Total Reconstruction of the Atrophic Maxilla with Intraoral Bone Grafts and Biomaterials: A Prospective Clinical Study with Cone Beam Computed Tomography Validation

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Purpose: *To perform a preliminary validation with cone beam computed tomography (CBCT) of the combined use of intraoral bone blocks and biomaterials for total reconstruction of the atrophic maxilla.* ***Materials and Methods:*** *Consecutive cases of total edentulism of the maxilla (Cawood and Howell classes IV or V) treated with bilateral sinus floor elevation, mandibular bone block grafts, and biomaterials were evaluated prospectively. Implants were placed 14 to 16 weeks after grafting. Each patient received a CBCT scan preoperatively, immediately after bone augmentation, and at reentry. A three-dimensional reconstruction of the maxilla with volumetric calculations was obtained at each stage.* ***Results:*** *Fourteen patients participated. Successful graft integration occurred in all cases, with no major complications. Mean preoperative volume was 11,312 mm³. Mean postoperative volume was 19,997 mm³ immediately after surgery and 19,042 mm³ before implant insertion. The average percentage volumetric increase between the preoperative condition and the situation at reentry was 71.99%. One hundred eight implants were inserted. Immediate loading was possible with 81 implants in 10 patients.* ***Conclusions:*** *The rehabilitation of the severely resorbed maxilla remains a formidable challenge. The results of this study suggest that the use of mandibular bone blocks in combination with biomaterials is an effective, reliable procedure for the rehabilitation of the severely resorbed maxilla. Significant volume increases and adequate stability of the augmented areas at reentry were found with CBCT analysis. The grafted bone provided sufficient mechanical support to permit provisionalization and immediate loading. This technique enabled the restoration of function and esthetics with a fixed rehabilitation at 4 months.* Int J Oral Maxillofac Implants 2013;28:241–251. doi: 10.11607/jomi.2405

The predictability of dental implants as a treatment option to replace missing teeth has been confirmed by more than 20 years of experience.[1] However, the unavoidable bone loss that takes place in the edentulous alveolar ridge over time often impedes the use of standard implant placement protocols, and calls for alternative or additional procedures.[2] In this sense, the universal tendency nowadays is to minimize patient morbidity and increase patient acceptance of the rehabilitation procedure by using graftless solutions or nonautogenous sources of graft material.

In cases of mild to moderate resorption, shorter and narrower implants[3–5] as well as angled implant placement[6–9] may be effective strategies to avoid bone grafting. Nevertheless, a deficiency in residual bone volume frequently must be addressed. Guided bone regeneration (GBR) with bone substitutes and resorbable membranes has become the standard approach to solve this problem because of its low morbidity, ease of use, and reasonable success rates.[10] For similar reasons, other techniques such as crestal split osteotomies are also widespread, well-established options.[11]

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However, the feasibility and predictability of these techniques in cases of severe resorption are questionable, especially in the case of the atrophic maxilla. Indeed, advanced resorption seldom causes major limitations in the mandible,[12] probably because of its denser bone quality and the greater stability of the basal bone over the long term resulting from numerous muscular insertions (especially in the interforaminal area). Conversely, advanced maxillary atrophy often prevents the conventional fixation and stabilization of dental implants and calls for alternative procedures. Nongrafting options can still be considered with the anchorage of implants in distant landmarks such as the zygoma,[13–17] pterygoid plates,[18] or orbital rim.[19] However, although these techniques enable early functional rehabilitation of the patient with low surgical morbidity, the surgeon must have specific training to avoid potential complications.[20,21] Moreover, the emergence profile of the implant platform implies a bulky prosthesis, with consequent problems in oral hygiene and phonetics. Alternatively, total volumetric restoration of the alveolar ridge reestablishes the initial configuration of the patient's bone and ideally permits prosthetic replacement of the missing teeth with their original shapes, sizes, and positions. This goal, together with the endeavor to minimize surgical morbidity, has led to substantial research in the field of tissue engineering.[22] Although promising results have been reported, questions regarding security, cost-effectiveness, and reliability persist.[23] Accordingly, at present, the gold standard treatment for cases of advanced atrophy is still autologous bone grafting. This is the only method that can reliably provide the required source of osteogenic cells and osteoconductive and osteoinductive architecture for the reconstruction of the lost vertical and horizontal dimensions in these demanding cases.

