For the 3D reconstruction of atrophic maxillae

Graft volumetric changes of collagenated xenograft

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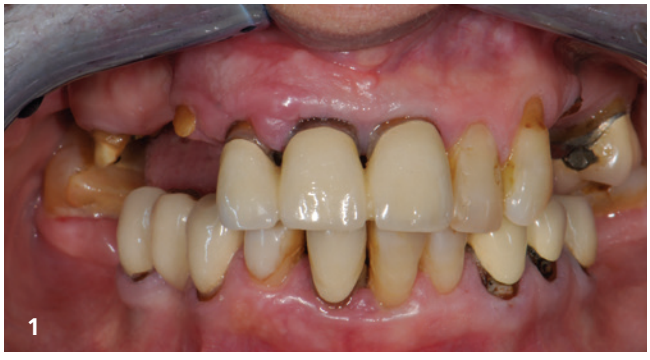
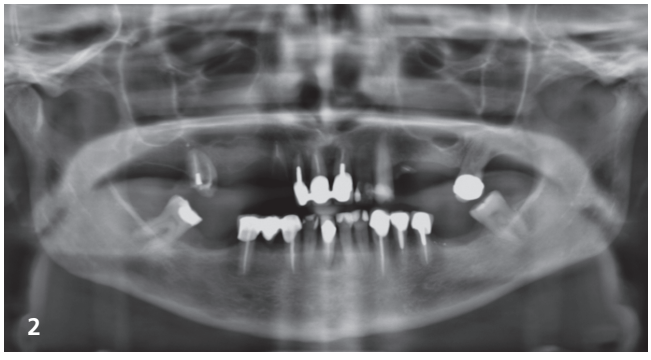
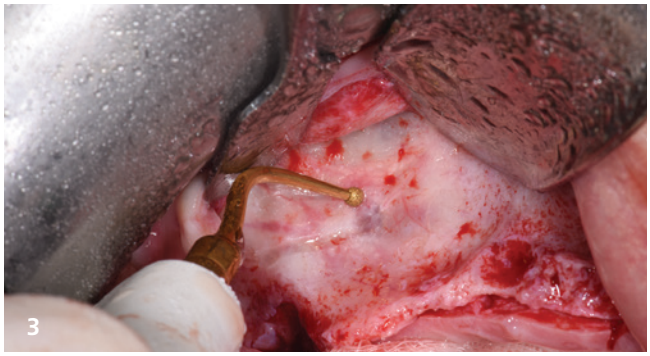
Introduction

Placement of dental implants is an increasingly common approach to the replacement of missing teeth.[1] Implant-supported prostheses can be used as an alternative to traditional bridgework or removable dentures in case of partially and completely edentulous patients. However, the posterior region of the maxilla is usually a challenge for surgeons owing to the bone resorption that occurs after tooth extraction.[2–3] Moreover, the maxilla mainly consists of spongy bone, which is one of the least dense in the oral cavity.[4] To compensate for atrophy and increase the bone volume available for the insertion of implants, various techniques have been developed.[5] Maxillary sinus elevation is a predictable and well-documented method to increase bone volume for maxillary implant placement.[6,7] This procedure may even increase bone quality by augmenting the sinus cavity with a bone grafting material that generates a denser bone. The standard maxillary sinus elevation methodology involves creation of an external window, careful lifting of the sinus membrane and packing of the sinus floor under the lifted membrane with a bone graft. Its predictability and safety have been demonstrated since 1980 by evaluating bone formation, noting low complication rates and high implant success rates[8,9] regardless of the residual crestal bone height.[10]

Instead, for minor and moderate horizontal ridge deficiency, guided bone regeneration (GBR) offers the possibility of restoring the bone architecture through the application of bone grafting materials in conjunction with barrier membranes to stabilise and protect the grafting materials placed.[11] Recently, GBR using resorbable membranes has been shown to correct or augment knife edge ridges.[12–14] The PASS principle (primary wound closure, angiogenesis, space maintenance and stability







