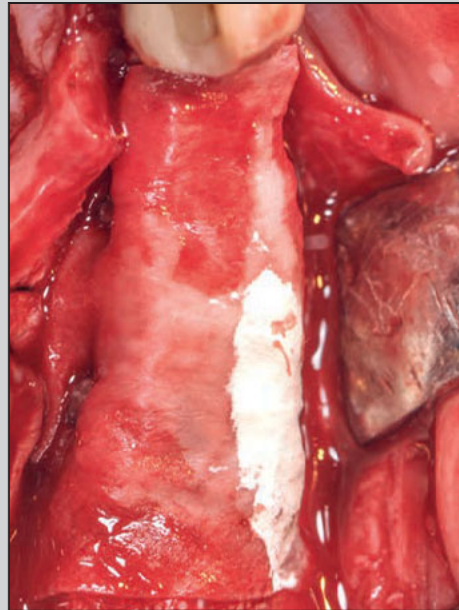
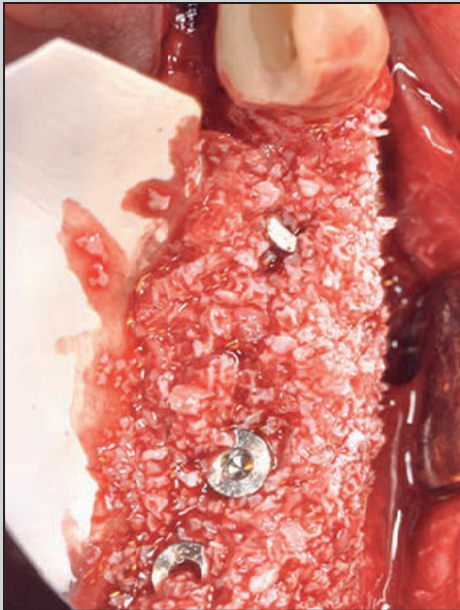
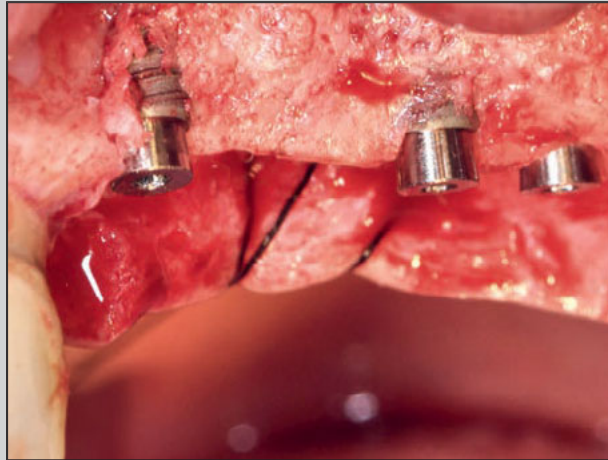




Simultaneous GBR and Implant Placement with Resorbable Membranes in the Rehabilitation of Partially Edentulous and Horizontally Atrophic Dental Arches: A Retrospective Study on 97 Implants with a 3- to 7-Year Follow-up



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This retrospective study evaluates the clinical and radiographic outcomes of simultaneous guided bone regeneration (GBR) and implant placement procedures in the rehabilitation of partially edentulous and horizontally atrophic dental arches using resorbable membranes. A total of 49 patients were included, and 97 implants were placed. Patients were followed up for 3 to 7 years after loading. The data indicate that GBR with simultaneous implant placement and resorbable membranes can be a good clinical choice, and the data suggest that it could be better to horizontally reconstruct no more than 3 mm of bone in order to reduce the number of complications and to obtain stable results. However, this technique remains difficult and requires expert surgeons. Int J Periodontics Restorative Dent 2022;42:371–379. doi: 10.11607/prd.5641

Implant placement could be limited by insufficient bone height and/or width and can require bone augmentation procedures.¹ In selected cases, it is possible to exploit the residual native bone by placing short or narrow implants with some compromises.^{2–6} Various techniques have been proposed in the literature to vertically and horizontally augment the bone, but it is still unclear which methods are the most efficient.¹