Good results have been reported with traditional extraoral donor sites such as the iliac crest,[24–30] tibia,[31,32] or calvarium.[33–36] However, they include time-consuming surgeries that are usually done under general anesthesia, long recovery times, and substantial donor site morbidity, including the potential for donor site infection. Moreover, iliac crest and tibial grafts have the disadvantage of higher resorption risks because of the bone's endochondral origin.[37] Conversely, intraoral harvesting sites reduce these inconveniences while providing appropriate amounts of membranous bone, which seems to be less prone to resorption than grafts of endochondral origin.[37] Bone blocks harvested from the mandibular symphysis and ascending ramus show adequate volumetric stability[38–40] and provide effective mechanical support for early implant placement and immediate loading in the majority of cases. Moreover, research has shown that block coverage with particulated low-resorption-rate bone substitutes

and resorbable barrier membranes reduces the rate of bone loss following mandibular bone block grafting.[41–43] In addition, the osteoconductive properties of particulated bone substitutes placed in the gaps between the grafted blocks, plus the cell guidance effect of membranes, contribute to the creation of a homogenous area of regenerated bone.[10]

The use of autogenous grafts from intraoral sites in combination with biomaterials represents an effective, reliable procedure for the rehabilitation of the atrophic maxilla prior to endosseous implant placement.[38,40–43] Although there are previous reports of the treatment of localized bone defects with this technique,[38,40–43] to the authors' knowledge, this has not yet been described for total maxillary reconstruction. Hence, the objective of this paper was to present a prospective evaluation of total reconstruction of the atrophic maxilla using autogenous bone blocks from intraoral sources combined with biomaterials and to validate the efficacy of the technique with cone beam computed tomography (CBCT).

MATERIAL AND METHODS

A prospective evaluation of 14 consecutive cases treated at the authors' institution for total maxillary edentulism was performed between February 2007 and December 2009. Inclusion criteria were total edentulism of the maxilla (class IV or V atrophy according to the Cawood and Howell classification[44]), maximum alveolar bone height of 6 mm and maximum width of 4 mm measured in the anterior maxilla (ie, medial to the anterior limit of the sinus), and less than 6 mm of posterior bone height (measured at the level of the sinus). These dimensions refer solely to the alveolar process of the maxilla, excluding the basal bone. Exclusion criteria included smoking, previous radiotherapy, and refusal to provide written informed consent. Institutional review board approval was obtained to perform this study. The Helsinki Declaration guidelines were followed in all treatment phases.

Diagnosis involved clinical examination and CBCT. CBCT scans were taken with the IS i-CAT (version 17-19, Imaging Sciences International). The following parameters were established: 120 kV, 5 mA, axial slice distance 0.300 mm^3, 23-cm field of view. Each CBCT was processed using the SimPlant Pro Crystal software (Materialise Dental), and an individualized volumetric analysis of the maxilla was performed as follows. Both infraorbital foramina and the posterior nasal spine were used as the key anatomical landmarks with which a plane was delineated. The volume of interest was defined below this plane until the inferior limit of the residual alveolar ridge. In this manner, the analyzed volume included not only the alveolar process of the

maxilla but also the anterior maxilla, ascending maxillary processes, tuberosities, palatine bones, posterior maxillary walls, and the inferior part of the ethmoid. To digitally excise the volume of interest, threshold limits were modified to an appropriate range that adequately captured all the bone within the region of interest in each particular CBCT scan. As in previous studies,[45] undesired structures, together with any artifacts or background scatter, were eliminated by hand from each slice. The volume of the segmented region was calculated from the "Masks list window" and a three-dimensional display of the excised area was obtained (Fig 1). This volumetric analysis allowed for residual bone evaluation and, hence, an estimation of graft volume.