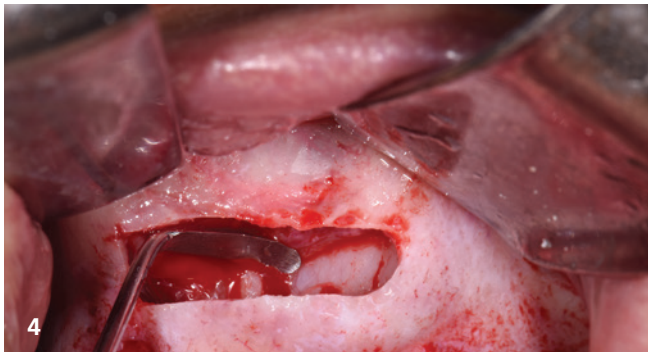
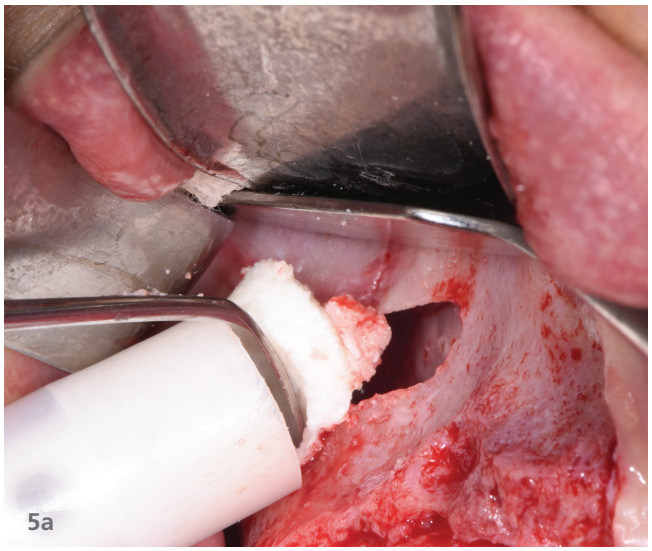
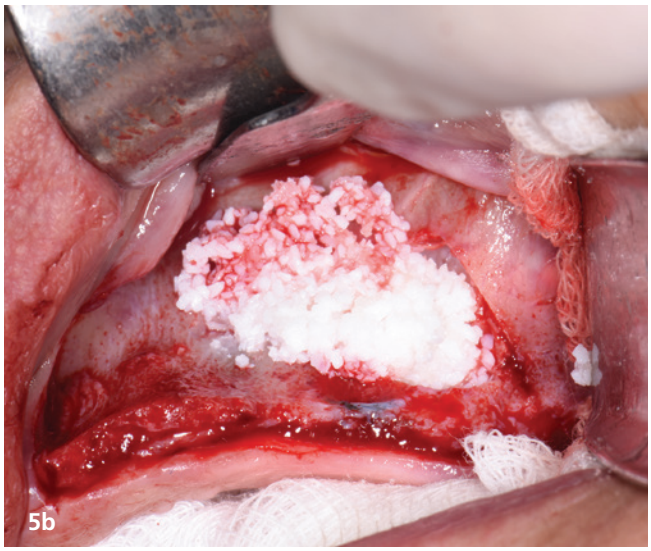


Fig. 1: Intra-oral image. **Fig. 2:** Pre-operative radiograph. **Fig. 3:** Antrostomy design by means of piezo-surgery. **Fig. 4:** Elevation of the Schneiderian membrane.





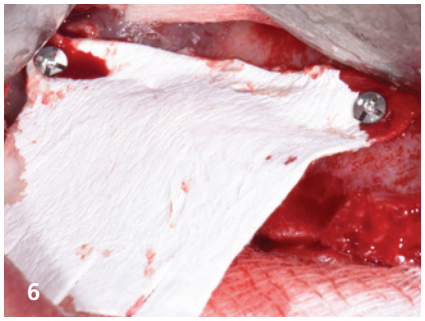
Figs. 5a & b: Placement of collagenated sticky bone substitute inside the antrostomy on the right side **(a)** and prehydrated heterologous bone substitute inside the antrostomy on the left side **(b)**.

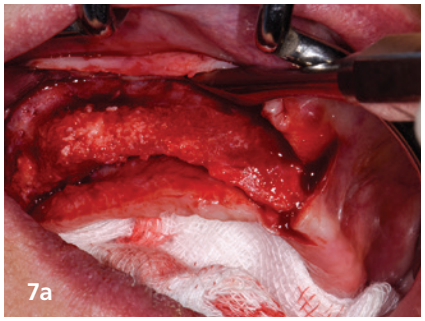
of the blood clot) remains a cornerstone of successful GBR.[15] A combination of ridge and sinus augmentation for partially edentulous patients has been documented to produce medium- to long-term implant survival.[16–18] In the arena of GBR as well as sinus augmentation, a wide variety of materials have been investigated. So far, no consensus has been reached with regard to the clinical superiority of one material over another. The purpose of the current article is to illustrate how the combination of different techniques, the correct use of bone substitutes and soft-tissue management can restore a maxillary arch and deliver a fixed implant-supported prosthesis, as well as to evaluate the volumetric change of the bone substitute used over time.

