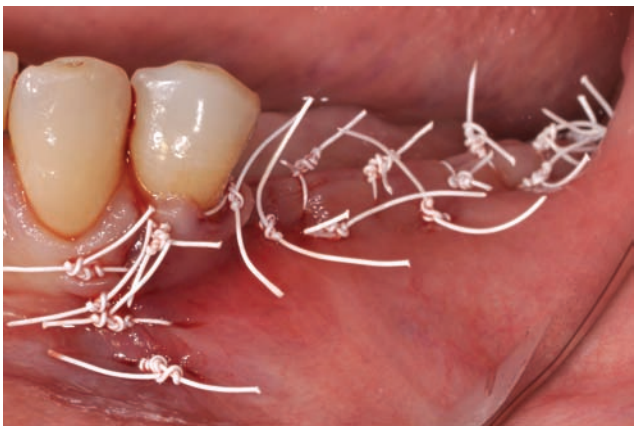


Fig. 17.11 Suturing technique with two lines of closure. First horizontal mattress sutures to overlap the two flaps and then single interrupted stitches.

Once positioned in the recipient site, the device is stabilized lingually with fixation mini-screws (Pro-fix; Deorematerials) in the mandible and/or with titanium tacks (Maxill) in the maxilla. A particulated bone graft is then placed on the bone crest under the partially fixated membrane. The device is gently pulled buccally over the graft and fixed at the mesial and distal buccal borders in order to achieve optimal flap adaptation.

Bone graft

There is scientific evidence [30–33] that the use of a bone graft to fill the space increases the potential and the predictability of bone regeneration as well as bone-to-implant contact. The rationale for using a bone graft in association with GBR includes the fact that it provides membrane support and acts as a scaffold for bone formation. A wide variety of graft materials have been employed in experimental studies and in clinical practice. However, many of these materials lack adequate scientific evidence to support their use in GBR. Autogenous bone grafts, collected from both intraoral and extraoral donor sites, are considered to be the gold standard in bone regeneration [30, 33–35]. However, morbidity and patient discomfort associated with harvesting procedures must be taken into consideration. Autogenous bone grafts are usually harvested from the mandibular ramus and/or from the mental symphysis with a bone scraper or with trephine burs.

In order to avoid the disadvantages associated with autogenous bone harvesting, some authors suggested the use of a bone substitute or a combination graft [36–38].

Allogenous bone grafts have been proposed for use with GBR. Fontana *et al.* [12] provided histological and clinical evidence for the use of an allogenous bone matrix to obtain vertical ridge augmentation. Similar results were reported by Simion *et al.* with the use of demineralized freeze-dried bone allograft [33, 39].

Deproteinized bovine bone has been also recommended [40–44] for use with GBR techniques with both absorbable and non-absorbable membranes.

Although to date only a few reports have been published using autogenous bone grafts combined with a xenograft and a non-absorbable membrane [14], emerging clinical evidence suggests that a 1:1 ratio of autograft and deproteinized bovine bone combines the scaffold properties of a bone substitute with the osteogenetic and osteoinductive properties of the autograft.

Suturing

A precise suturing technique is essential for successful healing (Figs. 17.11–17.13). The sutures function to maintain the soft tissue flaps in the advanced position made possible by the periosteal releasing incisions. Before suturing, the surgeon must clinically evaluate the coronal extension of both flaps. Ideally they should overlap each other by at least 10 mm. Suturing consists of two lines of closure. Horizontal mattress sutures with U stitches should be used first to ensure proper flap apposition, with the connective tissue surfaces facing each other by at least 3 mm. Subsequently, interrupted sutures are placed between the horizontal mattress sutures and are used to close the vertical incisions. Sutures are removed 12–15 days following surgery. The use of an e-PTFE non-absorbable monofilament suture (Gore-Tex suture; WL Gore) is recommended.

Membrane/mesh removal

When a nonresorbable device is used, a second surgery is required for its removal. These devices should remain completely submerged and in place for 6–10 months,

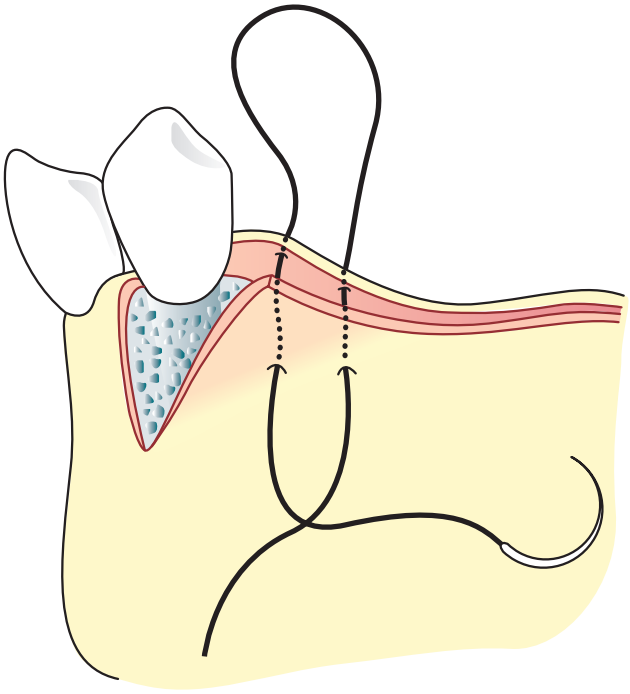


Fig. 17.12 Illustration showing the horizontal mattress suture.

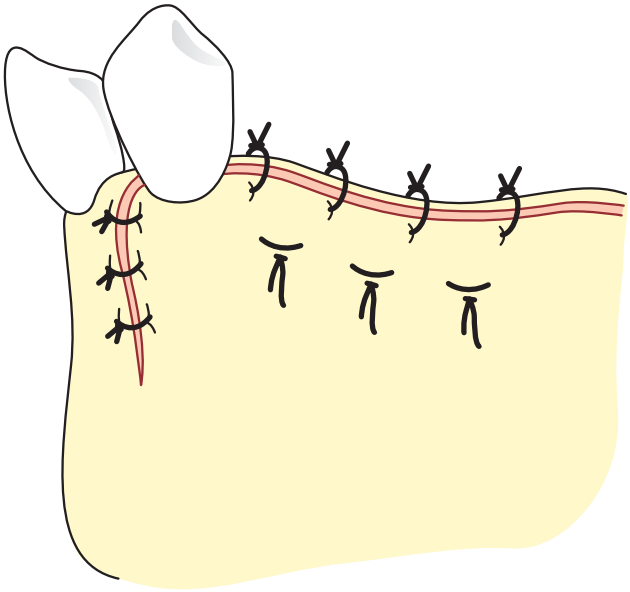


Fig. 17.13 Illustration showing the suturing technique.

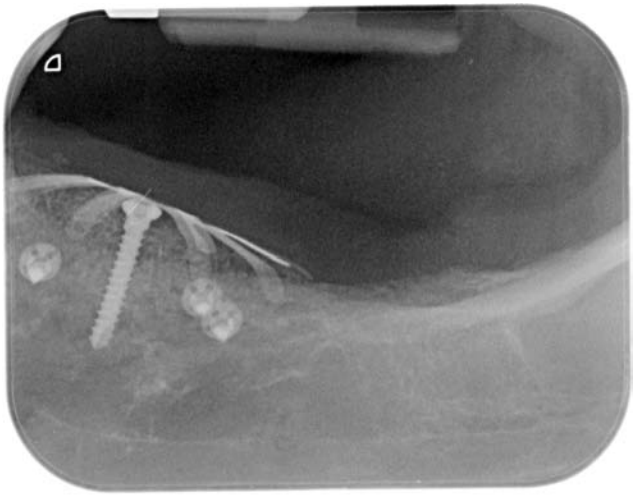


Fig. 17.14 X-ray after surgery.

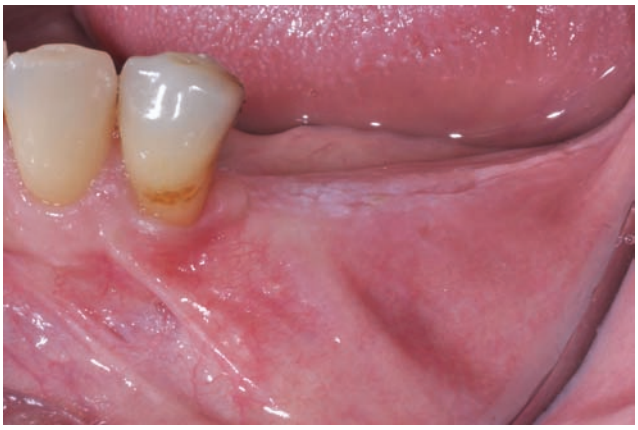


Fig. 17.15 Lateral view of the regenerated area after eight months of submerged uneventful healing.

depending on the volume of bone to be regenerated (Figs. 17.14–17.16). This period is considered the optimal healing time to obtain sufficient regeneration and maturation of the new bone [13, 45]. Removal is performed with a crestal incision and with mesial and distal vertical releasing incisions. Two full-thickness flaps are then elevated buccally and lingually/palatally to localize and remove the mini-screws (or the tacks in the upper jaw). The device is gently dissected from the bone (Figs. 17.17–17.20). Usually a connective tissue-like soft tissue layer is present coronal to the vertically regenerated bone [46]. It is about 1 mm thick and it can be used to suture the buccal flap in a more apical position to augment the keratinized mucosa where necessary.