Operations were performed under local anesthesia and intravenous sedation or under general anesthesia. A crestal incision was followed by a full-thickness flap to uncover the buccal aspect of the atrophic maxilla. The flap was elevated to the piriform aperture of the nose anteriorly and the infraorbital nerves posteriorly. At this stage, horizontal releasing incisions were made with a no. 15 blade to allow easy advancement of the flap and subsequent coverage of the reconstructed area. Sinus floor augmentation was performed bilaterally through a window in the anterior sinus wall. A resorbable collagen membrane (Bio-Gide, Geistlich Pharma) was positioned against the elevated membrane, and the underlying space was filled with demineralized bovine bone particles (Bio-Oss, Geistlich Pharma).

To access the mandibular ramus and body, a through-and-through incision was performed in the buccal mucosa, extending from the mandibular second premolar to the retromolar area. The same approach was followed in the contralateral side. Full periosteal elevation was accomplished on the buccal aspect and up to Spix's spine on the lingual. The size of the grafts to be harvested was determined by the preoperative CBCT measurements of the recipient sites. The limits of the donor areas were outlined with a sterile marker; subsequently, the osteotomies were performed with a piezoelectric device (Implant Center 2, Satelec-Acteon Group). Only the cortical bone was cut with the ultrasonic saw; then, a wedged chisel allowed for careful dislodgement of the graft. In 5 of the 14 cases, the neurovascular bundle was exposed during graft elevation. At this point, a layer of hemostatic collagen (Surgicel, Ethicon) was applied, and the incision was then closed with continuous 4/0 polyglactin (Vicryl, Ethicon) horizontal mattress sutures.

To optimize graft adaptation to the recipient sites, each graft was divided into two parts, so that it would settle into the curvature of the maxilla, and a layer of small-particle Bio-Oss was applied to the buccal wall. Each graft was fixed in place with one or two lag screws (Tekka). Gaps between blocks were filled with Bio-Oss, and the entire reconstruction was covered
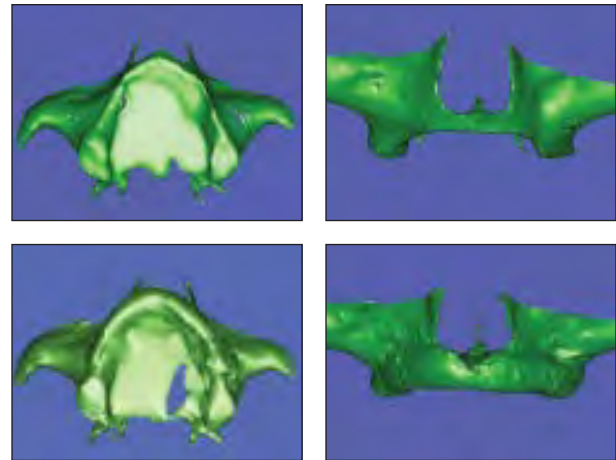

Fig 1 Three-dimensional reconstruction of the maxilla (frontal and occlusal views) and corresponding volumetric calculations. *(Above)* Preoperative analysis; *(below)* delayed postoperative analysis.

with Bio-Gide membranes. Finally, a hermetic, tension-free closure of the flap was achieved with continuous horizontal mattress 4/0 Vicryl sutures. Figures 2 and 3 summarize the complete sequence of grafting surgery.

A CBCT scan was obtained immediately postoperative. The same volumetric measurements were recorded in this scan as in the preoperative CBCT.

Patients were discharged within 2 hours of the procedure. Patients who received general anesthesia were discharged within 6 hours. Routine nonsteroidal anti-inflammatory drugs, analgesics, and prophylactic antibiotic medication were prescribed for 7 days. Patients were allowed to wear a complete vestibule-free denture after 1 postoperative week.

