Retrospective Observational Study

USE OF TI-MESH FOR GUIDED BONE REGENERATION IN VERTICAL AUGMENTATIONS WITH AUTOLOGOUS BONE. A RETROSPECTIVE OBSERVATIONAL STUDY OF LONG-TERM REMODELING WITH 5-YEAR FOLLOW-UP

F. Carini[1], M. Cancelleri[2], M. Giordano[3,4], F. Carini[3,4] and G. Porcaro[3,4]

[1]Private practitioner, Monza, Italy;
[2]Private practitioner, Monza, Italy;
[3]Department of Medicine and Surgery, University of Milano-Bicocca, Monza, Italy;
[4]Fondazione IRCCS San Gerardo dei Tintori, Monza, Italy

**Correspondence to:*
Gianluca Porcaro, DDS
Department of Medicine and Surgery,
University of Milano-Bicocca,
20100 Monza, Italy
e-mail: gianluca.porcaro@unimib.it

ABSTRACT

Numerous materials and techniques are used for guided bone regeneration in edentulous patients. Autologous bone with Ti-mesh titanium grids offers excellent osteoconductive, osteoinductive, and osteogenic properties, reducing post-operative healing times and costs compared to heterologous materials. This retrospective observational study aims to evaluate, at a 5-year follow-up, the remodeling of atrophic ridges regenerated vertically using Ti-mesh and autologous bone. Following vertical bone regeneration with autologous material and Ti-mesh, 35 implants were placed in 18 healthy, non-smoking patients (7 women and 11 men) with an average age of 53 years, who presented a Cawood and Howell grade V or VI mandibular/maxillary atrophy. Six maxillary and 12 mandibular segments were rehabilitated. All patients entered a professional oral hygiene control program scheduled every 6 months for the duration of the entire follow-up. The study involved measuring the bone increase in the vertical direction via intraoral radiographs performed with the long cone technique or using CBCT data. Each patient underwent level I or II radiographic investigations at T0 (surgical rehabilitation), T1 (prosthetic rehabilitation) and T2 (5 years after rehabilitation). The bone defects on the mesial and distal sides of the implants were measured in mm at T0, T1 and T2. The GBR Ti-Mesh technique in association with autologous bone in particulate form allowed a gain in bone height on average equal to 5.6 ± 0.65 mm at the time of removal of the titanium mesh and an average resorption after 5 years of 1.06 ± 0.45 mm. This corresponds to an average resorption after 5 years of 19% of the autogenous bone grafted at T0. Osseointegration was achieved in all 35 implants at the time of abutment connection. After a minimum of 5 years of functional loading, all 35 implants included in this study caused no pain, sensitivity or mobility and maintained stable osseointegration. Therefore, the cumulative survival and success rates of the implants at the end of the follow-up period were 100% and 88.6% respectively as 4 out of 35 implants (11.4%) presented a greater bone resorption. The GBR Ti-Mesh technique allowed the regeneration of large vertical bone defects in patients with severe bone atrophy. It guaranteed predictability and reproducibility of results for all 35 implant sites. The use of autologous bone yielded results comparable to implants in defects regenerated with heterologous bone. Autologous bone is presented as a material of choice for its osteoinductive, osteoconductive, and osteogenetic properties, as well as its low cost and predictability. The use of autologous bone in the vertical GBR technique with Ti-mesh resulted

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in vertical bone resorption comparable to implants in regenerated bone with heterologous biomaterial, reduced post-operative healing times, lower costs, and bone remodeling indistinguishable from native bone. Autologous bone has proven to be a valid alternative to heterologous bone. Further studies could expand the sample size and data available.