Guided bone regeneration (GBR) was first proposed by Dahlin et al in 1988 in order to reconstruct bone by using grafts and barriers, promoting the ingrowth of osteogenic cells and preventing the migration of undesired soft tissues into the wound.⁷ In 2006, Wang and Boyapati proposed four crucial elements necessary for GBR success.⁸ Nowadays, GBR is a common treatment option for bone reconstruction, providing adequate support for osseointegrated implants.^{9,10} Nevertheless, the technique's complexity and the need for experienced operators, especially in managing complications, are still a challenge.¹

In particular, in cases of horizontal bone atrophy wherein the defects are limited and therefore allow contextual implant placement, using resorbable membranes could reduce the incidence of complications and the discomfort related to a

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second surgical phase. However, it is still not fully clear **how much bone** it is possible to successfully horizontally regenerate when using resorbable membranes with implant placement to reduce rehabilitation times.¹¹

The aim of this study was to evaluate clinical and radiographic outcomes of GBR procedures in the rehabilitation of partially edentulous and **horizontally atrophic arches**, with a 3- to 7-year follow-up. A special focus was placed on trying to evaluate a possible **threshold** for **maximum horizontal bone gain** to recommend when using resorbable membranes with a simultaneous implant placement approach.

Materials and Methods

A retrospective single cohort study was conducted, and patients were treated by two expert surgeons (R.P. and P.F.). The inclusion criteria were as follows: previous partial edentulism, horizontal bone atrophy treated with GBR (simultaneous implant positioning approach) performed with resorbable membranes, and at least 3 years of follow-up. Clinical and radiographic data were collected by examining clinical charts. Included **patients** were divided into three groups: **nonsmokers**, **moderate smokers** (≤ 10 cigarettes per day), and **heavy smokers** (> 10 cigarettes per day). Patients signed a specific written consent form after receiving thorough information about the surgery.

This retrospective study was carried out in accordance with the Declaration of Helsinki and the Eu-

ropean Standards for Good Clinical Practice.

Surgical Procedures

All treated patients received antibiotic prophylaxis before undergoing GBR and received a subsequent postoperative long-course therapy. Surgeries were performed under local anesthesia.

The flap design ensured a primary, tension-free closure. In the **posterior mandible**, a midcrestal incision was performed, reaching the proximity of the retromolar trigone. A **subperiosteal detachment** was then made on the lingual side using the digitoclastic technique to coronally displace the lingual flap.¹² **On the vestibular side, the flap was carefully elevated to reveal the neurovascular bundle in the mental foramen area**, and a periosteum incision was made using the tip of a scalpel in order to stretch out the flap. In the **maxilla**, a paracrestal buccal incision was made in order to obtain a longer palatal flap, and **vertical releasing incisions were made only buccally**.

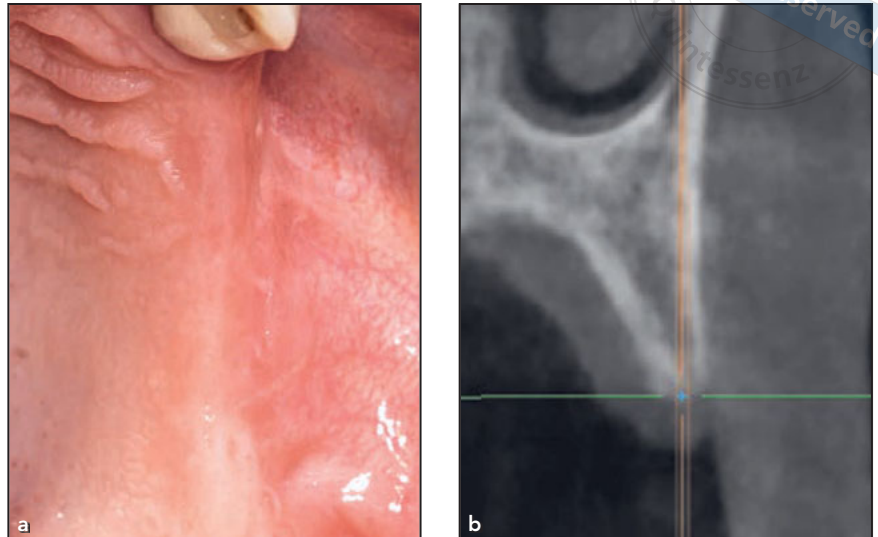
Implants were placed with a simultaneous approach at the same surgical session as membrane positioning. Two different implant systems were used: In-Kone (Global D) and AnyOne (MegaGen Implant). **Multiple cortical bone perforations were performed in the receiving bone bed to activate the regional acceleratory phenomenon, favoring blood supply**. After **collecting the autologous bone** using a Safescraper (Meta), perforations were made. A **60:40 mixture of deproteinized bo-**