Case 1: Maxillary sinus surgery and delayed implant placement

A 50-year-old female patient presented at Lake Como Institute in Italy needing complete maxillary rehabilitation. Careful clinical examination and radiographic (conventional and CBCT scan) assessment were carried out, and all the teeth were deemed hopeless (Figs. 1 & 2). The patient requested rehabilitation of the maxilla with a fixed prosthetic solution. The treatment plan included four surgical steps: the extraction of all of the remaining teeth, bilateral maxillary sinus elevation with initial horizontal augmentation, implant placement with a second horizontal augmentation and the uncovering phase for the management of the soft tissue. After the extractions, a complete denture was delivered to the patient. It was decided to wait for four months before moving on to the next surgery in order to allow the post-extraction sockets to heal. The prosthesis was relined twice during this time to obtain correct adaptation.

Before performing the bilateral maxillary sinus elevation, a clinical and radiographic evaluation were carried out to determine the difficulty of the surgery.[19] After local anaesthesia (4% articaine with 1:100,000 adrenaline) of the maxillary edentulous areas, two crestal incisions displaced towards the palatal sides were performed. Divergent releasing incisions were made buccally in the canine and tuberosity sites, and two full-thickness flaps were elevated at the buccal sides to expose the lateral walls of the maxillary sinuses. Two lateral osseous windows were then cut using different inserts of a piezoelectric device (Fig. 3). Care





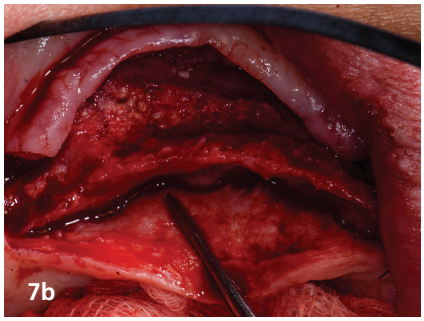
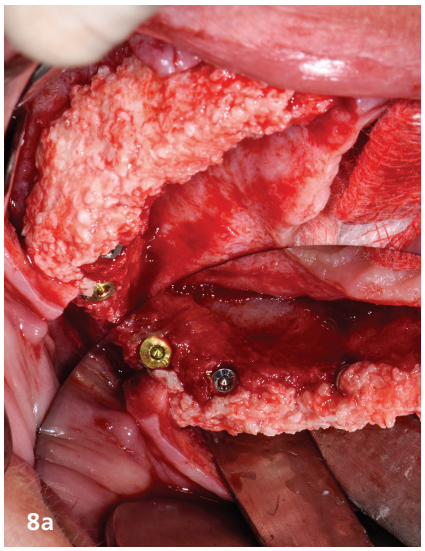
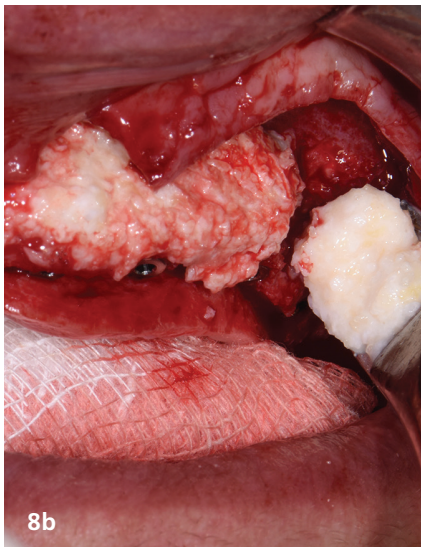
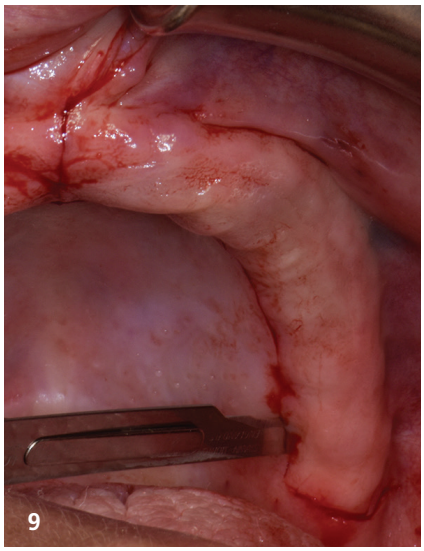


Fig. 6: Fixation of the collagen membrane with mini-screws. **Figs. 7a & b:** Result of the first horizontal augmentation of the right side **(a)** and the left side **(b)**.



