What is Guided Bone Regeneration (GBR) capable of today?

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GBR is frequently necessary to reconstruct atrophied jaw regions before and/or during insertion of dental implants. It may be necessary not only for mechanical reasons i.e. the secure stabilisation of the implants in the insertion area, but also for the restoration of the “red-white aesthetics” without using pink ceramic material. Here the authors answer the question as to whether GBR is a viable alternative to autogenous block bone graft transplants, and further describe the relevant success factors.

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When reconstructing atrophied jaw regions, autogenous bone blocks, e.g. from the iliac crest, were once considered to be the gold standard, especially when performing large-volume augmentations. On the other hand, this is understandable, as these grafts offer osteoconductive and even osteoinductive properties; however, on the other hand, they frequently show resorption rates of up to more than 50%.16,29,35 Furthermore, large-volume grafts may result in significant co-morbidity due to the secondary intervention at the removal site.20,21 Augmentations using the Guided Bone Regeneration (GBR) technique offer reproducible high rates of success.5,28 Non-resorbable polytetrafluoroethylene membranes (PTFE) have been extensively studied in this field and for a long time their results seemed superior to those of the later-developed resorbable collagen membranes. If membrane exposure did not occur during healing, excellent results were achieved with PTFE membranes even in demanding vertical jaw ridge reconstructions. However, the exposure rate of PTFE membranes often reached up to 40 percent in augmentations. In cases of dehiscence with membrane exposure to the oral cavity, it frequently becomes necessary to remove the PTFE membrane due to bacterial contamination.8 In such cases, membrane exposure results in a significantly lower volume of regenerated bone.28

Resorbable membranes in Guided Bone Regeneration

Within further developments of the Guided Bone Regeneration method, resorbable membranes have proven to be more efficacious than non-resorbable membranes as they offer better tissue compatibility, easier handling, and they do not require secondary intervention for membrane removal.1,36 Furthermore, they show high cell compatibility regarding PDL fibroblasts and osteoblasts25, and a significantly higher bio-compatibility compared to PTFE membranes.77 That is why resorbable collagen membranes of animal origin are used most often in Germany today. Their use is well documented and backed by results demonstrating high rates of success.8,12,13 The barrier function of the membrane is of particular importance for augmentation of larger bone defects, and above all in case of exposure of the membrane after dehiscence. Unlike the non-resorbable membranes, resorbable membranes are not necessarily subject to contamination of the augmentation material in case of dehiscence. Nevertheless, exposure usually results in a lower augmentation volume due to faster degradation of the membrane upon exposure.36 However, non-cross-linked collagen membranes do show lower dehiscence rates of 22–32 percent,5,12,30 with a stable barrier function for approx. four to six weeks.4,17 Although, chemical cross-linking supports longer degradation times before the membrane is fully resorbed, this is also accompanied by significantly higher dehiscence rates of 39–64 percent.9,18,30 Thus, an important requirement for resorbable membranes is that they offer both good biocompatibility and high resorption stability. Moreover, the success of larger augmentations using the GBR technique largely depends upon achievement of a stress-free primary wound closure, as well as stable positioning of the augmentation material.10,11,19 This is of utmost importance when using the GBR technique for large horizontal and vertical augmentations. Moreover, when a suitable bone substitute material is applied, the GBR technique shows significantly higher success rates.8 Since 2010, for large augmentations in our practice, we have been using autogenous bone chips from the retromolar region combined with Bio-Oss® (Geistlich Pharma AG, Wolhusen, Switzerland) bone substitute material covered by the Remaix/creos™ xeno.protect non-chemically cross linked collagen membrane (Remaix, Matricel GmbH, Herzogenrath, Germany/creos™ xeno.protect, Nobel Biocare AG, Zurich, Switzerland). Remaix/creos™ xeno.protect is a natural bio-resorbable barrier membrane made of highly purified porcine collagen and elastin, introduced in Germany as a CE-certified class-3 medical device in 2009. It has a homogeneous structure on both sides so that either side can be applied towards the defect; this avoids any mix up of the sides during placement in surgery. In-vitro studies showed a significantly higher denaturation tempera-
ture, as well as a significantly higher collagenase stability of the Remaix/creos™ xeno.protect membrane compared to the—also non-chemically cross-linked—reference membrane, Bio-Gide® (Geistlich Pharma AG, Wolhusen, Switzerland). Exploring stability of decomposition with bacterial collagenase in an experimental model allowed for conclusions to be drawn regarding the degradation behaviour of the collagen membranes when exposed to periodontopathogenic germs in the oral cavity.35 At our practice the Remaix/creos™ xeno.protect membrane proved successful as a new resorbable collagen membrane with a low dehiscence rate, increased stability in case of dehiscence, and extended resorption time. Furthermore, it offers higher mechanical stability and correspondingly provides the required stability for immobilisation of the augmentation material in case of larger bone augmentations.