Implant insertion

Implants can be placed with a simultaneous or staged approach. When there is sufficient residual bone to allow primary implant stability (>6 mm), fixtures are inserted at the time of the vertical augmentation procedure. Therefore, placing the healing abutments coincides with membrane removal. In the staged approach, implants are placed at time of membrane removal following at least 6–8 months of submerged membrane healing (Figs. 17.21–26). Occasionally, when there is observed to be an insufficient band of keratinized tissue, a soft

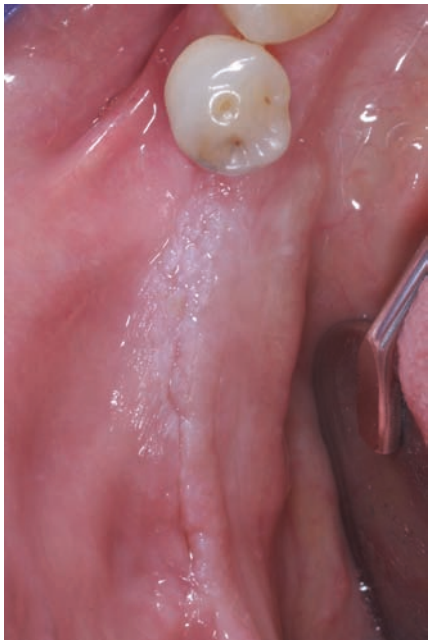


Fig. 17.16 Occlusal view of the same area.

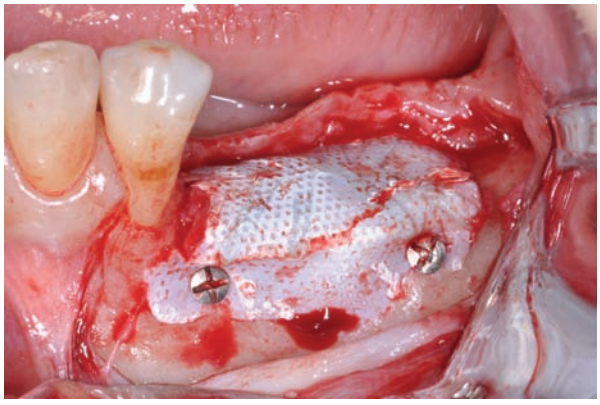


Fig. 17.17 Membrane removal. Two full-thickness flaps are elevated to localize and remove the mini-screws.

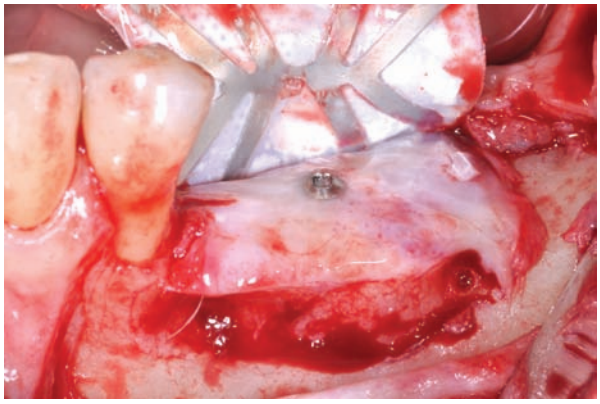


Fig. 17.18 The membrane is gently dissected from the regenerated area. A thin layer of connective tissue is found under the membrane. The tissue has been removed to appreciate the regenerated bone and for a proper positioning of dental implants.

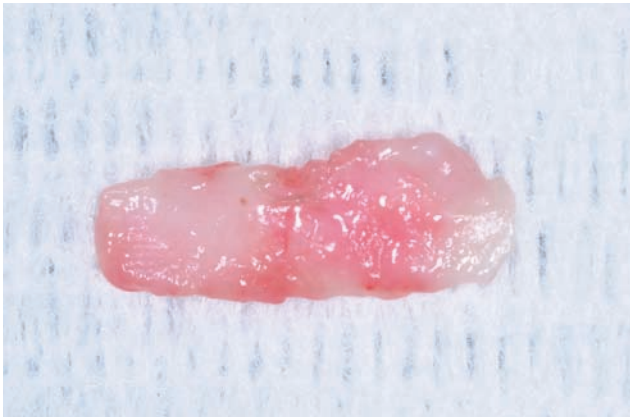


Fig. 17.19 The layer of connective tissue has been prepared to be positioned over the regenerated area at the end of the implant placement.

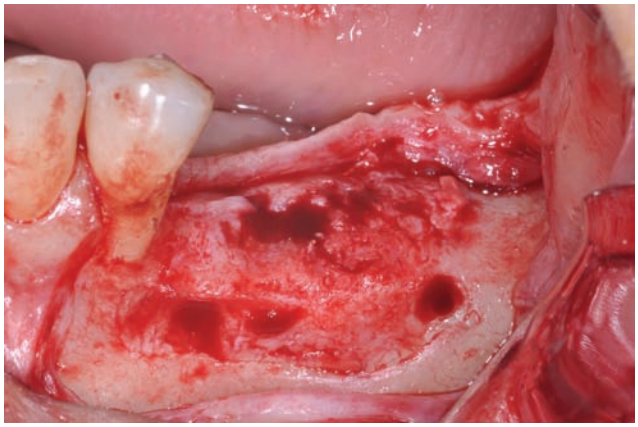


Fig. 17.20 The underlying regenerated area has a clinical appearance of bone.

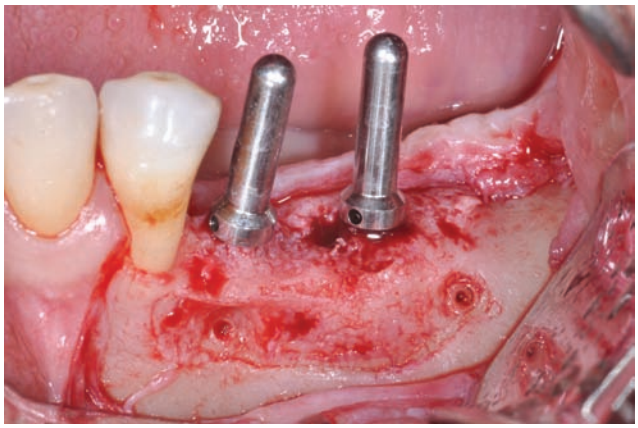


Fig. 17.21 Implants positioned in correctly.

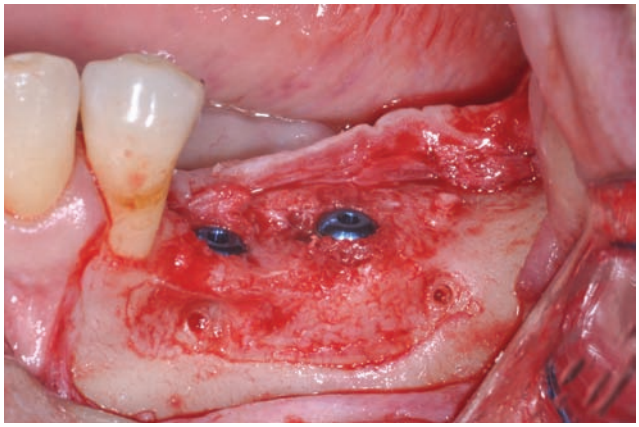


Fig. 17.22 Lateral view of the implants positioned.

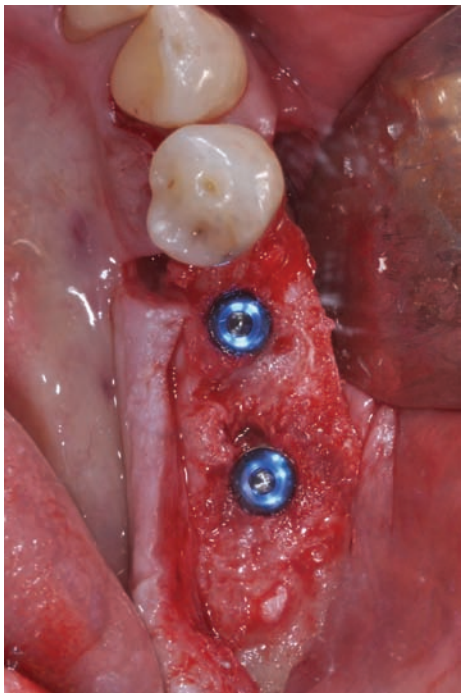


Fig. 17.23 Occlusal view of the implants positioned.

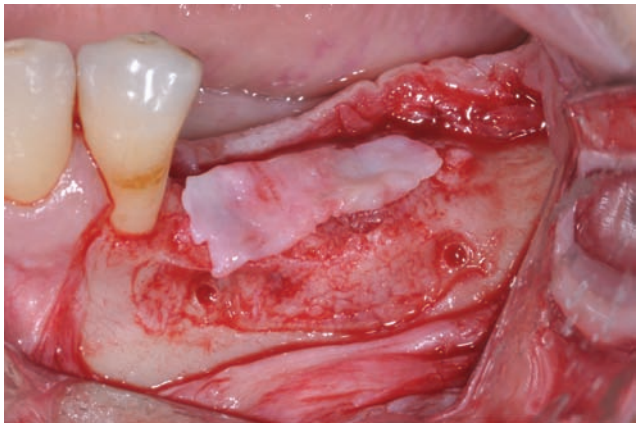


Fig. 17.24 The connective tissue has been placed on the area to ensure better soft tissue healing.

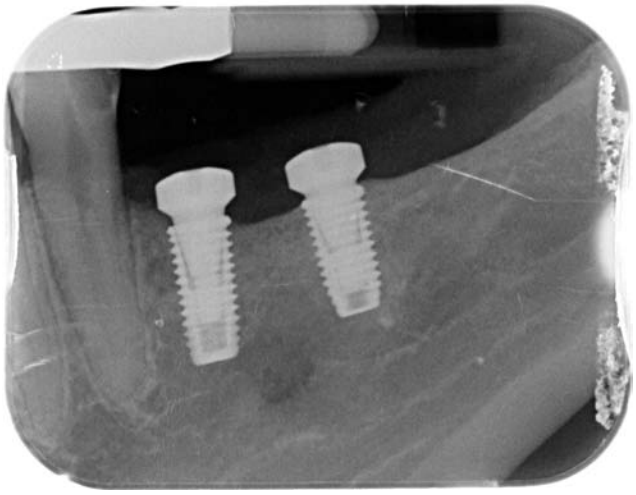


Fig. 17.25 X-ray after implant insertion.