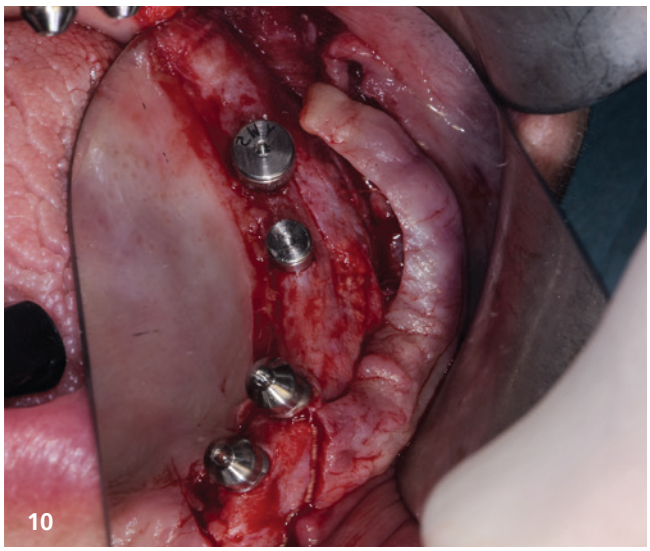




Figs. 8a & b: Second horizontal augmentation of the right side **(a)** and the left side **(b)** with the implants already placed. **Fig. 9:** Flap design of the uncovering phase.

was taken to avoid perforation of the sinus membrane throughout the procedure.[20] The membrane was elevated using special sinus curettes until the sufficient height for the implants had been achieved (Fig. 4). A collagen sponge was inserted into the tuberosity to keep the sinus membrane elevated, and microholes were made to increase vascularisation and bone regeneration. A collagenated heterologous sticky bone substitute in a collagen matrix (OsteoBiol GTO, Tecnoss) was then inserted directly into the antrostomy of the right sinus (Fig. 5a) and a pre-hydrated heterologous bone substitute (OsteoBiol mp3, Tecnoss) into the left sinus (Fig. 5b), and both of them were compacted. A collagen membrane (OsteoBiol Evolution, Tecnoss) was fixed through micro-screws above the antrostomies (Fig. 6), a first layer of bone substitute (GTO) was placed on the buccal side of the right sinus because of the horizontal atrophy and the membranes were folded beneath the palatal wall. Before suturing, a layer of PRF membranes was arranged to protect and enhance the healing of the sites. Both of the sides were sutured, for healing by primary intention. Owing to the limited bone height under the sinus floor, implant placement was delayed for graft consolidation until three months later. A CBCT scan was taken to examine the degree of augmentation, and two other measurements on each side were taken in order to have a starting point for evaluating the future volumetric changes of the biomaterials.

The patient returned after three months for CBCT examination to decide whether the healing was optimal for the implant surgery. Unfortunately, owing to medical problems, she delayed the surgery. When the patient was able to come back, after three additional months, another CBCT scan was taken before implant surgery to assess the further volumetric change of the biomaterials and to plan appropriate implant surgery. A