Clinical use of the GBR technique

The GBR method is a straightforward method for use in everyday practice, offering high probability of success and low invasiveness for the patient. When performing vertical bone augmentation using the GBR technique, success highly depends upon the ability to provide a stable space above the augmentation material.3 We frequently apply the GBR technique with augmentation procedures and examinations have been performed with approx. 50 patients for various indications including socket preservation, horizontal and vertical GBR, bone splitting, bone spreading, and sinus lift surgery. The augmentations were performed with autogenous bone chips (from the intervention area, if possible) or xenogenous, bovine bone substitute material (Bio-Oss®), or with a combination of the two. In all cases the augmentation material was then covered with the Remaix/creos™ xeno.protect membrane. Our approach avoids harvesting autogenous bone block from a donor site to ensure successful implant treatment.

Socket preservation

For socket preservation, the bone resorption processes can be prevented at tooth extraction, provided that there is no acute apical inflammation. In such cases—especially in the anterior region of the maxilla—we often perform socket preservation by filling of the alveolus with bone substitute material (patient case example 1). Here, when filling defects larger than 2 mm or even whole alveoli, the probability of success is higher when using a barrier membrane.34

Patient case 1: Socket preservation

A 48-year-old male patient presented himself at our clinic and stated the desire for aesthetic improvement of his anterior teeth in the maxilla. Tooth 21 showed a dark edge above the gingival margin. The X-ray showed an oversized cast pivot with—after 15 years—an insufficient metal-ceramic crown. Treatment of the tooth with maintenance of biological width and additional aesthetic improvement was not possible and the patient was recommended to have tooth 21 extracted and replaced by an implant. Since apical infection was absent, the patient and the dentist decided on initial augmentation at extraction by means of socket preservation. The patient also requested a provisional fixed bonded bridge. Tooth 21 was removed in a tissue-maintaining manner using narrow perirotomes, and the alveolus was filled with BioOss® bone substitute material, covered by the Remaix/creos™ xeno.protect membrane, and treated with a bonded bridge. Re-entry at four months after surgery revealed a completely ossified alveolus with the whole width of the jaw ridge maintained. An implant (NobelReplace® Straight Groovy 4.3 x 13 mm, Nobel Biocare AG, Zurich, Switzerland) was safely inserted at 40 Ncm. After another four months of healing, soft tissue was de-epithelialised and moved into a vestibularly formed pocket, using the rolled flap technique, in order to

Patient case 1

![Fig. 1: Initial situation: tooth 21 with repositioned, oversized pivot design *alia loco*, not worth being maintained. – Fig. 2: Loosening of Sharpey’s fibres using perirotome. – Fig. 3: “Removal” of dental root 21. – Fig. 4: Application of double Remaix/creos™ xeno protect membrane (Matricel GmbH, Herzogenrath/Nobel Biocare AG, Zurich, Switzerland) between buccal and palatinal bone and periosteum for covering of augmentation material (Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland).]
move the implant from palatal to buccal position and to further thicken the buccal soft tissue conditions. Two weeks later, the implant was temporarily provisionalised and an emergence profile was created. After conditioning, the impression of the implant and the soft tissue conditions was taken using individualised impression posts. The final restoration was made from an individualised zirconium dioxide framework with a zirconium dioxide crown (NobelProcera, Nobel Biocare AG, Zurich, Switzerland; Figs. 1–9).

Large horizontal and vertical augmentations

In cases of larger augmentations, as per the sausage technique (Patient case 2 & 3), we mainly use Bio-Oss® as bone substitute material, and starting at a certain size of the area to be augmented, we additionally use autogenous bone chips yielded from the surrounding operation area or from the retromolar region using the Safescraper Twist (Integra, Rostock, Germany). The augmentation material is covered by a resorbable Remaix/creos™ xeno.protect collagen membrane fixed tightly with titanium pins to immobilise the augmentation material. This means the membrane should also offer high mechanical stability when wet. Visual appearance of the augmentation material under the tightened membrane resulted in the term “sausage technique”. Wound closure should be made without stress by means of single or multiple periosteal incisions and correct suturing. If suture dehiscence still occurs, the collagen membrane should have a high resistance to biodegradation. These oral-surgical interventions with jaw augmentation are performed at our practice with prophylactic antibiotics (Amoxicillin or Clindamycin) one day before surgery and for up to five days after surgery.

Patient case 2: Augmentation in anterior part of maxilla after trauma

A 32-year-old male patient with missing teeth 12–21 after trauma and with significant bone defect presented at our clinic with the desire to receive a fixed appliance in this region. At this time and during the treatment phase, the patient wore a removable interim denture. Implant placement without jaw ridge augmentation was not possible and, therefore, initial augmentation was performed by applying GBR with the sausage technique. To treat the large defect, the Safescraper Twist was used to harvest bone chips from the retromolar region and the bone chips were mixed with Bio-Oss® at approx. an equal ratio. After perforation of the cortical bone up to the cancellous bone, the mixture of bone and bone substitute material was placed onto the area to be augmented and covered with a Remaix/creos™ xeno.protect membrane that was fixed buccally and palatally with titanium pins in a position as basal as possible. Despite the stress-free wound closure after multiple periosteal incisions, this case showed dehiscence in the area 12–11 after one week. The defect closed spontaneously after approx. two weeks without any further surgical intervention and without wound infection. After the first three days
post surgery, the patient did not experience any further pain. However, pain control during the initial stage was achieved with regular administration of ibuprofen 400 mg 2–3 times per day. After healing of the augmentation material, the operation site showed a wide jaw ridge with vital, newly formed bone (bleeding with pilot drilling and removal of Bio-Oss® particles in the surface region). After a healing time of six months, two NobelReplace® Conical Connection (Nobel Biocare AG, Zurich, Switzerland) measuring 4 x 11.5 mm were inserted in the areas 12 and 21. The implants were inserted with a good primary stability with an insertion torque of 35 Ncm. Following a healing time of another four months for osseointegration of the implants, the implants were restored with zirconium dioxide abutments and a NobelProcera zirconium dioxide bridge.