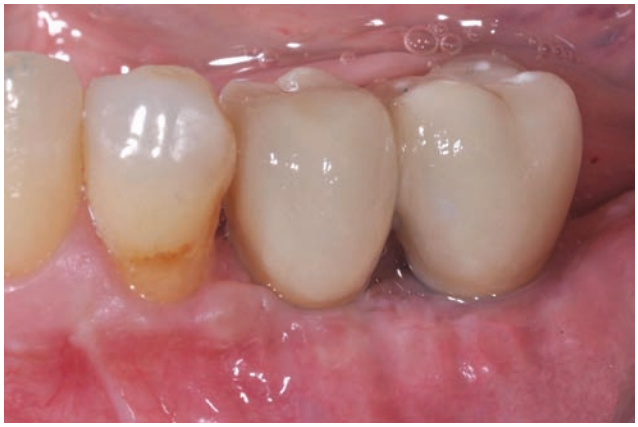


Fig. 17.26 Cemented-retained crowns are positioned after two months of soft tissue healing.

tissue graft from the palate is necessary to augment this tissue. The graft may be performed at time of abutment insertion or prior to final restoration.

Clinical management of GBR complications

Exposure and infection of the device

Membrane exposure to the oral environment is considered to be the most common complication of GBR. When a membrane is exposed, the amount of the regenerating tissue under the barrier is negatively influenced as reported in both animal studies [47–49] and clinical investigations [7, 13, 50–52]. The consequences of wound dehiscence and membrane or mesh exposure

range from a minor problem necessitating membrane removal with a resultant incomplete bone growth to a major problem including treatment failure and implant loss with additional cost and time for the patient [7, 13, 51, 52].

Several different clinical situations have been identified as possible cofactors in the etiopathogenesis of this clinical situation. These include:

- insufficient soft tissue healing after tooth extraction
- improper flap design
- insufficient flap release
- suturing under tension
- compression from the removable provisional prosthesis.

Treatment

The treatment of a premature exposure depends on the presence or absence of a purulent exudate and on the extent of the soft tissue dehiscence.

Class I: device exposure <3 mm without purulent exudate

An exposure smaller then 3 mm without any purulent exudation does not cause any signs or symptoms in a patient and thus is an occasional finding during postsurgical follow-up. The treatment approach differs depending on the timing of the exposure. If fenestration happens within the first two months a surgical approach can be appropriate (Fig. 17.27a–f). After a full-thickness flap, the exposed portion of the PTFE or titanium mesh plus 2 mm of surrounding membrane is removed. Flaps are sutured to close the dehisced area. A connective tissue graft or a resorbable membrane should be placed into the opening to protect the healing of the underlying regenerating bone.

If the exposure happens after the fourth month, the device can be maintained in place with a focused hygiene regimen consisting of topical application of 0.2% chlorhexidine gel twice a day to reduce plaque formation and avoid inflammation of the surrounding tissues. Nevertheless, a weekly follow-up is necessary. The rational of this approach is to postpone device removal for as long as possible in order to enhance bone regeneration. According to data presented in the literature [17, 18] an e-PTFE membrane can be left in place for a maximum of 3–4 weeks. In contrast, d-PTFE and titanium mesh seem to have more resistance to bacterial penetration and thus can probably be left in place for a longer period. There is a complete lack of scientific evidence for this, hence well-conducted studies would be beneficial.

The use of titanium mesh is associated with an increased risk of perforation of the mucosa compared to the use of PTFE. Perforation is more frequent near the anterior vertical edge of the grid. This is due to the stiffness of the titanium mesh, which may lead to an increased risk of mucosa perforation throughout the entire period of healing.

Class II: device exposure >3 mm without purulent exudate

In cases exhibiting an exposure larger than 3 mm (class II), the membrane/mesh must be removed immediately to avoid infection of the regenerating tissue (Fig. 17.28a–g). If the underlying bone graft is not compromised, the flaps should be closed to allow the grafted area to heal for at least 4–5 months. At removal, the underlying soft tissue must not be removed to avoid damage to the regenerating tissue. Antibiotics coverage with amoxicillin and clavulanic acid is also suggested.

Class III: device exposure with purulent exudate

If the exposure is associated with a purulent exudate, the membrane/mesh must be removed immediately to limit the damage caused by the infection spreading to the underlying regenerating tissue. After removal, a gentle curettage of the graft is essential to remove the infected particles and inflammatory tissue that could jeopardize the regenerative process. Amoxicillin (875 mg) and clavulanic acid (125 mg) (Augmentin; GlaxoSmithKline) should be prescribed twice a day for at least 5 days.

Key points to avoid device exposure

- *Healing of the soft tissues*: A complete healing of the soft tissue prior to any GBR procedure is fundamental for a successful outcome of the technique. The soft tissue must be healthy and well keratinized without any signs of inflammation. These factors allow a proper flap design, optimal suturing technique, and primary soft tissue healing. If tooth extraction has been performed, a 10–14 week soft tissue healing period is recommended before any GBR procedure is performed.
- *Flap design and meticulous recipient site preparation*: As reported in the previous section on Prevention of complications, the flap must be properly designed in order to achieve a tension-free suture closure to complete the surgery.
- *Releasing periosteal incisions*: A horizontal continuous periosteal incision of the buccal flap is necessary. The buccal and lingual/palatal flaps should overlap at least 10 mm to obtain a tension-free closure. Tension leads to ischemia of the tissue adjacent to the sutures with subsequent necrosis and membrane dehiscence.
- *Suturing technique*: A suitable suturing technique is essential for successful healing. Flaps are sutured with two lines of closure: first internal horizontal mattress sutures

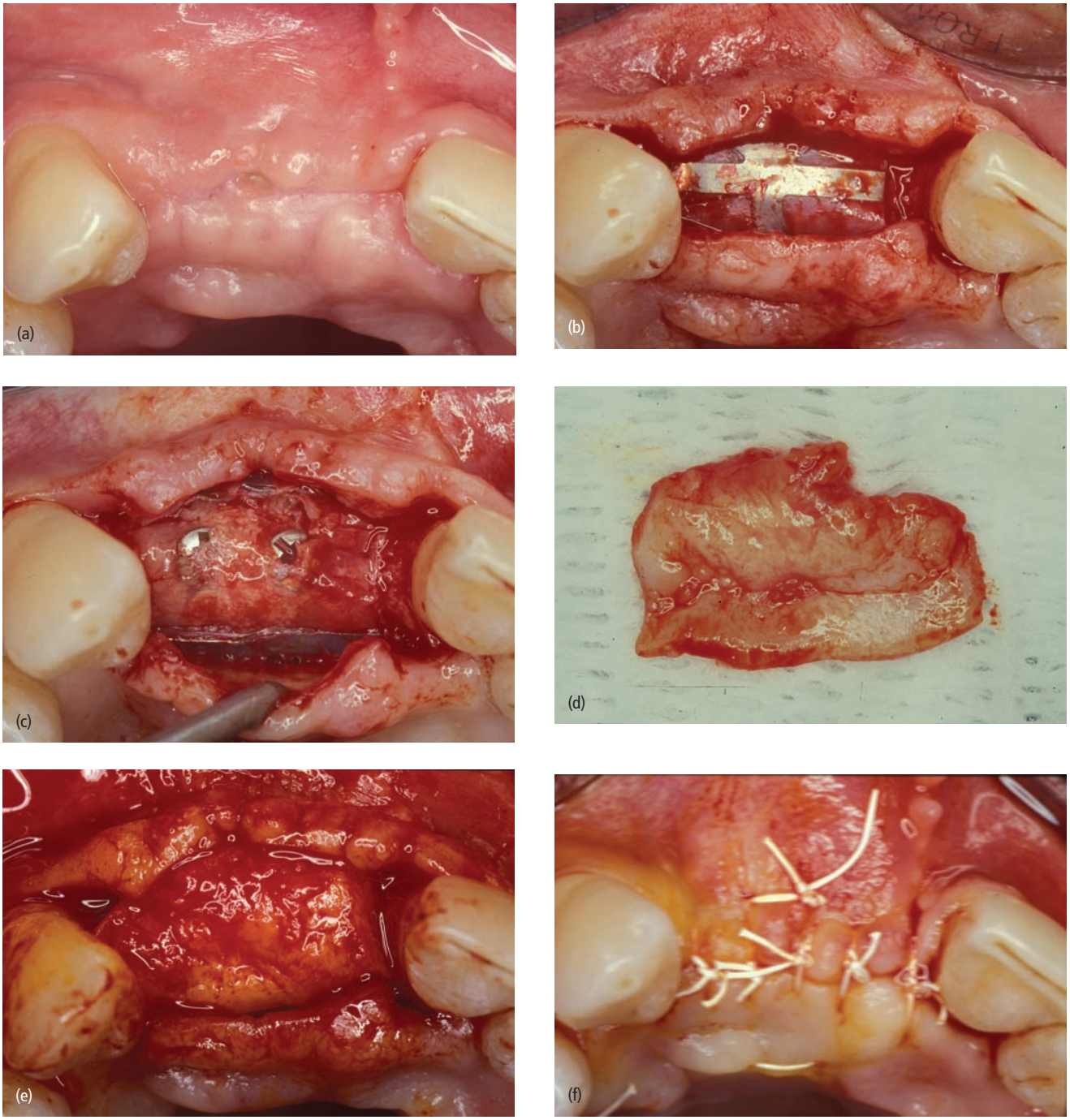


Fig. 17.27 Case 1: (a) A small exposure of the e-PTFE membrane is present one month after the regenerative procedure. (b) A mucoperiosteal flap is elevated to isolate the e-PTFE membrane. (c) The part of the membrane exposed to the oral environment is cut with scissors and removed, leaving the residual membrane in place. Note that regenerating tissue similar to bone is detectable. (d) A connective tissue graft is taken from the palate. (e) The connective tissue is placed on the regenerating area, acting as a barrier to protect the healing of the underlying tissue. (f) The buccal and lingual flaps are sutured with horizontal mattress suture and single interrupted stitches.

are used to obtain proper flap apposition and then single interrupted sutures to close the space between the horizontal mattress and the vertical incisions.