Between the 14th and 16th weeks after reconstruction, a new CBCT scan was obtained and measured according to the same protocol as the previous CBCT scans (Fig 1). Each patient's percentage variation in volume was calculated as follows: (delayed postoperative volume $\times$ 100/preoperative volume) – 100. This CBCT study was also used to plan implant positions with the SimPlant Pro Crystal software. Guided surgery was performed in all cases.

Implant placement was performed under local anesthesia (Fig 4). The number, size, and position (anterior/posterior maxilla) of all implants was noted, and the stability of each implant was measured via resonance frequency analysis and recorded in implant stability quotients (ISQs) (Osstell Mentor, Integration Diagnostics).[46] Each patient received 6 to 10 Osseotite (Biomet 3i) implants. It was planned that if the ISQ values were above 65 for at least four implants, an immediate loading protocol would be followed using a provisional acrylic resin prosthesis. At 1 year, all implants were loaded with definitive fixed metal-ceramic restorations.

Figs 2a to 2i *Surgical technique of bilateral sinus floor elevation, recipient site preparation, and bone block fixation.*

Fig 2a A full-thickness flap is elevated to the piriform aperture anteriorly and the infraorbital nerves posteriorly. It is important to perform periosteal releasing incisions at this stage.

Fig 2b Window approach at the anterior sinus wall for sinus floor elevation.

Fig 2c A layer of small-particle inorganic bovine bone is applied to the buccal wall.

Fig 2d The graft is adapted to the recipient site after division into two parts and fixed with lag screws.

Figs 2e and 2f The gap between bone blocks is filled with bone substitute.

Figs 2g and 2h A resorbable collagen membrane covers the augmented sites.
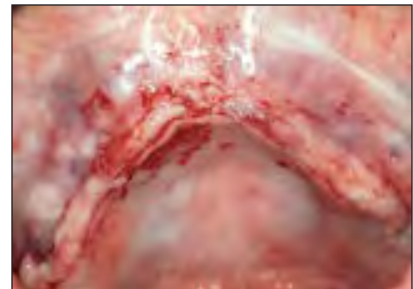

Fig 2i The wound is closed.

Fig 3 Surgical technique: Bone block harvesting. (*Left*) Sagittal osteotomy of the mandibular right ramus; (*right*) bone blocks obtained from both mandibular ramus donor sites.

Figs 4a to 4f Surgical technique: Reentry after 14 to 16 weeks for implant placement.

Fig 4a Clinical appearance at 14 to 16 weeks postoperative.

Fig 4b Surgical template fixation. In this case, a palatal screw has been used to ensure immobility of the template.
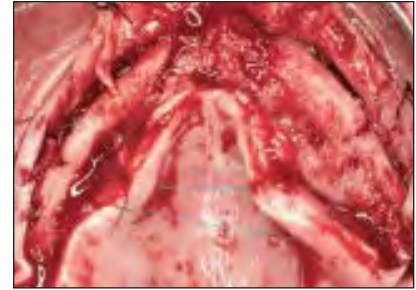
Fig 4c Reentry. In this case, flaps were elevated to allow removal of the fixation screws. Excellent bone block integration and volumetric stability are evident.

Fig 4d The fixation screws were removed because they interfered with the planned implant positions.

Fig 4e The implants were placed with guided surgery.

Fig 4f The surgical wound is closed.

Table 1	Volume Measurements of the Maxilla at the Three Studied Time Points			
Patient	Preoperative volume (mm^3)	Immediate postoperative volume (mm^3)	Delayed postoperative volume (mm^3)	Percent change (postop vs preop)
1	14,658	23,220	21,115	44.05
2	13,698	21,347	21,050	53.67
3	11,323	18,559	17,468	54.27
4	9,576	20,490	18,332	91.44
5	12,945	19,311	18,507	42.97
6	8,995	17,922	16,972	88.68
7	14,397	22,090	20,308	41.06
8	10,284	18,791	18,734	82.17
9	9,197	15,337	14,981	62.89
10	8,644	17,921	17,334	100.53
11	12,947	23,540	22,333	72.50
12	10,405	24,297	22,905	120.13
13	7,933	15,322	15,622	96.92
14	13,367	21,530	20,921	56.51
Mean	11,312	19,977	19,042	71.99

RESULTS

The studied sample comprised 10 women and 4 men with a median age at the time of surgery of 51 years (mean, 57 years; range, 46 to 68 years). The reconstructive procedure was performed under intravenous sedation and local anesthesia in 11 patients; the remaining 3 were operated under general anesthesia. Implant placement was performed under local anesthesia in all cases.