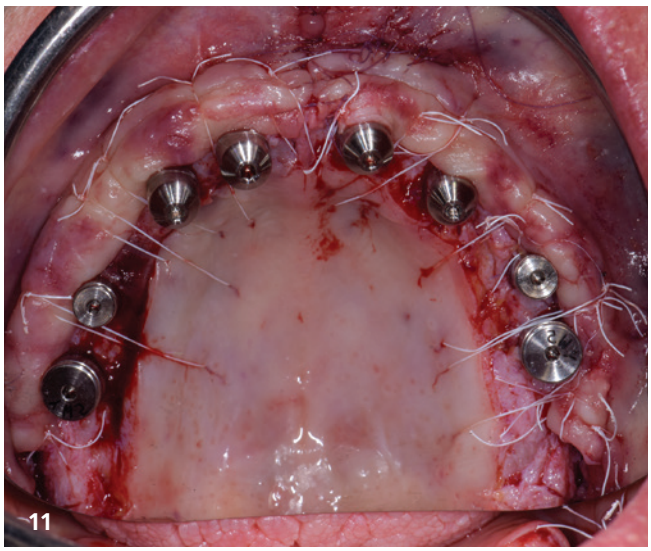
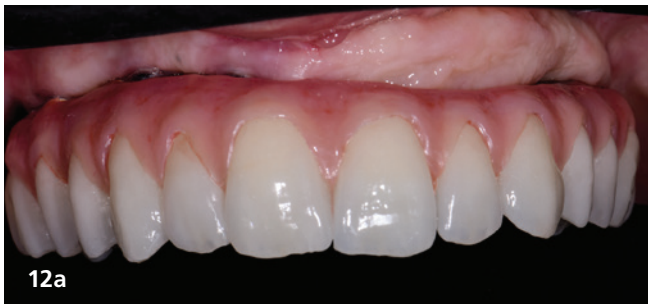
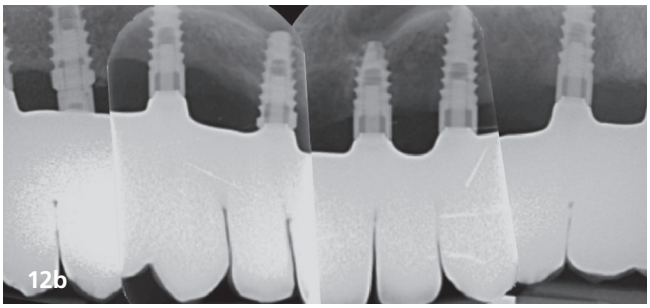


Fig. 10: Split thickness-flap during the uncovering phase with healing abutments placed. **Fig. 11:** Final sutures of the fourth surgical step.





Figs. 12a & b: Intra-oral image **(a)** and periapical radiograph **(b)** of the definitive prosthesis.

full-thickness flap was elevated to evaluate the results of the previous bone augmentation on both the right (Fig. 7a) and the left sides (Fig. 7b). Eight implants then were placed, and another layer of biomaterial (GTO) was placed on the buccal site of both sides. Thanks to the properties of this collagenated sticky biomaterial, there was no need to hydrate it because it adhered where it was placed, removing the risk of losing granules during the procedure (Figs. 8a & b). The biomaterial was then covered with a membrane (OsteoBiol Evolution) and both sides were sutured.

Four months later, the patient was scheduled for the final surgical step: the uncovering phase. Before proceeding with the final step, a last CBCT scan was taken to evaluate the positions of the implants and how the height of the new sinus floor had adapted to the implants placed. The uncovering phase was scheduled after implant osseointegration in order to recreate keratinised tissue on the buccal side and to re-establish the correct fornix depth. This time, a partial-thickness flap was elevated, starting from the palatal side (Fig. 9), to expose the cover screws of the implants while leaving the connective tissue around the implants. The cover screws were removed and replaced with healing abutments of the desired heights (Fig. 10). The flap was then sutured, leaving all the keratinised tissue on the vestibular side while allowing the palatal side to heal by secondary intention (Fig. 11). After complete healing of the tissue, after about eight weeks, an impression was taken and the provisional prosthesis was fabricated and delivered. After complete maturation of the tissue, after about four months, another impression was taken and a definitive prosthesis was fabricated and delivered (Figs. 12a & b).

Clinical outcome

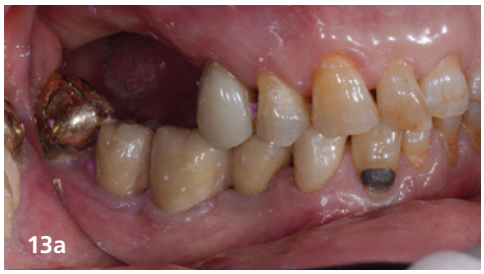
Before the final surgical step (the uncovering phase), a CBCT scan showed the exact positions of the implants and the height

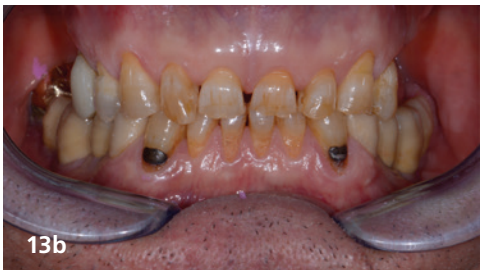
OsteoBiol GTO	First measurement	Second measurement
Post-op	22.20 mm	21.61 mm
3 months of healing	15.61 mm	15.40 mm
6 months of healing	12.88 mm	13.20 mm
At uncovering (after 10 months)	9.63 mm	9.60 mm
% shrinkage after 3 months	6.59 mm (22.20–15.61 mm; 29.7%)	6.21 mm (21.61–15.40 mm; 29.7%)
% shrinkage after 6 months	9.32 mm (22.20–12.88 mm; 42.0%)	8.41 mm (21.61–13.20 mm; 38.9%)
% shrinkage after 10 months	12.57 mm (22.20–9.63 mm; 56.6%)	12.10 mm (21.61–9.60 mm; 55.6%)