- *Adequate provisional prosthesis*: A fixed provisional prothesis is always preferred when performing GBR. A removable prosthesis should not be used within 15–20 days after any GBR procedure. Following that period, the removable prosthesis must be adjusted to avoid any pressure and movement to the underlying soft tissue. Compression during the early healing period always leads to ischemia, flap necrosis, and subsequent membrane exposure. When a vertical

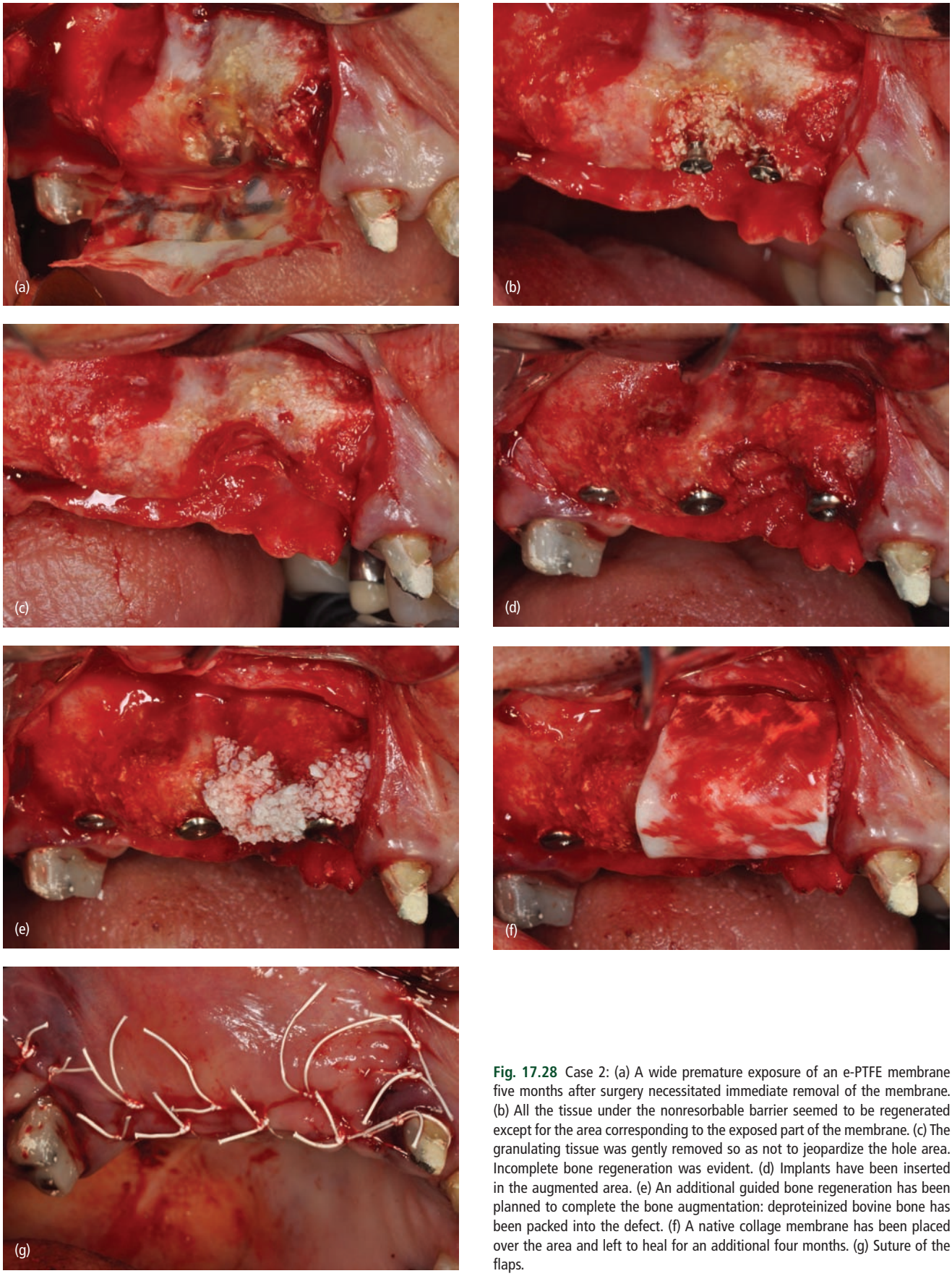


Fig. 17.28 Case 2: (a) A wide premature exposure of an e-PTFE membrane five months after surgery necessitated immediate removal of the membrane. (b) All the tissue under the nonresorbable barrier seemed to be regenerated except for the area corresponding to the exposed part of the membrane. (c) The granulating tissue was gently removed so as not to jeopardize the hole area. Incomplete bone regeneration was evident. (d) Implants have been inserted in the augmented area. (e) An additional guided bone regeneration has been planned to complete the bone augmentation: deproteinized bovine bone has been packed into the defect. (f) A native collage membrane has been placed over the area and left to heal for an additional four months. (g) Suture of the flaps.

ridge augmentation has been performed, any removable prosthesis must not be worn for the entire healing period.

- *Adequate adaptation of the titanium mesh edges to the bone crest*: Perforation of the oral mucosa under the mucogingival line is more frequent when a titanium mesh is used compared to PTFE membrane. This is due to the stiffness of the grid that acts as a trauma on the overlying tissue. When a titanium device is positioned, particular care must be taken to ensure that all the edges of the titanium mesh are smooth and strictly adherent to the bone.

Class IV: abscess formation without device exposure

This is a severe clinical complication with an incidence up to 5%. It is clinically characterized by the formation of an abscess in the surgical area without any exposure. When this occurs, the abscess usually forms within the first 3–4 weeks postoperatively. The surgical area contains swollen, inflamed tissue with pus formation. Pain, tension, increased temperature, and fistula formation may also be reported (Fig.17.29a–f).

The etiopathogenesis of this phenomenon may include any one or more of the following:

- bacterial contamination of the PTFE during membrane handling
- bacterial contamination of the bone graft
- improper suture removal
- endodontic/periodontic infections from adjacent teeth
- inadequate prosthetic margins
- patient inoculation of the area with exogenous bacteria (i.e., hands, nails, toothbrushes, removable provisionals).

Treatment

The membrane/mesh should be removed immediately. Two different clinical situations can be observed after flap elevation: class IVa and class IVb.

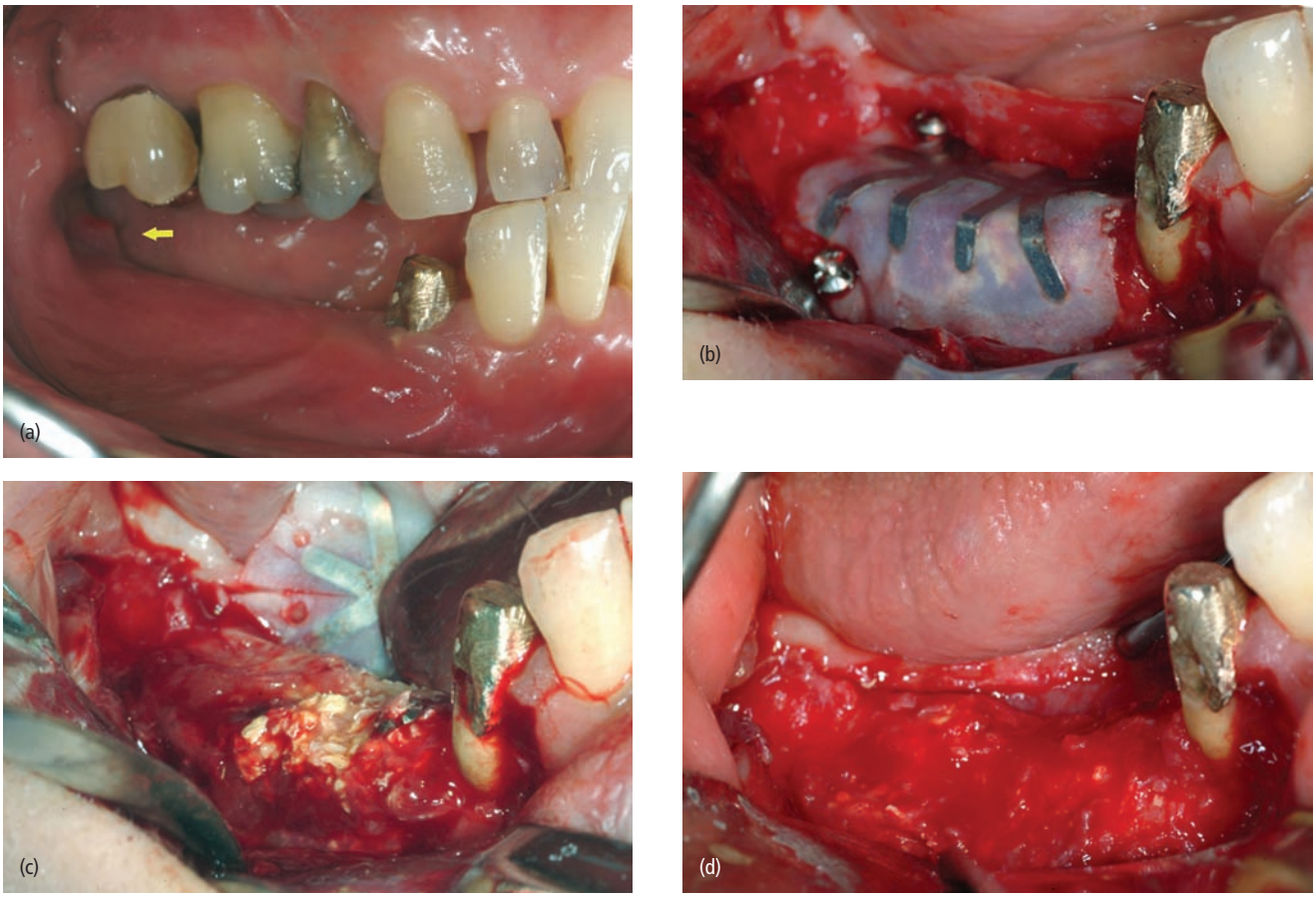
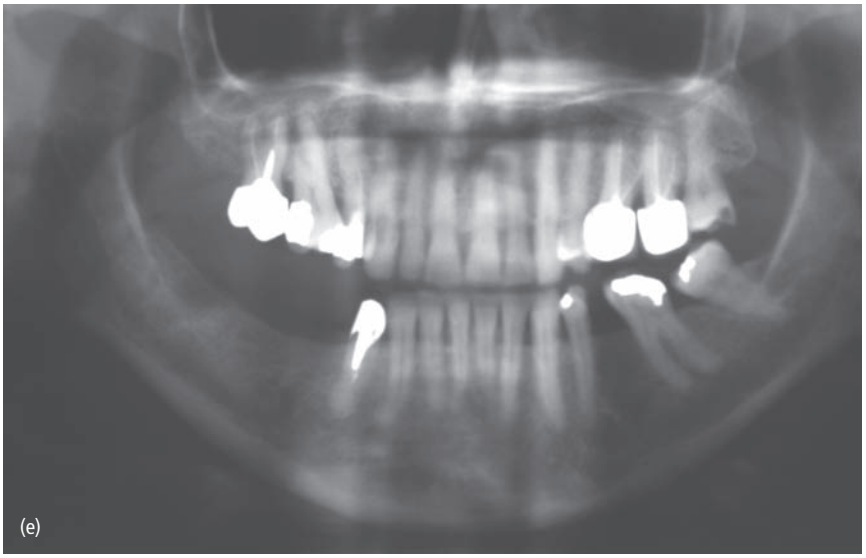