vine bone mineral particulate xenograft (Bio-Oss, Geistlich Pharma) and autogenous bone was used. The **resorbable collagen membrane (Bio-Gide [Geistlich Pharma] or Osseo-Guard [Zimmer Biomet])** was adapted and fixed on the lingual/palatal side. The graft was then placed on the defect, and **the membrane was fixed on the buccal side using titanium pins**. Finally, flaps were closed using nonresorbable polytetrafluoroethylene sutures. The aim of the reconstructive surgery was to obtain at **least 2 mm of bone** around 4-mm standard-width implants (8 mm of final horizontal bone).

Nonsteroidal analgesics (ketoprofen) were administered. Post-surgical instructions included **a soft diet and appropriate oral hygiene, avoiding brushing and trauma at the surgical sites**. Patients were instructed to rinse twice a day with 0.2% chlorhexidine mouthrinse for ~2 weeks. Sutures were removed at approximately 14 days postoperative. Antibiotic therapy was generally prescribed: amoxicillin (1 g) and clavulanic acid three times a day for 8 days and **metronidazole (250 mg) twice a day for 6 days**. All patients were recalled for additional postoperative check-ups and were registered in a maintenance hygiene program.

Implants and grafts underwent submerged healing for **at least 6 months**. Temporary acrylic prostheses were delivered about 3 to 4 weeks after implant exposure. **Definitive prostheses were delivered 3 to 4 months later**. Soft tissue grafts were performed when necessary, in agreement with patients, at implant-exposure surgeries.

Fig 1 Case 1. Horizontally atrophic posterior maxilla. (a) Clinical view before membrane positioning surgery and (b) 3D preoperative computed tomography scan.



Outcome Measures

The evaluated outcome measures were: (1) complications; (2) implant failures (implant mobility and/or removal of stable implants due to marginal bone loss or infection); (3) prosthetic failures (planned prostheses that were not placed due to implant or GBR failure, loss of the prosthesis secondary to implant failure, and prosthesis replacement for any reason); (4) horizontal radiographic mean bone gain evaluated at each implant site (measuring, at 3 mm apical from the top of the crest, the perpendicular linear distances between the lingual/palatal points and the vestibular ones, averaged for the entire group of patients) using the Horos software, comparing baseline/preoperative and 6-month scans; and (5) peri-implant marginal bone level changes (evaluated on radiographs using the same Horos software calibrated with the known implant diameter) at implant placement and at 3 and 7 years after loading.

Statistical Analysis

Descriptive analysis was performed, presenting the continuous variables as mean $\pm$ standard deviation or median $\pm$ interquartile range and presenting the categorical variables as absolute and relative frequencies. The surgical site was the statistical unit of analysis. A multiple logistic regression model was performed for biologic complications, including the following predictors: smoking habit, surgery site, extension of the defect, and the amount of required horizontal bone augmentation. The results are presented as an odds ratio with 95% confidence intervals (CIs). Multiple linear regression analyses were fitted to model the difference between the planned augmentation and the real one and the peri-implant bone loss. Paired *t* test was used to compare the peri-implant bone loss. The significance level was set at .05. All analyses were performed using Stata, version 15 (StataCorp).