KEYWORDS: *guided bone regeneration, vertical augmentation, autologous bone, Ti-mesh, biomaterials*

INTRODUCTION

The correct diagnosis of the degree of bone atrophy is the basis of an adequate treatment plan aimed at restoring correct volumes and specific implant-prosthetic rehabilitations for each individual patient (1-3). Bone atrophy is connected to factors that have different origins, divided into two broad categories: factors of genetic and epigenetic origin and environmental factors. The former include genetic alterations that affect the development of the entire dento-alveolar complex in the different phases of growth. The latter include total or partial loss of dental elements due to trauma, fractures, periodontitis, endo-periodontal lesions, cystic lesions or radiotherapy of the head and neck area. The lack of traction and pressure forces exerted by the dental elements during chewing leads to a complete involution first of the alveolar process and then of the mandibular and maxillary basal bone. To quantitatively evaluate the loss of alveolar bone, the Cawood and Howell (4) classification, developed in 1988, is still used today, in which 6 resorption classes are divided. Through guided bone regeneration and prosthetically guided implantology, all regenerative/reconstructive procedures of hard and soft tissues are previously programmed in size and in positioning the implants in an ideal position, both from an aesthetic and functional point of view (5).

Guided bone regeneration currently allows the effective correction of horizontal, vertical and combined defects, even if they are generally limited in size (6). There are currently numerous techniques and various graft materials that allow a predictable long-term regeneration/reconstruction of the deficient alveolar process to be achieved, in order to optimize the insertion of implants in a prosthetically guided manner and greatly improve the final result (7). The techniques are divided into the following groups: guided bone regeneration, apposition or interposition bone grafts (8-10), elevation of the floor of the maxillary sinus (11), osteogenetic distraction (12), expansion of the alveolar ridges (13), transposition of the inferior alveolar nerve (14) and revascularized bone transplants (15). Focusing on the first technique, there are numerous bone filling materials used for regeneration. They can be obtained from the patient himself as autogenous bone grafts or autografts, from an individual of the same species (frozen, lyophilized or lyophilized and demineralized allogeneic bone), from animals such as bovine (16) or equine (17) (xenografts), from bone-like minerals derived from corals (18) or calcified algae without the organic component or can be synthetic products such as calcium phosphates, bioactive glass (19) or polymers. In this study we focus on the use of autologous bone graft, today considered the gold standard of regeneration as it possesses all the characteristics of a good biomaterial such as biocompatibility, osteoconductive, osteoinductive or osteogenetic properties. Its harvest, however, always requires a second intra-or extra-oral surgical site which exposes the patient to increased surgical risk and morbidity. The availability of autogenous bone is often limited and partial resorption of the graft is observed. The principle underlying this family of reconstructive techniques is that semi-permeable barriers placed above a defect, such as reabsorbable membranes of collagen (20) or pericardium of animal origin (21), reabsorbable membranes obtained by synthesis, for example those of polylactic-polyglycolic acid or non-absorbable membranes such as those in e-PTFE (22) or titanium grids, separate the surrounding soft tissues for a variable period of time from the area in which the regeneration of the missing bone tissue must take place, carrying out an excellent containment and stabilization action on the clot and the underlying bone particulate.

Among non-absorbable membranes, titanium grids customized with CAD-CAM techniques have recently been introduced on the market, obtained by synthesis starting from three-dimensional resin models obtained from DICOM files of a bone defect. These new titanium grids, known on the market as Ti-Mesh (23-30), are characterized by extreme precision and easy adaptability to the bone defect (23). This simplifies the regenerative procedure and significantly reduces operating times. Ti-meshes not only allow for a better blood supply but even if exposed, they often resist infection (24). The advantages of Ti-mesh material include that it creates a rigid structure to provide a safe space for new bone to form and that it creates a better tent effect than resorbable membranes (25). It has a porous structure to allow for better blood supply and prevents bone resorption during healing. However, shaping the Ti-mesh material to fit the bone defect and fixing it precisely and stably is not always easy (26). Furthermore, the need to surgically intervene a second time to remove the grid represents a limit to the routine use of this device (27). The use of Ti-mesh is most commonly combined with various types of bone grafts (28). According to one study, coupled with autogenous block grafting, Ti-mesh achieved an average vertical gain of 4.8mm (25). A combination of inorganic bovine bone mineral and autogenous bone graft resulted in an average increase of 2.86 mm in vertical ridge height (31). In another study where inorganic bovine bone

mineral and autogenous bone were mixed in a ratio of 30:70, the mean vertical gain was 3.71 mm (16). Bovine bone was also used as the sole graft material supported by a configured Ti-mesh, resulting in mean vertical bone gain (VBG) of 5.2 mm after 9 months (32). Allograft use, however, has been reported less frequently combined with Ti-Mesh.