Fig. 17.29 Case 3: (a) An abscess formed in posterior right mandible where a vertical ridge augmentation by means of GBR has been performed three weeks before. The area is swollen and red, and the patient reports pain and tension. A fistula can also be observed in the retromolar area (yellow arrow). (b) Two full-thickness flaps are elevated to remove the membrane and the fixation devices. A yellow area of pus can be observed through the membrane. (c) Under the membrane, infected and hyperemic tissue can be detected. All the regenerating area must be removed to eliminate the infection. (d) The residual crest after the curettage of the area and washing with rifamycin solution.



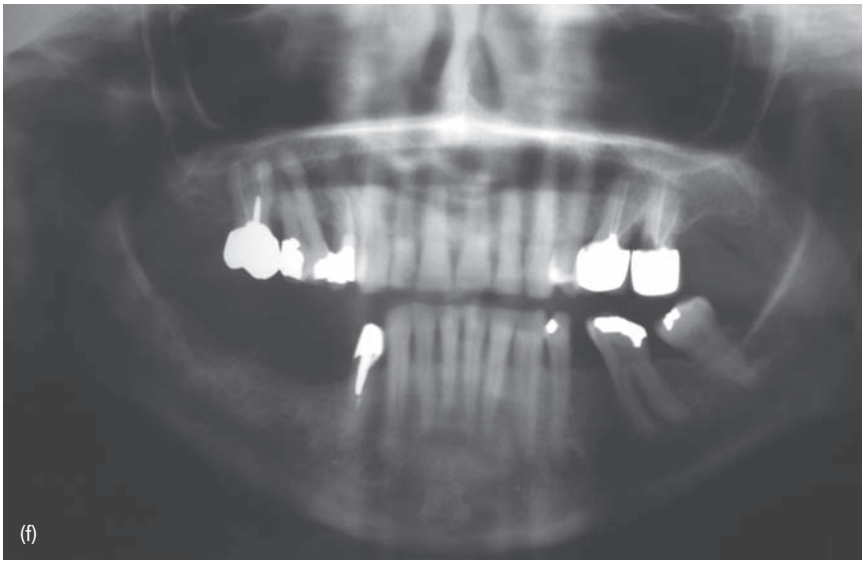


Fig. 17.29 (*cont'd*) (e) Orthopantomogram showing the edentulous area (lower right) before the GBR procedure. (f) Orthopantomogram showing the edentulous area (lower right) after abscess formation and membrane removal. Note that the residual defect after the complication occurred is more significant than the baseline defect.

In class IVa (Fig. 17.29) the abscess is located under the device. This is the most common finding and it has the most severe sequela. All the infected tissue must be curetted. Bone graft and implants, if present, are totally compromised. The use of a rifamycin (Rifocin 90 mg; Sanofi Aventis) or tetracycline (Ambramicina 250 mg; Scharper) antibiotic wash is also suggested to reduce bacterial contamination of the treated area. The patient should be placed on a regimen of amoxicillin (875 mg) and clavulanic acid (125 mg) for at least 5 days.

In class IVb (Fig. 17.30a–p) the exudate is found over the device. This uncommon complication is usually related to an incomplete suture removal. After membrane removal, the underlying bone graft can be left in place if not compromised. A resorbable membrane can be used to cover the graft. An additional 4–5 months of healing is necessary to achieve regeneration. Antibiotic coverage with amoxicillin and clavulanic acid is preferable.

Key points to avoid abscess formation

- *d-PTFE membrane*: Particular care must be taken to reduce the risk of bacterial colonization of the surface of the non-absorbable d-PTFE membrane. Presurgical preparation of the patient should consist of all necessary periodontal treatment, full-mouth disinfection with chlorhexidine digluconate 0.2% mouthrinse (Corsodyl; GlaxoSmithKline), and an extraoral scrub with a povidone–iodine solution (Betadine; Viatris).

Moreover, the membrane must be kept in a sterile field and the surgeon must wear new sterile gloves before membrane handling, since the first part of the surgery could cause bacterial contamination of the surgical gloves.

- *Autogenous bone graft harvesting procedure*: A systematic review by the Cochrane library [9] stated that "The use of particulated autogenous bone from intraoral locations might be associated with an increased risk of infective complications." Particular care must be taken to avoid contamination of the harvested bone with saliva. The authors suggest collecting bone with a bone scraper or trephine bur under abundant irrigation with saline solution. The use of bone traps, also with dedicated suction tubes, is not advisable because considerable