Results

A total of 49 patients were treated with a GBR procedure and simultaneous implant placement using a resorbable membrane, and 97 implants were placed. Of the GBR procedures, 26 (53.06%) were performed in the maxilla (20 in the posterior area) and 23 (46.94%) in the posterior mandible (Figs 1 to 6). All 49 patients had a follow-up of at least 3 years, while 33 patients (67.34%) had a follow-up of 7 years. Mean patient age at the time of the first surgery was 55.86 years (range: 18 to 75 years), and 77.55% were women ($n = 38$). Thirty-nine patients were nonsmokers (79.59%), and of the 10 patients (20.41%) who smoked, 8 (16.33%) smoked ≤ 10 cigarettes per day and 2 (4.08%) smoked > 10 cigarettes. Thirteen augmented sites (26.53%) had one implant placed, 24 augmented sites (48.98%) had 2 implants placed, and 12 augmented sites (24.49%) had three

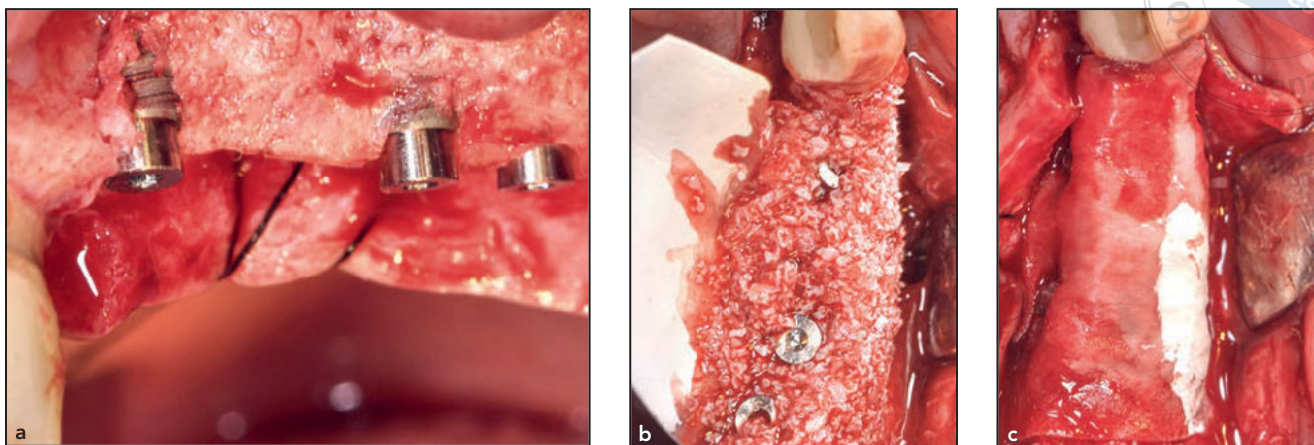


Fig 2 Case 1. GBR and simultaneous implant placement procedure in a horizontally atrophic posterior maxilla. (a) Implants were positioned. (b) One end of a resorbable membrane was fixed palatally, and a 60:40 mix of heterologous deproteinized bovine bone mineral (DBBM) and autogenous bone chips was applied. (c) The other end of the same resorbable membrane was fixed vestibularly.