All grafts integrated successfully. Table 1 displays the preoperative, immediate postoperative, and delayed postoperative volume measurements for each

Table 2   Implant Data for Treated Patients

Patient	No. of implants	Location	Implant size (mm)	ISQ	Immediate loading?	Patient	No. of implants	Location	Implant size (mm)	ISQ	Immediate loading?
1	6	A	4 × 15	80	Yes	8	8	A	4 × 13	79	Yes
		A	4 × 13	79	Yes			A	4 × 15	79	Yes
		A	4 × 15	81	Yes			A	4 × 15	80	Yes
		A	4 × 13	75	Yes			A	4 × 13	81	Yes
		P	5 × 10	64	No			P	5 × 10	65	No
		P	5 × 10	68	No			P	4 × 13	74	No
2	10	A	4 × 13	79	Yes			P	5 × 10	66	No
		A	4 × 15	80	Yes			P	4 × 13	64	No
		A	4 × 15	81	Yes	9	8	A	4 × 13	80	Yes
		A	4 × 15	80	Yes			A	4 × 15	77	Yes
		A	4 × 15	63	No			A	4 × 13	74	Yes
		A	4 × 15	69	Yes			A	4 × 15	76	Yes
		P	4 × 13	77	No			P	5 × 10	77	Yes
		P	4 × 13	78	No			P	5 × 10	68	Yes
		P	5 × 10	60	No			P	4 × 13	60	No
		P	4 × 13	65	No			P	4 × 13	67	No
3	6	A	4 × 15	78	Yes	10	10	A	4 × 13	81	Yes
		A	4 × 13	81	Yes			A	4 × 13	79	Yes
		A	4 × 15	80	Yes			A	4 × 13	79	Yes
		A	4 × 15	77	Yes			A	4 × 13	81	Yes
		P	4 × 13	66	No			A	4 × 13	74	Yes
		P	5 × 10	61	No			A	4 × 13	70	Yes
4	8	A	4 × 15	80	Yes			P	5 × 10	68	No
		A	4 × 13	80	Yes			P	4 × 13	70	No
		A	4 × 15	81	Yes			P	4 × 13	64	No
		A	4 × 15	79	Yes			P	5 × 10	75	No
		P	4 × 15	65	No	11	8	A	4 × 13	75	No
		P	4 × 13	60	No			A	4 × 15	70	No
		P	4 × 13	70	No			A	4 × 13	53	No
		P	5 × 10	63	No			A	4 × 13	64	No
5	8	A	4 × 15	81	Yes			P	4 × 13	63	No
		A	4 × 15	79	Yes			P	4 × 13	69	No
		A	4 × 15	80	Yes			P	4 × 13	60	No
		A	4 × 15	78	Yes			P	5 × 10	64	No
		A	4 × 13	79	Yes	12	8	A	4 × 13	67	No
		A	4 × 13	79	No			A	4 × 13	80	No
		P	4 × 13	65	No			A	4 × 15	60	No
		P	4 × 13	68	No			A	4 × 13	64	No
6	8	A	4 × 15	78	Yes			P	4 × 13	68	No
		A	4 × 15	80	Yes			P	4 × 13	63	No
		A	4 × 15	81	Yes			P	4 × 13	63	No
		A	4 × 13	79	Yes			P	4 × 13	64	No
		P	4 × 13	68	No	13	6	A	4 × 15	70	No
		P	4 × 13	65	No			A	4 × 13	79	No
		P	5 × 10	60	No			A	4 × 13	76	No
		P	5 × 10	53	No			A	4 × 13	F	No
7	8	A	4 × 15	79	Yes			P	4 × 13	58	No
		A	4 × 13	80	Yes			P	4 × 13	63	No
		A	4 × 15	81	Yes	14	6	A	4 × 15	77	No
		A	4 × 15	80	Yes			A	4 × 13	80	No
		P	4 × 13	70	No			A	4 × 13	79	No
		P	4 × 13	66	No			A	5 × 10	60	No
		P	4 × 13	54	No			P	4 × 13	64	No
		P	5 × 10	69	No			P	4 × 13	62	No