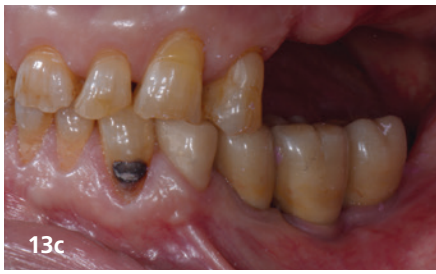
Table 1: OsteoBiol GTO: Graft volume evaluation over time.

OsteoBiol mp3	First measurement	Second measurement
Post-op	21.80 mm	25.20 mm
3 months of healing	17.60 mm	17.82 mm
6 months of healing	14.60 mm	14.82 mm
At uncovering (after 10 months)	10.81 mm	10.83 mm
% shrinkage after 3 months	4.20 mm (21.80–17.60 mm; 19.30%)	7.38 mm (25.20–17.82 mm; 29.30%)
% shrinkage after 6 months	7.20 mm (21.80–14.60 mm; 33.00%)	10.38 mm (25.20–14.82 mm; 41.20%)
% shrinkage after 10 months	10.99 mm (21.80–10.81 mm; 50.41%	14.37 mm (25.20–10.83 mm; 57.02%)

Table 2: OsteoBiol mp3: Graft volume evaluation over time.