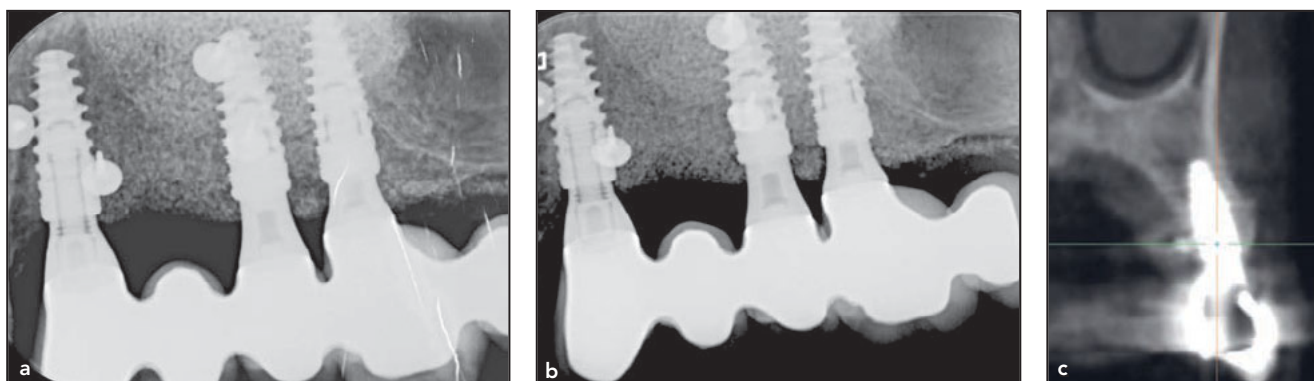


Fig 3 Case 1. (a) Radiographic view 3 years after loading and (b) 7 years after loading. (c) Computed tomography scan 7 years after loading.

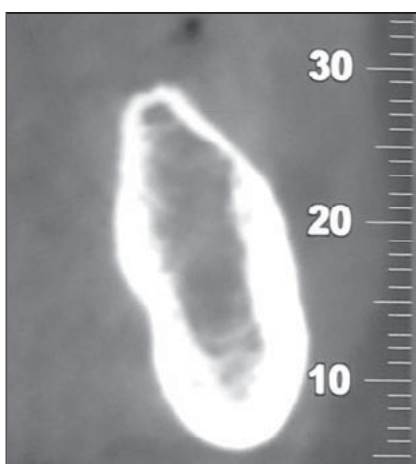


Fig 4 Case 2. Three-dimensional preoperative computed tomography scan of the horizontally atrophic posterior mandible.

implants placed. The mean implant length was 9.42 ± 1.44 mm (range: 6 to 13 mm), and the mean implant diameter was 3.95 ± 0.33 mm (range: 3.3 to 5 mm). The main patient and intervention characteristics are presented in Table 1.

Complications

Healing was uneventful, and a majority of patients ($n = 43$; 87.76%) experienced no complications. Six patients (12.24%) experienced

one or two complications: Five patients (10.20%) reported one complication, while one patient (2.04%) reported two complications. There were two cases of temporary paresthesia lasting 7 and 21 days, respectively, and five cases of incomplete bone augmentation. No membrane exposures were reported. Smoking habit and the extension of the defect had a positive correlation with the occurrence of complications (temporary paresthesia and incomplete bone augmentation), but it was not