A = anterior; P = posterior; F = failed.

patient. The percentage variation in volume between the preoperative and delayed postoperative measurements is also presented. Mean preoperative volume was 11,312 mm^3 (range, 7,933 to 14,658 mm^3). Mean postoperative volume was 19,997 mm^3 (range, 15,322 to 24,297 mm^3) immediately after surgery and 19,042 mm^3 (range, 14,981 to 22,905 mm^3) before implant insertion. The mean percentage variation between the initial volume and the delayed postoperative volume—that is, the average bone volume gain at 14 to 16 weeks after augmentation—was 71.99%.

In all, 108 implants were inserted. Fixation screws did not interfere with the anticipated position of the implants in eight cases, so implants were placed transmucosally. In the remaining six cases, limited flaps were elevated to allow for removal of the fixation screws and subsequent placement of the implants in the planned positions.

Table 2 details the total number of implants per patient, implant positions and sizes, ISQs, and loading protocols. Four patients received 6 implants each, eight patients received 8 implants, and two patients received 10 implants. Sixty-two implants were positioned in the anterior maxilla (bone block area); the remaining 46 were placed in the posterior maxilla (sinus elevation area). Sixty implants were 4 × 13 mm, 32 were 4 × 15 mm, and 16 were 5 × 10 mm. Mean ISQ at implant insertion was 72 (range, 53 to 81). The ISQs of 81 implants were above 65 in 10 patients, which permitted an immediate loading protocol with fixed provisional acrylic resin prostheses. In the remaining four patients, loading was delayed for 8 to 12 weeks after insertion. In one patient, one implant in the posterior maxilla was lost before loading.

No major complications occurred. However, transient hypoesthesia of the lower lip occurred in three sites in two patients (10.7% of all donor sites) in whom the neurovascular bundle had been exposed during graft harvesting. The condition resolved completely in all cases within 4 weeks.

To date, the patients have been followed for an average of 22.5 months. New CBCT studies are limited by ethical concerns, but clinical follow-up has shown excellent stability of the reconstructions and no further implant failures.

DISCUSSION

The rehabilitation of the atrophic maxilla remains a formidable challenge. Any comparison of the success rates of different reconstructive options must take into account the clinical situation at baseline,[38,47] since the degree of physiologic resorption of the edentulous maxilla varies greatly among patients.[48] A standardiza-

tion of treatment modalities according to the baseline situation is necessary to allow analysis of the outcomes of each particular procedure.[38] Furthermore, treatment outcomes should be monitored systematically over time, ideally with volume-rendering tools. In this prospective study, a specific clinical situation was treated with one particular approach: advanced maxillary atrophy (Cawood and Howell classes IV and V[44]) was treated with two-stage surgery consisting of reconstruction with autogenous grafts of intraoral origin and biomaterials and later implant placement. Although the use of this approach has been previously reported for the reconstruction of localized defects,[38,40–43] to the authors' knowledge this is the first description of total maxillary rehabilitation with this technique. Moreover, treatment outcomes were evaluated with volume-rendering software tools for CBCT, thereby permitting a standardized three-dimensional analysis of the results, rather than classical linear assessment.