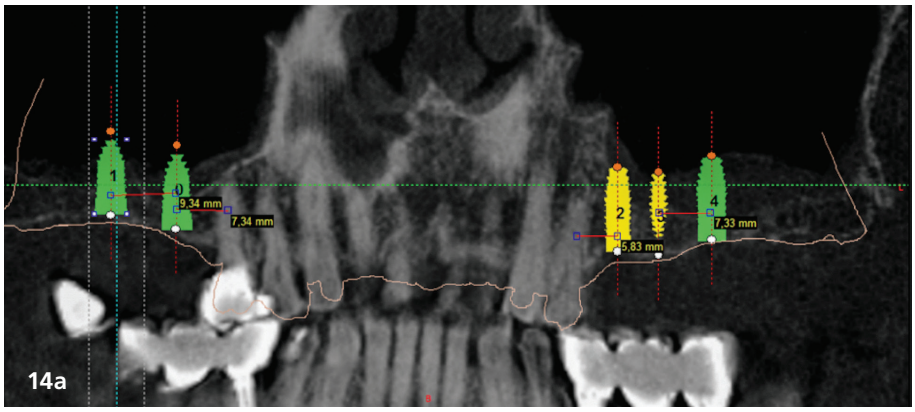


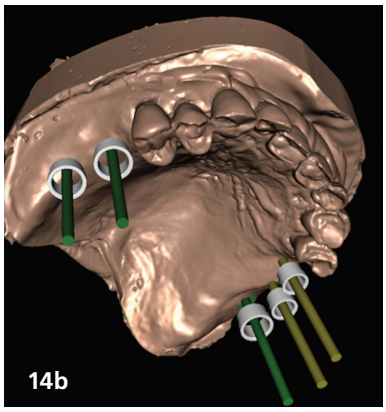


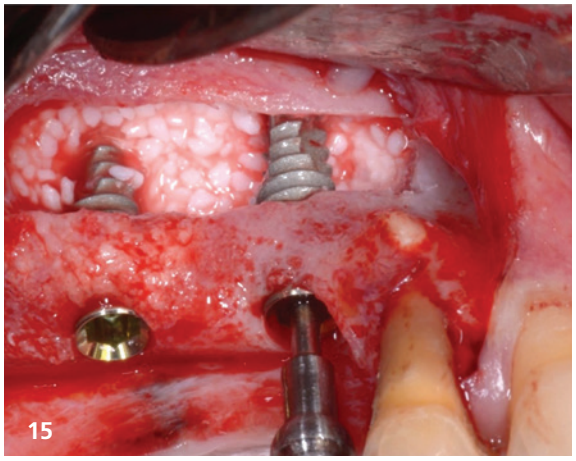


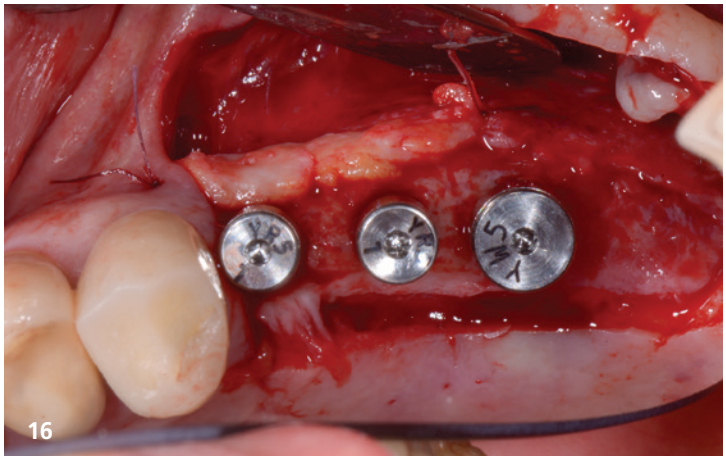
Figs. 13a–c: Pre-operative intra-oral images.

of the new sinus floor. The bone height augmentations were considered successful for implant placement under good conditions. After a healing period of four months, the CBCT scan showed that both sides had healed well. Recovery was uneventful, and there was no complaint of pain and no signs of infection. The same positive results could be deduced from the radiographic controls taken over time. All the measurements were collected in two charts, depending on the biomaterial used, to evaluate how the bone substitute used changed volume over time. The heights of the augmented sinuses decreased at a similar pace. Between the postoperative CBCT scan and the healing at three and six months, the right sinus, in which GTO was used, decreased from 22.20 mm to 15.61 mm (29.7% volumetric change) to 12.88 mm (42.0% volumetric change) and from 21.61 mm to 15.40 mm (29.7% volumetric change) to 13.20 mm (38.9% volumetric change). Similarly, the left sinus, where mp3 was used, decreased from 21.80 mm to 17.60 mm (19.3% volumetric change) to 14.60 mm (33.0% volumetric change) and from 25.20 mm to 17.82 mm (29.3% volumetric change) to 14.82 mm (41.2% volumetric change). Therefore, the augmented sites were of sufficient volume for implant placement. It is worth noting that the bone remodelling did not stop after the implants had been placed. In fact, when the last CBCT scan was taken at ten months of healing (before the uncovering phase), further resorption, to the tips of the implants, corresponding to around 55% resorption, was found (Tables 1 & 2).

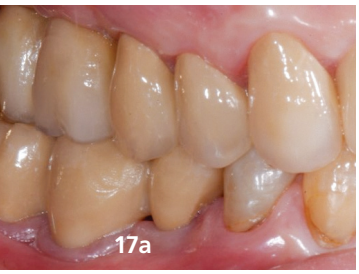


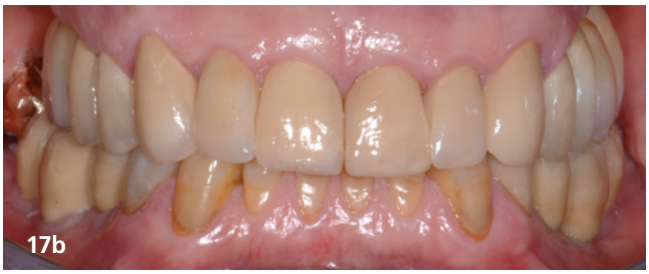


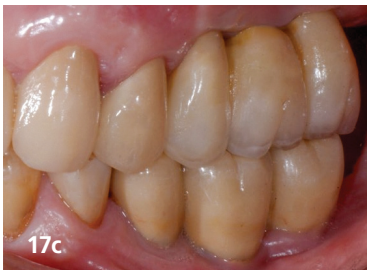




Figs. 14a & b: Digital implant planning: 2D **(a)** and 3D **(b)** view. **Fig. 15:** Insertion of the implants. **Fig. 16:** Connective graft sutured to the periosteum with healing abutments positioned.







Figs. 17a–c: Clinical and radiological follow-up at five years. *(Images © P. Zappavigna DDS)*

Nevertheless, it can be appreciated how both of the biomaterials allowed reconstruction of the crest height and how GTO allowed restoration of even the diameter of the crest. What is more, the morphology of these biomaterials resembled that of the natural bone. In fact, it was difficult to notice a difference between the bone grafts placed and the bone of the patient. However, it must be pointed out that GTO had a slightly greater resorption compared with mp3, probably due to its greater collagen gel component.