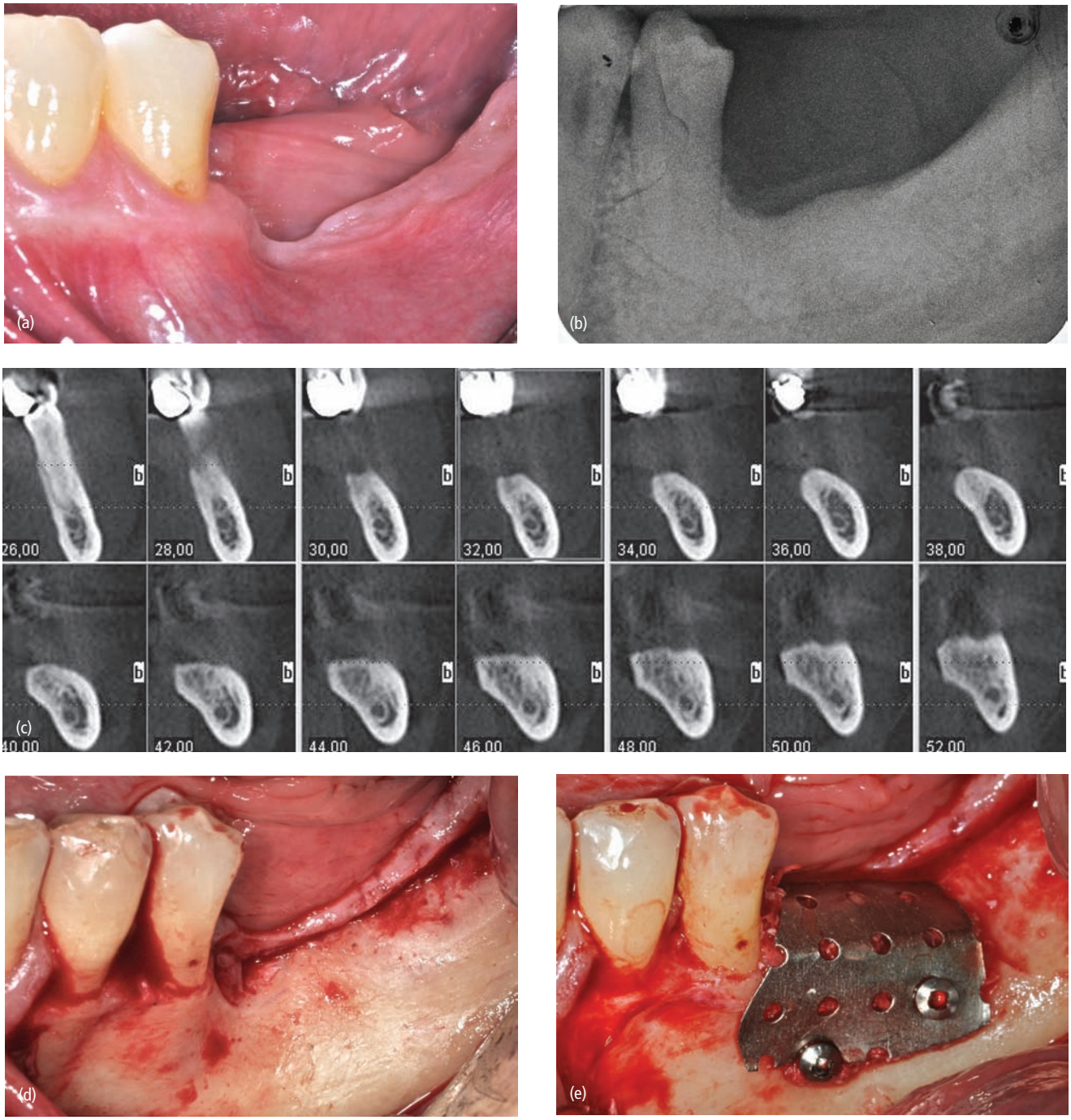
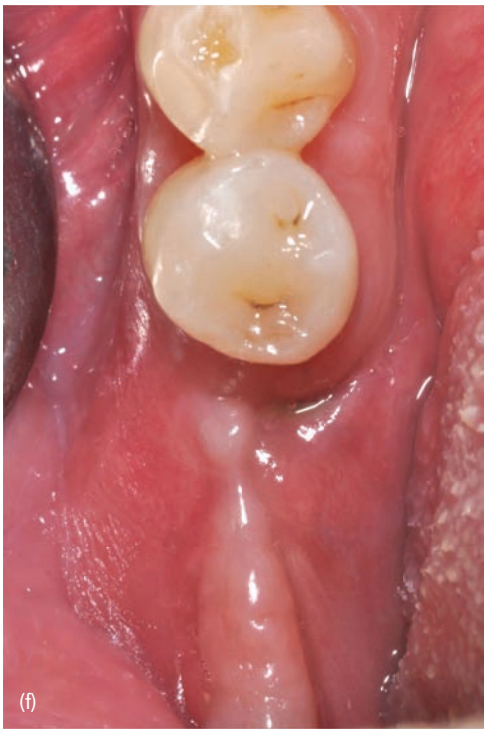
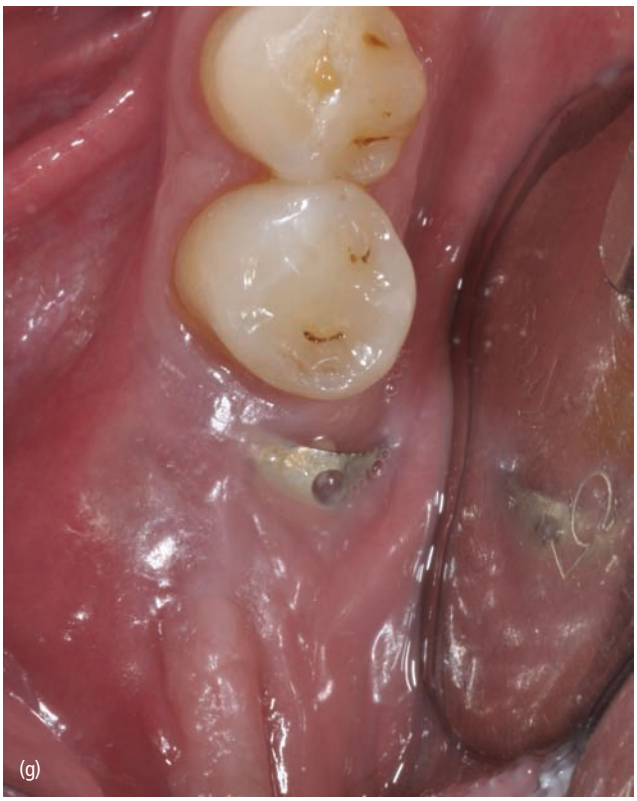
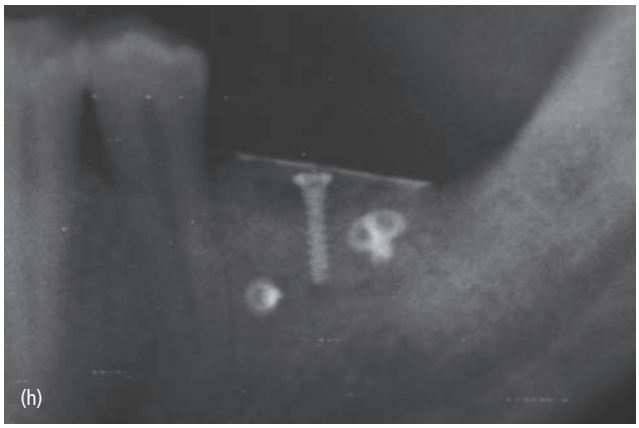
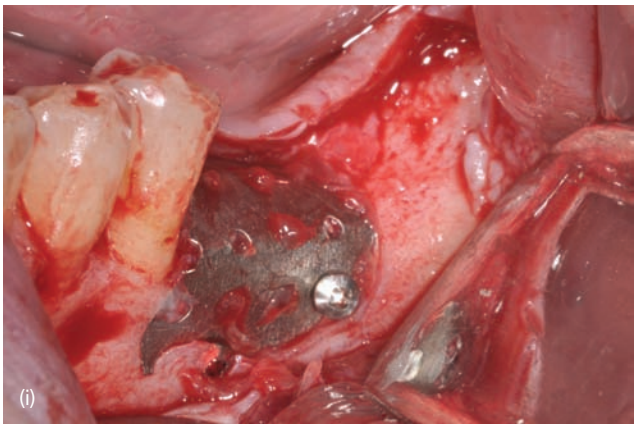


Fig. 17.30 Case 4: (a) Lateral view of the vertical defect in the posterior jaw. (b) X-ray of the area. (c) CT scan of the alveolar atrophy. (d) Two full-thickness flaps were elevated to reach the bone crest. (e) A titanium mesh has been shaped and fixed over the bone graft.









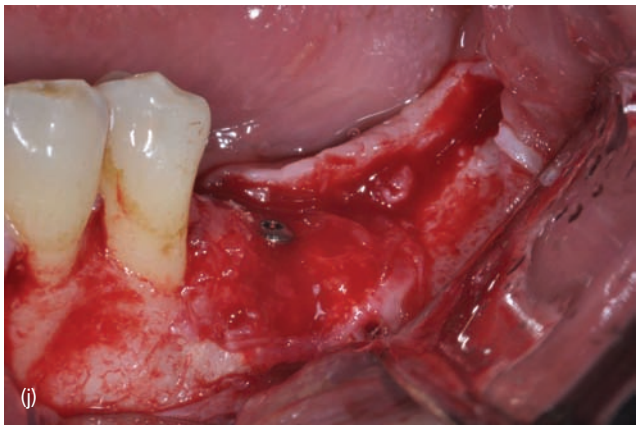
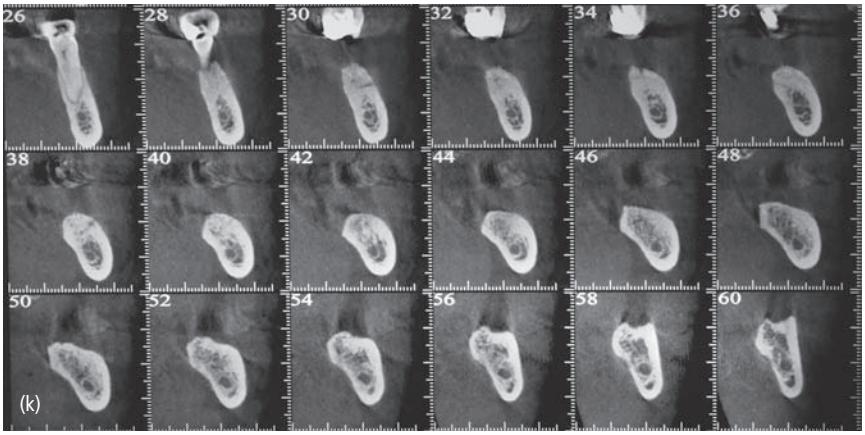
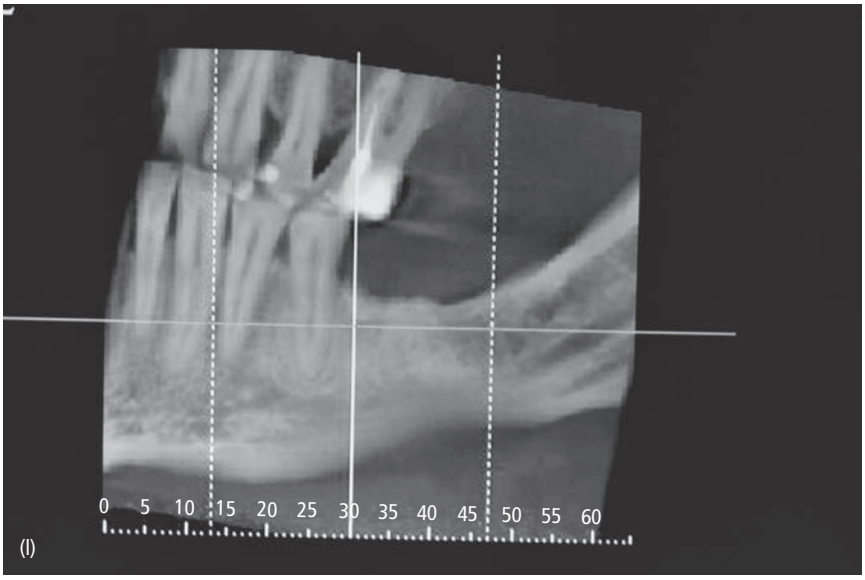
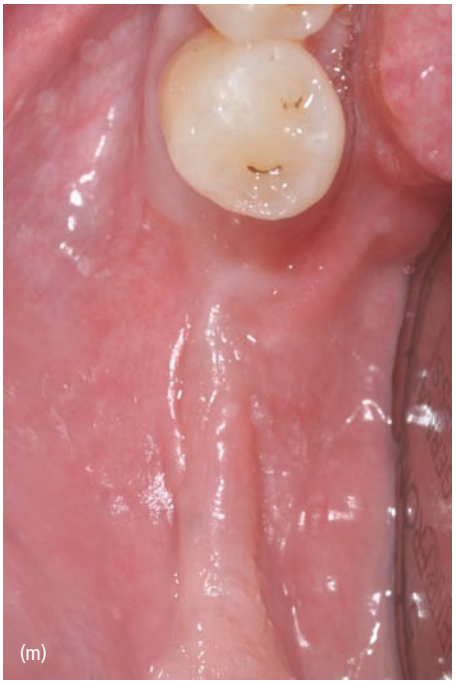


Fig. 17.30 (*cont'd*) (f) After six weeks a small exposure of the grid was evident. The mesh was left in place and the patient trained to use a clorhexidine gel over the area. (g) After six months some purulent exudate was detectable over the titanium mesh. Mesh removal was then necessary. (h) X-ray of the regenerating area. (i) Full-thickness flaps were elevated to remove the grid. (j) After titanium mesh removal, the regenerating area appeared to be incompletely matured. The flaps were closed to allow 2–3 months of additional healing.