When a clinician is confronted with a case of severe maxillary resorption, the following issues arise: *(1)* the patient's expectations regarding the desired type of prosthetic rehabilitation (fixed vs removable), time limitations, and surgical acceptability; *(2)* predictability of the technique; and *(3)* potential morbidity of the procedure. When the patient demands a fixed restoration that mimics the original configuration of the missing teeth, plus restoration of the alveolar bone volume and hence the restitution of lip and cheek support, the clinician must decide between grafting and nongrafting options. The latter imply the anchorage of implants in the residual bone or in distant regions to provide support for a prosthesis that replaces not only the teeth but also the missing hard and soft tissues. These nongrafting solutions are a fast, predictable option in patients who decline more invasive surgical procedures.[49] However, since the maxilla tends to resorb in a centripetal direction, buccal bone deficiency is practically universal; consequently, prosthetic rehabilitation entails a buccal cantilever, with implants emerging palatally. These circumstances are potential risk factors for prosthetic failure and hinder the ability to maintain good hygiene, thereby increasing the chance of marginal bone loss.

On the other hand, grafting solutions provide a less prosthetically demanding scenario because the alveolar anatomy is restored. Hence, implants may be placed in a prosthetically guided manner, which entails conventional prosthodontic techniques. The prosthesis is less prone to mechanical complications because forces are transmitted axially to the implants. Similarly, the prosthetic design favors hygiene, and hence reduces the rate of biologic complications as well.

Currently, the two most dependable grafting options for simultaneous horizontal and vertical restoration of the severely resorbed maxilla are GBR and autologous

bone block grafting.[50] The biologic rationale for GBR involves the mechanical exclusion of undesirable soft tissues from the osseous defect by the placement of a cell-occlusive membrane; in this manner, a secluded space is created to provide an environment that encourages the recruitment and proliferation of osteogenic cells.[51,52] Although the introduction of resorbable membranes has eliminated the need for a second surgery for membrane removal, thereby improving cost-effectiveness and simplifying surgical protocols,[10] the predictability of vertical bone regeneration remains uncertain. Because their barrier function cannot be controlled over time and their nonrigid nature may not adequately maintain space, resorbable membranes are considered unsuitable for the three-dimensional regeneration of large volumes.[10,53] Alternatively, titanium-reinforced expanded polytetrafluoroethylene membranes in combination with particulated autogenous bone and bone substitutes have demonstrated successful vertical and horizontal augmentation of large defects.[54–56] Moreover, some authors have considered simultaneous implant placement.[54,56,57] However, the high incidence of membrane exposure is a crucial limiting factor for this technique, since wound dehiscence and subsequent infection lead to inevitable failure of the bone regeneration procedure.[58] The technical sensitivity and risk of infection of this approach limit the widespread use of these membranes for the rehabilitation of large defects.

On the other hand, autogenous bone blocks currently offer a more predictable treatment option.[59] Although variable rates of resorption have been reported, bone integration is usually accomplished if adequate graft immobilization is achieved, thereby permitting implant fixation in most cases. However, traditionally, donor site morbidity has been considered a major drawback. Compared to extraoral harvesting sites, intraoral donor sites reduce patient morbidity and the need for general anesthesia while providing good-quality bone of membranous origin in sufficient quantity for implant placement. Moreover, adequate volumetric stability has been demonstrated.[38–40] This is particularly true for the ascending ramus. Indeed, all the patients in this study showed successful graft integration, with an excellent immediate volumetric increase (mean absolute volume: 19,997 mm^3) that remained adequately stable after 4 months (mean absolute volume: 19,042 mm^3). This time point was chosen on the basis that a CBCT control scan was desirable for precise implant planning. Moreover, previous studies have considered it relevant to evaluate the stability of reconstructed areas at this stage.[38]

Nevertheless, this does not mean that further remodeling of the grafted area after this time point is impossible. Bone remodeling is expected to be higher during the first year after reconstruction and to slow significantly in subsequent years.[50,60] However, several variables, such as the type and site of reconstruction, the nature of the donor bone, the use of a removable provisional restoration over reconstructed sites, or the timing of implant loading, may influence the final outcome greatly.[50] In fact, it is widely acknowledged that implants inhibit resorption of both residual and transplanted bone.[61–66] Therefore, even though additional remodeling can be anticipated, the authors believe that implants will aid in stabilizing the graft volume. An ongoing study will provide long-term verification of this hypothesis.