To thicken and improve the soft tissue, the patient was recommended to have a connective tissue graft from the palate transplanted prior to reopening. With the transplanted tissue it might have been possible to create a natural papilla and avoid the small pink ceramic artificial papillas in the interdental region. However, as the patient moved to another domicile, and he does not have a high smile line, he decided against the connective tissue transplantation (Figs. 10–17).

Patient case 3:
Posterior horizontal and vertical augmentation of mandible

The 38-year-old male patient presented himself with the desire to receive implant-prosthetic treatment of the gaps in his teeth in the regions 36, 37 and 45, 46. The teeth in these regions had been missing for several years, represented by an atrophied knife-edge or Cawood-Howell class VI.5–7 Implantat placement in these regions was not possible without improvement of the implant base. Horizontal and vertical GBR as per the sausage technique with autogenous bone chips distally of the operation site was performed under endotracheal anaesthesia; no other region was impacted for bone harvesting. The surgical intervention was performed as in the example described above. Healing took place without any complications and resulted in

### Patient case 2

![Fig. 10](image10.png) Operation site 22–21 after extraction and healing due to trauma. – ![Fig. 11](image11.png) Massive GBR (horizontal & vertical) with autogenous bone chips and Bio-Oss®, fixation of membrane and immobilisation of augmentation material using titanium pins (Ti-System, RIEMSER Pharma GmbH, Greifswald, Germany). – ![Fig. 12](image12.png) Augmented jaw ridge after healing time of six months. – ![Fig. 13](image13.png) Insertion of NobelReplace® CC implant (Nobel Biocare AG, Zurich, Switzerland). – ![Fig. 14](image14.png) Implants in jaw ridge created in regions 12 and 21. – ![Fig. 15](image15.png) Occlusal view of individual zirconium dioxide augmentations (NobelProcera). – ![Fig. 16](image16.png) En-face view of Procera bridge (zirconium dioxide) in regions 12–21. – ![Fig. 17](image17.png) Individual zirconium dioxide augmentations (NobelProcera).
sufficient width and height of the jaw ridge. Implant placement is still to be performed (Figs. 18–24).

**Summary**

The GBR techniques and materials described above have allowed for large augmentations and subsequent implant placement without the need to use autogenous bone blocks. As a result, the use of jaw ridge expansion with autogenous bone block grafts e.g. from the retromolar region of the mandible or even from the iliac crest, is below 1 percent at our practice, while implant success rates over the past five years amounting to approx. 98.9 percent (according to our own follow-up). Our implant success rate has remained constant at a high level since we introduced the Remaix/creos™ xeno.protect membrane. During surgery, the easy handling of the Remaix/creos™ xeno.protect membrane is beneficial for these GBR techniques as compared with the previously used Bio-Gide, as it offers a higher stability even after wetting, particularly during and after fixation with titanium pins. This allows for better coverage and shaping within the scope of GBR. In cases of dehiscence, we have observed spontaneous healing after approx. two weeks without complete degradation of the membrane or denudation of the augmentation material. Here, we observed a dehiscence rate of approx. 10 percent within scope of GBR therapy with Remaix/creos™ xeno.protect, which is significantly lower than the values stated for non-chemically cross-linked membranes in literature. 15, 17, 30

Follow-up of approx. 50 patients up to now showed promising results and points out that the right concept and modern materials may often prevent invasive interventions such as iliac crest transplantations. However, it should be noted that the clinical data are limited, above all with regard to long-term success, bone resorption in the augmented region, and crestal bone remodelling. Further examination in the context of randomised clinical studies, should be performed for validation of these results.

**Fig. 18:** Occlusal view: in the region of the missing teeth 36, 37 and 45, 46 there is a highly atrophied, sharp jaw ridge. – **Fig. 19:** Operation site with atrophied jaw bone. – **Fig. 20:** Drilling through compact bone into cancellous bone for yielding of “bone blood.” – **Fig. 21:** Applied mixture of autogeneous bone chips and Bio-Oss® – **Fig. 22:** Remaix™/creos™ xeno.protect membrane (Matricel GmbH, Herzogenrath, Germany) fixed by titanium pins for stabilisation of augmentation material. – **Fig. 23:** Postoperative OPG image. – **Fig. 24:** Occlusal view after removal of suture three weeks after surgery.

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