Case 2: Maxillary sinus surgery and simultaneous implant placement

This patient also presented at Lake Como Institute, having been referred by a colleague, requesting fixed rehabilitation of the edentulous areas of his posterior maxilla. A careful clinical examination was conducted (Figs. 13a–c) and a CBCT scan taken to plan proper implant surgery (Figs. 14a & b). The patient requested as few surgeries as possible and completion of the treatment in the shortest possible time. Bilateral sinus elevation with bilateral horizontal augmentation and simultaneous implant placement was the chosen treatment plan. The approach was similar to that of the first case: two flaps with two vertical incisions were elevated to expose the lateral sinus walls and then two antrostomies were opened with the help of piezo-surgery inserts. The sinus membranes were elevated, paying attention not to perforate them, and two collagen sponges were inserted into the posterior recesses to keep the membranes elevated so that the osteotomies could be made. The biomaterial (GTO) was inserted through the antrostomies and compacted. The implants were then placed, since this time there was greater residual bone height (Fig. 15), and a layer of biomaterial was used to compensate for the horizontal atrophies. To stabilise the biomaterial, a double layer of collagen membranes (Evolution) was used, a final layer of L-PRF (leukocyte- and platelet-rich fibrin) membrane was placed to enhance soft-tissue healing and the flaps were sutured. A CBCT scan was taken to evaluate the degree of vertical and horizontal augmentation, and the patient was scheduled for the last surgery four months later. During the uncovering phase, two split-thickness flaps were elevated, exposing the underlying implants, and a connective graft was collected by thinning the palatal flap. The cover screws of the implants were replaced with healing abutments, and the connective graft was placed on the vestibular side to further expand the crest diameter (Fig. 16). A final layer of L-PRF was put around the healing abutments and the flaps were sutured. The patient then returned to his dentist for finalisation of his treatment.

Clinical outcome

The implants and the soft tissue healed uneventfully, and the patient underwent just two surgeries. The implants were still stable after five years of loading (Figs. 17a–c).

Discussion

The two cases demonstrate how there might be perfect timing for placing implants after the first vertical augmentation. The idea is not to let the bone substitutes remodel too much, in order to allow easier implant placement and the use of longer implants to obtain a correct implant–prosthesis proportion. Probably, as can be seen from Tables 1 and 2, four months would be the best time to proceed with the implant placement, because the biomaterials act like natural bone: they will continue to remodel over time if not stimulated by occlusal forces. Instead, when the implants are placed simultaneously with sinus elevation, the implants create a tenting effect that serves as support to the Schneiderian membrane, arresting bone physiological resorption. That is why, when possible, often the best treatment may be placing the implants simultaneous to sinus augmentation.

Edentulous maxillary segments have several anatomical and physiological limitations, such as deficiency of spongy maxillary alveolar bone and increased pneumatisation of the maxillary sinuses. These factors render rehabilitation of the region challenging. In these two cases, maxillary sinus elevation procedures through lateral access were successfully performed using GTO or mp3. Horizontal augmentation was successfully performed using only GTO. These materials were able to increase vertical bone height and horizontal bone diameter and allowed for the placement of the requested implants. A follow-up panoramic radiograph was obtained at the delivery of the prosthesis and demonstrated what appeared to be new bone formation in the maxillary areas and the areas at the tips of the implants. It is important to emphasise the benefits of this approach for maxillary reconstruction via GBR and sinus augmentation over other treatments (e.g. autogenous block

grafting): no complications at the donor site, no need for hospitalisation and less postoperative discomfort. The current results are in agreement with those of previous studies,[21,22] as well as systematic reviews,[23,24] illustrating that implant survival rate and peri-implant bone level in the grafted bone are comparable to those of implants placed in native bone. A similar outcome has been observed for implants placed in augmented sinuses.[7]

Conclusion

Complete reconstruction of atrophied maxillae can be successfully achieved by means of GBR for horizontal and/or vertical bone gain, including bilateral sinus augmentation when GTO and mp3 are used. In fact, the morphology of these grafted sites resembles the anatomy of a natural sinus, the bone remodelling at the level of the tips of the implants, and has the same radiographic appearance as the natural lost bone of the patient. Moreover, it appears that the best time to place the implants after sinus augmentation, in a delayed approach, might be around four months, to ensure as little graft resorption as possible.Peri-implant bone level in the completely reconstructed maxilla showed minimal changes. Furthermore, proper training in hard- and soft-tissue management is imperative for achieving successful outcomes and avoiding potential complications.

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