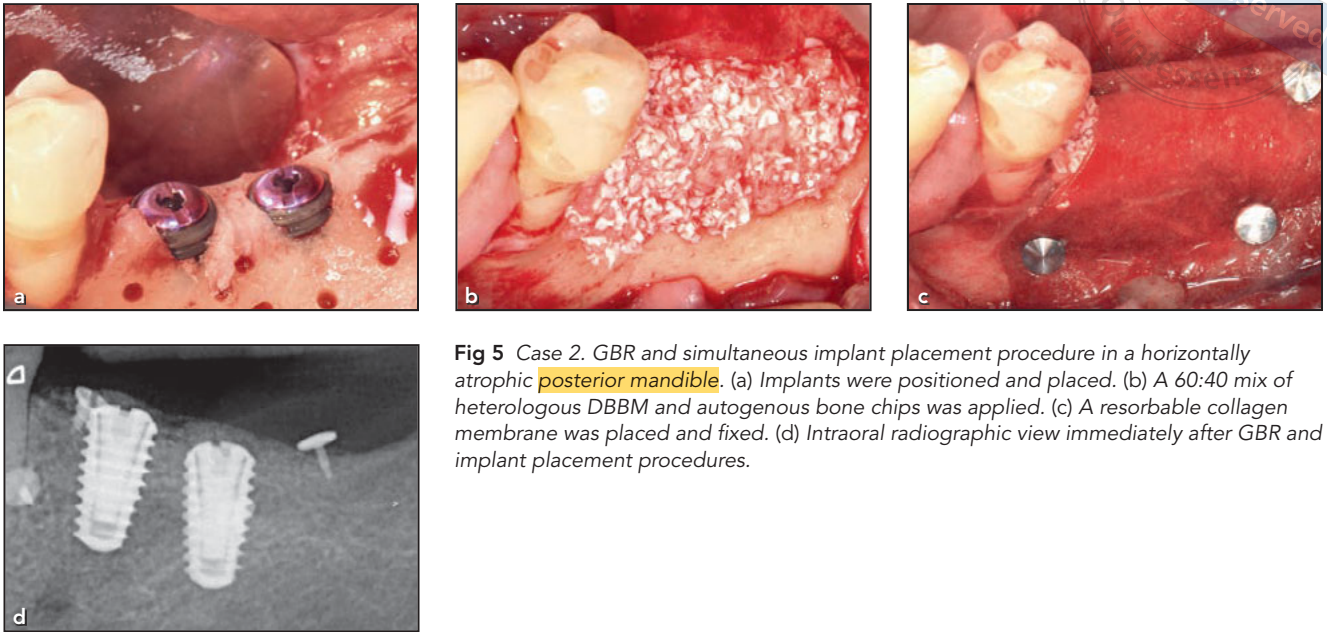


Fig 5 Case 2. GBR and simultaneous implant placement procedure in a horizontally atrophic posterior mandible. (a) Implants were positioned and placed. (b) A 60:40 mix of heterologous DBBM and autogenous bone chips was applied. (c) A resorbable collagen membrane was placed and fixed. (d) Intraoral radiographic view immediately after GBR and implant placement procedures.

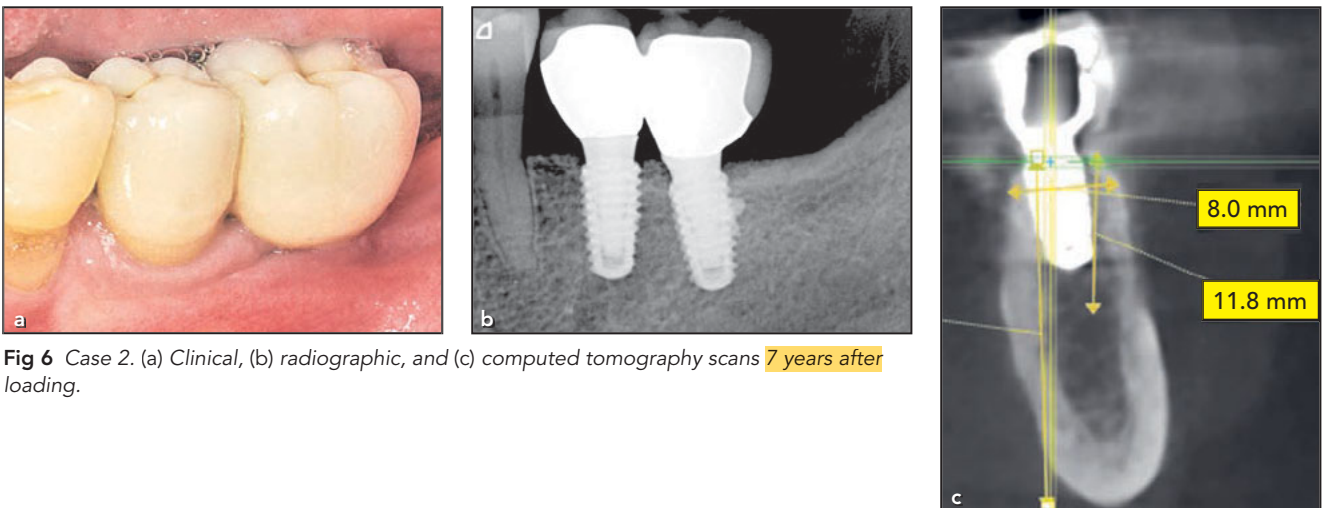


Fig 6 Case 2. (a) Clinical, (b) radiographic, and (c) computed tomography scans 7 years after loading.

statistically significant. No implants or prostheses failed during the entire follow-up.