The fact that CBCT volumetric evaluation of both the donor and recipient sites was performed pre- and postoperatively in the present study provides a new parameter for treatment evaluation beyond clinical outcome. Since its development in the 1990s, CBCT has become a well-accepted tool for oral and maxillofacial diagnosis and treatment planning, mainly because of its advantages in lower effective radiation dose, lower costs, easy access, and shorter acquisition times in comparison to conventional multidetector CT.[67] Clinicians should exploit the possibilities provided by current third-party software packages. In particular, the accuracy and reliability of CBCT for the three-dimensional analysis of the upper airway is already widely acknowledged.[45,68–70] Regarding hard tissue analysis, the assessment of bony anatomy has proven to be comparable to that of multidetector CT.[71] Consequently, implant position planning, volumetric display, quantification of the donor and recipient sites, and stability analysis of the augmented hard tissue can now be performed in an unprecedented way. According to the results of this study, the preoperative volume of the maxilla (mean 11,312 mm^3) nearly doubled after surgery (mean 19,997 mm^3) and was maintained at reentry (mean 19,042 mm^3), with an average percentage increase of 71.99% at reentry.

Several authors believe that the addition of barrier membranes and or particulated bone substitutes over grafted mandibular bone blocks minimizes onlay graft resorption during healing.[41–43] The patients in this study received a collagen membrane directly over the bone blocks; anorganic bovine bone was used to fill the gaps between adjacent blocks and between the blocks and the recipient bone bed to create an osteoconductive matrix for the bone grafts and to optimize graft adaptation to the underlying recipient site. Although control CBCT scans at reentry showed excellent maintenance of the augmented volume and clinical follow-up corroborated the stability of the reconstruction and implants, ongoing analyses will elucidate the long-term outcome of this technique.

It must be pointed out that not only the quantity but also the quality of the regeneration achieved with

mandibular ramus grafts plus biomaterials provided sufficient mechanical support to permit immediate loading of many implants. In this study, immediate loading was possible in 71% of the cases. This implied the restoration of function and esthetics with a fixed rehabilitation after no more than 4 months; this is a substantially shorter treatment time than with GBR and simultaneous implant placement (6 to 9 months).[72]

Another aspect of treatment that is critical for patient comfort is provisionalization during graft healing. There is widespread concern about the effect of this removable provisional prosthesis on the outcome of the augmentation. Indeed, it seems logical to think that the space-maintaining capacity of membranes, although reinforced with titanium, is very unlikely to persist under the action of compressive forces caused by a mucosa-supported provisional prosthesis. The patients in this study were allowed to wear a full vestibule-free denture after 1 postoperative week, and CBCT scans at 14 to 16 weeks showed only mild resorption.

The rate of complications in the studied sample was relatively low. Only one implant was lost before loading in one patient. Postoperative pain and swelling were managed successfully with routine anti-inflammatory and analgesic drugs. No infectious complications occurred at the donor or recipient sites. Transient hypoesthesia of the lower lip was diagnosed in two patients (10.7% of all donor sites) where the inferior alveolar nerve had been exposed during bone block harvesting, but it resolved without sequelae after 4 weeks. Indeed, compared to the symphyseal region, the ascending ramus donor site causes minor postoperative sensory disturbances and discomfort, and patient concern regarding altered facial contour is minimized.[39] Some authors have reported that the combined use of mandibular bone block grafts with bone substitutes and collagen membranes is associated with an increased frequency of complications related to soft tissue dehiscences.[41–43] The present findings do not support these assertions.

CONCLUSIONS

The use of autogenous grafts of intraoral origin in combination with biomaterials represented an effective, reliable procedure for the rehabilitation of the atrophic maxilla (Cawood and Howell classes IV and V). Cone beam computed tomographic analysis confirmed substantial volumetric gain and adequate stability at reentry. The quality of the augmented bone enabled provisionalization during graft healing and immediate loading in the majority of cases.

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