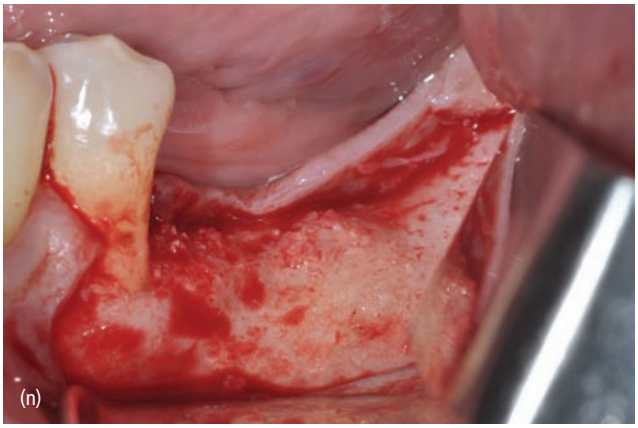
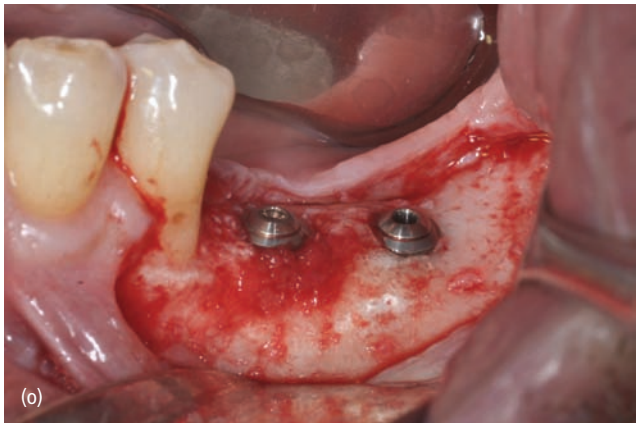


Fig. 17.30 (*cont'd*) (k) Two months later, a CT scan was performed to check the regenerated bone. (l) Sufficient bone regeneration seemed to be evident from the CT scan. (m) Occlusal view of the area at the time of CT scan. (n) After flap elevation, the area seemed to be properly healed for implant positioning.



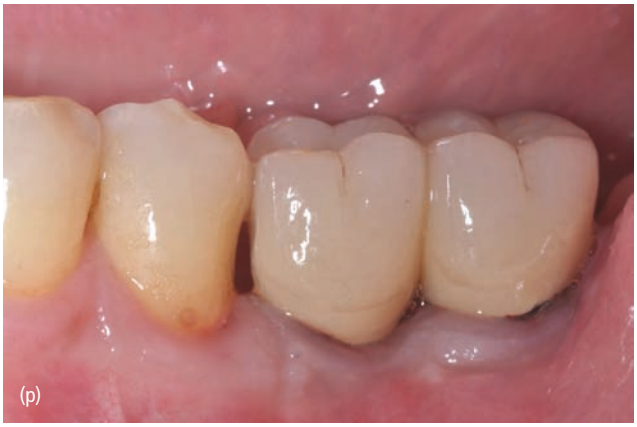


Fig. 17.30 (*cont'd*) (k) Two months later, a CT scan was performed to check the regenerated bone. (l) Sufficient bone regeneration seemed to be evident from the CT scan. (m) Occlusal view of the area at the time of CT scan. (n) After flap elevation, the area seemed to be properly healed for implant positioning. (o) Lateral view of the implants inserted in the regenerated bone. (p) Final restoration.

amounts of bacteria can be found in particulated bone collected with these devices as reported by Young *et al.* [53].

- *Suture removal*: During the first two weeks of healing, the horizontal mattress sutures tend to "invaginate" into the soft tissue. Thus, suture removal may be difficult and require local anesthesia. Non-absorbable sutures should be removed within this time period. If left in the tissue they may cause granuloma and abscess formation.
- *Remove all the sources of infection*: Every possible source of endodontic or periodontic infection must be removed prior to performing a GBR procedure. For the same reason any inadequate restorations or restorative margins on teeth adjacent to the area planned for regeneration must be corrected or reconstructed prior to the surgery.

Lesions associated with periosteal incisions

One of the key steps in the GBR technique is adequate release of buccal and lingual flaps to ensure tension-free suture closure. This procedure includes the incision of the buccal periosteum in both lower and upper jaw. In the lingual aspect of the mandible, release of the periosteum is performed by reflecting the flap beyond the insertion of the mylohyoid muscle.

In the mandible, particular care should be taken to avoid any damage to the inferior alveolar nerve at its exit from the mental foramen. The same care should be taken in the upper jaw with the infraorbitary nerve. Improper procedures may cause temporary or permanent sensory effects (anesthesia, paresthesia, or dysesthesia).

Moreover, surgical trauma to the lingual flap can also lead to edema of the sublingual space (over the mylohyoid muscle) and of the submandibular space (under the mylohyoid muscle). These areas are susceptible to space infections, which may be serious and require emergency medical treatment.

Key points to prevent these complications

- *Be aware and locate (radiographically and clinically) the anterior loop of the mental nerve*: The buccal periosteal incision must be performed at a distance which is at least 4–5 mm away from the mental foramen and must be very superficial, as a deep incision could damage the mental nerve.
- *Avoid any incision of the lingual periosteum*: The lingual flap must be managed with care because its proximity to the floor of the mouth, which represents one of the most critical areas when performing GBR. Apical to the floor of the mouth is the sublingual space – the area between the mylohyoid muscle, the mandible, and the geniohyoid and genioglossal muscles. This contains important anatomical structures, such as the sublingual artery (branch of the lingual artery), the mylohyoideus artery (branch of the inferior alveolar artery), the lingual nerve, Wharton's duct, the sublingual gland, and some extrinsic tongue muscle fibers. To minimize postoperative edema and hemorrhage and to avoid any damage to these anatomical structures, incision of the lingual periosteum should be avoided.

In all cases a thorough knowledge of oral anatomy is essential for any clinician performing these procedures.

Conclusions

Although the GBR technique is considered to be a predictable surgical procedure, further modifications in

materials and techniques are being developed in order to reduce clinical complications. Adherence to proven clinical protocols and the introduction of new materials could reduce the incidence of complications and increase the predictability of bone augmentation.

The clinical protocols related to the GBR technique, including surgical procedures, postoperative care, and healing time, were established using non-absorbable membranes. However, the use of absorbable membranes is increasing due to their proven effectiveness and user-friendly properties, limiting non-absorbable membranes to specific indications.

Take-home hints

- Allow adequate healing of the soft tissue before performing a GBR procedure.
- Remove all sources of infection prior to surgery (e.g., periodontally, endodontally, or hopelessly involved teeth).
- Design flaps to ensure adequate blood supply and flap closure.
- Ensure meticulous recipient site preparation.
- Clearly locate (radiographically and clinically) important adjacent anatomical structures.
- Ensure adequate release of the buccal flap with a periosteal incision.
- Use appropriate membrane/mesh positioning and fixation.
- Ensure precise suturing technique, first with internal horizontal mattress sutures and then single interrupted sutures.
- Use adequate pre- and postsurgical care, including systemic antibiotics and local antiseptics.
- Ensure adequate knowledge regarding oral anatomy and the prevention and treatment of complications.

References

1. Nyman S, Gottlow J, Karring T, Lindhe J. The regenerative potential of the periodontal ligament. An experimental study in the monkey. *J Clin Periodontol* 1982; **9**(3): 257–65.
2. Gottlow J, Nyman S, Karring T, Lindhe J. New attachment formation as the result of controlled tissue regeneration. *J Clin Periodontol* 1984 Sep;11(8):494–503.
3. Gottlow J, Nyman S, Lindhe J, Karring T, Wennström J. New attachment formation in the human periodontium by guided tissue regeneration. Case reports. *J Clin Periodontol* 1986; **13**(6): 604–16.
4. Gottlow J, Karring T, Nyman S. Guided tissue regeneration following treatment of recession-type defects in the monkey. *J Periodontol* 1990; **61**(11): 680–5.
5. Dahlin C, Linde A, Gottlow J, Nyman S. Healing of bone defects by guided tissue regeneration. *Plast Reconstr Surg* 1988; **81**(5): 672–6.
6. Dahlin C, Sennerby L, Lekholm U, Linde A, Nyman S. Generation of new bone around titanium implants using a membrane technique: an experimental study in rabbits. *Int J Oral Maxillofac Implants* 1989; **4**(1): 19–25.
7. Buser D, Dula K, Belser U, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. 1. Surgical procedure in the maxilla. *Int J Periodontics Restorative Dent* 1993; **13**(1): 29–45.
8. Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement. A systematic review. *J Clin Periodontol* 2008; **35**(8 Suppl): 203–15.
9. Esposito M, Grusovin MG, Kwan S, Worthington HV, Coulthard P. Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment. *Cochrane Database Syst Rev* 2008; (3): CD003607. doi: 10.1002/14651858.CD003607.pub3
10. Ricci L, Perrotti V, Ravera L, Scarano A, Piattelli A, Iezzi G. Rehabilitation of deficient alveolar ridges using titanium grids before and simultaneously with implant placement: a systematic review. *J Periodontol* 2013; **84**(9): 1234–42.
11. Verardi S, Simion M. Management of the exposure of e-PTFE membranes in guided bone regeneration. *Pract Proced Aesthet Dent* 2007; **19**(2): 111–17.
12. Fontana F, Santoro F, Maiorana C, Iezzi G, Piattelli A, Simion M. Clinical and histologic evaluation of allogeneic bone matrix versus autogenous bone chips associated with titanium-reinforced e-PTFE membrane for vertical ridge augmentation: a prospective pilot study. *Int J Oral Maxillofac Implants* 2008; **23**: 1003–12.
13. Buser D, Bragger U, Lang NP, Nyman S. Regeneration and enlargement of jaw bone using guided tissue regeneration. *Clin Oral Implants Res* 1990; **1**(1): 22–32.
14. Simion M, Fontana F, Rasperini G, Maiorana C. Vertical ridge augmentation by expanded-polytetrafluoroethylene membrane and a combination of intraoral autogenous bone graft and deproteinized anorganic bovine bone (Bio-Oss). *Clin Oral Implants Res* 2007; **18**: 620–9.
15. Merli M, Migani M, Esposito M. Vertical ridge augmentation with autogenous bone grafts: resorbable barriers supported by ostheosynthesis plates versus titanium-reinforced barriers. A preliminary report of a blinded, randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 2007; **22**(3): 373–82.
16. Simion M, Fontana F, Rasperini G, Maiorana C. Long-term evaluation of osseointegrated implants placed in sites augmented with sinus floor elevation associated with vertical ridge augmentation: a retrospective study of 38 consecutive implants with 1-to 7-year follow-up. *Int J Periodontics Restorative Dent* 2004; **24**(3): 208–21.
17. Simion M, Baldoni M, Rossi P, Zaffe D. A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. *Int J Periodontics Restorative Dent* 1994; **14**(2): 166–80.
18. Simion M, Trisi P, Maglione M, Piattelli A. A preliminary report on a method for studying the permeability of expanded polytetrafluoroethylene membrane to bacteria