Mean Radiographic Horizontal Bone Gain

The mean bone crest width was 5.19 ± 0.72 mm (range: 3.30 to

6.76 mm) at baseline and was 7.95 ± 0.51 mm (range: 6.56 to 9.22 mm) before reentry (implant exposure) at least 6 months later. The amount of horizontally augmented bone was 2.76 ± 0.74 mm (range: 1.43 to 4.73 mm). Table 2 lists bone crest measurements according to time point and arch. The mean planned augmentation had to be $2.96 \pm$

0.72 mm (range: 1.54 to 4.73 mm) to achieve 8 mm of crestal bone width, and the difference between the planned and actual bone width was 0.20 ± 0.32 mm (range: 0 to 1.44 mm), with the actual bone not meeting the desired augmentation width. The mean percentage of radiographic bone filling was 93.21%. The mean planned

Table 1 Main Patient and Intervention Characteristics

Patients	
Total, n	49
Women, n (%)	38 (77.55%)
Mean age at recruitment, y (range)	55.86 (18–75)
Smokers, n (%)	10 (20.41%)
Location	
Maxilla, n (%)	26 (53.06%)
Mandible, n (%)	23 (46.94%)
Implants	
Total, n	97
Mean $\pm$ SD length, mm	9.42 $\pm$ 1.44
Mean $\pm$ SD width, mm	3.95 $\pm$ 0.33
Patient attendance at follow-up	
Patients at 3 y, n	49
Patients at 7 y, n	33

horizontal augmentation was 2.81 ± 0.67 mm (range: 1.54 to 4.73 mm) when complete regeneration was obtained, while the mean planned horizontal augmentation was 3.12 ± 0.76 mm (range: 1.78 to 4.7 mm) when the regeneration was incomplete. The incomplete radiographic bone gain was significantly correlated with smoking habit ($\beta = 0.62$; 95% CI: 0.18 to 1.08; $P = .007$).

Peri-implant Marginal Bone Loss

A peri-implant bone loss of 0.65 ± 0.40 mm (range: 0.04 to 1.34 mm) occurred at 3 years, with an additional loss of 0.30 ± 0.21 mm (range: 0.02 to 0.84 mm) occurring between the 3-year and 7-year follow-ups. The 7-year follow-up resulted in $0.99 \pm$

0.63 mm (range: 0.05 to 2.18 mm) of peri-implant bone loss. The bone loss that occurred in the first 3 years was significantly greater than the loss between the 3-year and 7-year follow-ups (mean difference: 0.35 mm; 95% CI: 0.29 to 0.49; $P < .001$). Peri-implant bone loss had a significant, positive correlation with smoking habit.

Discussion

Treating partially edentulous atrophic arches with GBR procedures in order to horizontally augment the bone and place conventional-diameter implants is a well-documented procedure.^{11,13–18}

Using resorbable membranes can bring some advantages: the reduction of exposure rates, the decreased risk of total failure when an

exposure occurs, and not needing to perform a second surgical phase to remove the membrane. The difficulty of maintaining the barrier function for an appropriate length of time is considered a major drawback of resorbable membranes, whereas nonresorbable ones are able to maintain larger spaces (for the blood clot) for a longer period of time, and thus they could be indicated for wider reconstructions.¹³ The possibility to simultaneously place implants without requiring a second surgery can also reduce rehabilitative times. However, the simultaneous approach is only possible when there is a sufficient amount of residual bone to obtain primary implant stability, and therefore it is limited to minor horizontal augmentations.¹⁹

For these reasons, the present authors evaluated the potential of GBR and simultaneous implant placement with resorbable membranes for limited horizontal bone augmentation. No severe complications or membrane exposures occurred. This is in contrast with another retrospective study in which a wound dehiscence rate of 12% and a graft failure rate of 4% were reported.²⁰

Considering peri-implant marginal bone levels reported in other studies (0.99 mm after 7 years),^{15,16,18} the results are in agreement with or superior to the literature. As the current study was retrospective in nature, no jig was used to standardize the radiographs. The 3-year postloading results of a randomized controlled trial²¹ indicated that radiographic bone loss ranged from 1.02 to 1.61 mm.

Table 2 Mean Horizontal Radiographic Bone Gain

	Bone width, mm		
	Both arches	Maxilla	Mandible
At T0	5.19 ± 0.72	4.88 ± 0.74	5.56 ± 0.51
At T1	7.95 ± 0.51	7.90 ± 0.59	8.02 ± 0.41
T1–T0	2.76 ± 0.74	3.03 ± 0.82	2.46 ± 0.53
Mean augmentation w/out complications	2.81 ± 0.67	3.17 ± 0.72	2.54 ± 0.50

T0 = baseline, before membrane-positioning surgery; T1 = before reentry surgery, after at least 6 months (implant exposure). Measurements were made on CT scans. Values are presented as mean ± SD.

The aim of the present procedure was to reconstruct the minimum bone width, making it sufficient for (1) the placement of standard-diameter implants (4 mm) and (2) maintaining at least a 2-mm width buccally and palatally/lingually to guarantee bone stability over time, in accordance with the literature.^{17,22} Of course, this assumption could be a limit that was accepted in order to retrospectively define success for the procedure. The mean horizontal bone regeneration in the present study was only 2.76 mm, specifically 3.03 mm in the maxilla and 2.46 mm in the posterior mandible. As a matter of fact, it was found that increasing the width by more than 2.81 mm led to more frequent incomplete regeneration. Thus, the present authors suggest that bone regeneration not exceed 3 mm when using resorbable membranes. A possible reason for the present findings could be the biologic features of the augmented site: The greater the bone increase, the longer the distance from the native bone that guarantees a blood supply and cells.¹⁷ Similar results

were described in a previous article in which nonresorbable membranes were used and the maximum suggested vertical augmentation was 6 mm.²³ A recent pilot study was conducted to analyze the volumetric bone changes—and to compare them with the literature—after a lateral GBR procedure using bone allografts and collagen resorbable membranes, and a linear overall net bone gain of 2.86 ± 0.23 mm was reported.²² According to a recent systematic review, the overall mean horizontal bone gain after GBR with collagen membranes was 2.27 ± 1.68 mm, but the follow-ups were limited.²⁴ Additionally, the present study's bone filling percentage (93.21%) is in agreement with the literature, as Simion et al reported a very similar rate (93.38%).²⁵ This is related to the five incomplete bone augmentations (10.20%) that occurred in the present study, which could be noted as a potential disadvantage of simultaneous grafting with implant placement.^{14–16}

Finally, it should be taken into consideration that the GBR technique remains difficult and requires

expert surgeons. Furthermore, to obtain these results and keep them stable over time, proper hygienic care is very important, and the patient should be adequately motivated. Sessions of professional oral hygiene should be regularly performed.

When considering other treatment approaches described in the literature for these partially atrophic cases, an onlay/veneer bone graft and narrow implants are possible alternatives. Conversely, the use of bone block is difficult to manage, is associated with significant resorption, and has its best results with autologous bone, thus increasing postoperative morbidity due to the need for a donor site.^{26,27} Narrow implants have been also proposed as a way to avoid horizontal reconstructions, but there is a lack of long-term data on these implant cases of partial horizontal bone atrophy, and there are certain esthetic limitations.⁶

In clinical cases where a horizontal increase in bone width is necessary, it is possible to perform a GBR using only autologous bone,

nonresorbable membranes, and/or placing delayed implants, according to Urban et al.^{28,29}

Regarding the clinical choice between GBR with simultaneous or delayed implant placement, the staged approach should be used in cases requiring > 4 mm of newly horizontal bone, according to Urban et al.²⁹ However, according to the current study results, the present authors recommend using a simultaneous approach for a maximum increase of 3 mm.

Conclusions

GBR with resorbable membranes and simultaneous implant placement can be a good clinical choice for the treatment of limited horizontal defects in partially edentulous arches. Within all the limitations of this retrospective study, the results reflected that horizontal augmentation should be limited to a maximum increase of 3 mm in order to reduce the number of complications, therefore increasing the success rate and bone stability over time. In any case, this technique requires expert surgeons, and these findings should be confirmed by randomized controlled clinical trials with long-term follow-ups.

Acknowledgments

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