in vitro: a scanning electron microscopic and histological study. *J Periodontol* 1994; **65**(8): 755–61.
19. Simion M, Trisi P, Maglione M, Piattelli A. Bacterial penetration in vitro through GTAM membrane with and without topical chlorhexidine application. A light and scanning electron microscopic study. *J Clin Periodontol* 1995; **22**(4): 321–31.
20. Barber HD, Lignelli J, Smith BM, Bartee BK. Using a dense PTFE membrane without primary closure to achieve bone and tissue regeneration. *J Oral Maxillofac Surg* 2007; **65**(4): 748–52.
21. Bartee BK. A simplified technique for ridge preservation after tooth extraction. *Dent Today* 1995; **14**(10): 62–7.
22. Bartee BK. The use of high-density polytetrafluoroethylene membrane to treat osseous defects: clinical reports. *Implant Dent* 1995; **4**(1): 21–6.
23. Ronda M, Rebaudi A, Torelli L, Stacchi C. Expanded vs. dense polytetrafluoroethylene membranes in vertical ridge augmentation around dental implants: a prospective randomized controlled clinical trial. *Clin Oral Implants Res* 2013; **25**(7): 859–66.
24. Urban IA, Lozada JL, Jovanovic SA, Nagursky H, Nagy K. Vertical ridge augmentation with titanium-reinforced, dense-PTFE membranes and a combination of particulated autogenous bone and anorganic bovine bone-derived mineral: a prospective case series in 19 patients. *Int J Oral Maxillofac Implants* 2014; **29**(1): 185–93.
25. Artzi Z, Dayan D, Alpern Y, Nemcovsky CE. Vertical ridge augmentation using xenogenic material supported by a configured titanium mesh: clinicohistopathologic and histochemical study. *Int J Oral Maxillofac Implants* 2003; **18**(3): 440–6.
26. Corinaldesi G, Pieri F, Sapigni L, Marchetti C. Evaluation of survival and success rates of dental implants placed at the time of or after alveolar ridge augmentation with an autogenous mandibular bone graft and titanium mesh: a 3-to 8-year retrospective study. *Int J Oral Maxillofac Implants* 2009; **24**(6): 1119–28.
27. von Arx T, Wallkamm B, Hardt N. Localized ridge augmentation using a micro titanium mesh: a report on 27 implants followed from 1 to 3 years after functional loading. *Clin Oral Implants Res* 1998; **9**(2): 123–30.
28. von Arx T, Hardt N, Wallkamm B. The TIME technique: A new method for localized alveolar ridge augmenta-tion prior to placement of dental implants. *Int J Oral Maxillofac Implants* 1996; **11**: 387–94.
29. Schenk RK, Buser D, Hardwick WR, Dahlin C. Healing pattern of bone regeneration in membrane-protected defects: a histologic study in the canine mandible. *Int J Oral Maxillofac Implants* 1994; **9**(1): 13–29.
30. Tinti, C, Parma-Benfenati, S, Polizzi, G. Vertical ridge augmentation: What is the limit? *Int J Periodontics Restorative Dent* 1996; **16**: 221–9.
31. Tinti C, Parma-Benfenati S. Vertical ridge augmentation: surgical protocol and retrospective evaluation of 48 consecutively inserted implants. *Int J Periodontics Restorative Dent* 1998; **18**: 434–43.
32. Parma-Benfenati S, Tinti C, Albrektsson T, Johansson C. Histologic evaluation of guided vertical ridge augmentation around implants in humans. *Int J Periodontics Restorative Dent* 1999; **19**: 424–37.
33. Simion M, Jovanovic SA, Trisi P, Scarano A, Piattelli A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. *Int J Periodontics Restorative Dent* 1998; **18**(1): 8–23.
34. Burchardt H. The biology of bone graft repair. *Clin Orthop Relat Res* 1983; **174**: 28–42.
35. Buser D, Dula K, Hirt HP, Schenk RK. Lateral ridge augmentation using autografts and barrier membranes: a clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg* 1996; **54**(4): 420–32; discussion 432–3.
36. Tidwell JK, Blijdorp PA, Stoelinga PJ, Brouns JB, Hinderks F. Composite grafting of the maxillary sinus for placement of endosteal implants: a preliminary report of 48 patients. *Int J Oral Maxillofac Surg* 1992; **21**: 204–9.
37. Misch CE, Dietsh F. Bone grafting materials in implant dentistry. *Implant Dent* 1993; **2**: 158–67.
38. Yildirim M, Spiekermann H, Handt S, Edelhoff D. Maxillary sinus augmentation with the xenograft Bio-Oss and autogenous intraoral bone for qualitative improvement of the implant site: a histologic and histomorphometric clinical study in humans. *Int J Oral Maxillofac Implants* 2001; **16**: 23–33.
39. Simion M, Jovanovic SA, Tinti C, Benfenati SP. Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. A retrospective study on 123 implants with 1–5 year follow-up. *Clin Oral Implants Res* 2001; **12**: 35–45.
40. Zitzmann NU, Naef R, Scharer P. Resorbable versus nonresorbable membranes in combination with Bio-Oss for guided bone regeneration. *Int J Oral Maxillofac Implants* 1998; **13**(4): 576.
41. Zitzmann NU, Scharer P, Marinello CP. Long-term results of implants treated with guided bone regeneration: a 5-year prospective study. *Int J Oral Maxillofac Implants* 2001; **16**(3): 355–66.
42. Canullo L, Trisi P, Simion M. Vertical ridge augmentation around implants using e-PTFE titanium-reinforced membrane and deproteinized bovine bone mineral (bio-oss): A case report. *Int J Periodontics Restorative Dent* 2006; **26**(4): 355–61.
43. Fugazzotto PA. GBR using bovine bone matrix and resorbable and nonresorbable membranes. Part 1: histologic results. *Int J Periodontics Restorative Dent* 2003; **23**(4): 361–9.
44. Fugazzotto PA. GBR using bovine bone matrix and resorbable and nonresorbable membranes. Part 2: Clinical results. *Int J Periodontics Restorative Dent* 2003; **23**(6): 599–605.
45. Becker W & Becker BE. Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: surgical techniques and case report. *Int J Periodontics Restorative Dent* 1990; **10**(5): 376–91.
46. Dahlin C, Simion M, Nanmark U, Sennerby L. Histological morphology of the e-PTFE/tissue interface in humans subjected to guided bone regeneration in conjunction with oral implant treatment. *Clin Oral Implants Res* 1998; **9**(2): 100–6.
47. Gotfredsen K, Nimb L, Buser D, *et al.* Evaluation of guided bone regeneration around implants placed into fresh extraction sockets. An experimental study in dogs. *J Oral Maxillofac Surg* 1993; **51**: 879–84.
48. Kohal RJ, Trejo PM, Wirsching C, Hürzeler MB, Caffesse RG. Comparison of bioabsorbable and bioinert membranes

for guided bone regeneration around non-submerged implants. An experimental study in the mongrel dog. *Clin Oral Implants Res* 1999; **10**(3): 226–37.
49. Lekholm U, Becker W, Dahlin C, Becker B, Donath K, Morrison E. The role of early versus late removal of GTAM membranes on bone formation at oral implants placed into immediate extraction sockets. An experimental study in dogs. *Clin Oral Implants Res* 1993; **4**(3): 121–9.
50. Becker W, Dahlin C, Becker BE, Lekholm U, van Steenberghe D, Higuchi K, Kultje C. The use of e-PTFE barrier membranes for bone promotion around titanium implants placed into extraction sockets: a prospective multicenter study. *Int J Oral Maxillofac Implants* 1994; **9**(1): 31–40.
51. Jovanovic SA, Spiekermann H, Richter EJ. Bone regeneration around titanium dental implants in dehisced defect sites: a clinical study. *Int J Oral Maxillofac Implants* 1992; **7**(2): 233–45.
52. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. *Int J Periodontics Restorative Dent* 1994; **14**(6): 496–511.
53. Young MP, Carter DH, Worthington H, Korachi M, Drucker DB. Microbial analysis of bone collected during implant surgery: a clinical and laboratory study. *Clin Oral Implants Res* 2001; **12**(2): 95–103.