The aim of this observational retrospective study is to evaluate, through the use of intraoral radiographs and/or cone-beam CT, the long-term bone remodeling of atrophic ridges regenerated vertically using Ti-mesh and autologous bone alone.

MATERIALS AND METHODS

Patient selection

Between 2015 and 2018, 18 partially edentulous patients (7 women and 11 men) with an average age of 53 years (range, 35 to 71 years) were selected for our study (Table I). The patients came at our attention for implant-prosthetic rehabilitation. The study included individuals over 18 years of age who presented grade V or VI segments of mandibular/maxillary atrophy according to the Cadwood and Howell classification with an insufficient amount of residual bone to position single or multiple implants in the correct prosthetic position in the anterior or posterior area. A total of 6 maxillary segments and 12 mandibular segments were rehabilitated. Those who agreed to enter a 5-year postoperative follow-up program were also included. Each patient signed the consent form for the operation after being correctly informed about the execution and the possible risks and complications. However, individuals with the following adverse conditions were excluded: local infections, smokers of more than 10 cigarettes a day, carriers of systemic diseases such as uncompensated diabetes (glycated hemoglobin levels >7 mg/%), patients with osteoporosis, being treated with drugs that interfere with bone metabolism, undergoing anti-tumor chemotherapy treatment, with a history of head and neck radiotherapy, with liver, blood or kidney disease, immunosuppressive conditions, current use of corticosteroids, current pregnancy, inflammatory or -immune.

Patients who were poorly motivated for correct oral hygiene were also excluded. Following a careful anamnestic investigation and a clinical examination for treatment planning, each patient received a prophylaxis session with ultrasonic scalers (P5 Booster, Acteon, De Gotzen S.r.l., Olgiate Olona,Varese, Italy) and instructions for correct oral hygiene at home. If necessary, scaling and root planing sessions were carried out. Before starting the surgical procedure, all patients demonstrated adequate plaque control (full-mouth plaque index <25%). First and second level radiographic investigations were carried out for each patient, including periapical radiographs, orthopantomographies, and computed tomography (CT).

Table I. *Collection of amnestic data from treated patients.*

Patient	Genre	Age in years	Implants	Surgery site	Complications
1	F	54	2	Jaw	None
2	M	37	2	Jaw	None
3	M	62	2	Maxilla	None
4	F	45	2	Jaw	Post pain
5	M	39	2	Jaw	None
6	F	43	2	Jaw	None
7	F	52	2	Jaw	None
8	M	65	2	Jaw	Swelling
9	M	71	2	Jaw	Post pain
10	F	48	2	Jaw	None
11	M	55	2	Jaw	None
12	M	57	3	Maxilla	None
13	M	64	3	Maxilla	None
14	F	68	3	Maxilla	None
15	M	41	1	Maxilla	None
16	F	59	1	Maxilla	None
17	M	66	1	Jaw	None
18	M	35	2	Jaw	None

Surgical procedures

All patients were pre-medicated with 3 g of amoxicillin 1h before surgery. In the case of penicillin allergy, 600 mg of clindamycin was prescribed 1h before. All procedures were performed by an experienced clinician. Before surgery, patients were asked to rinse with 0.20% chlorhexidine for 2 minutes. After local anesthesia, a crestal incision and an intrasulcular buccal incision were made on the adjacent teeth, including divergent buccal incisions using a #15c surgical

blade. Full thickness mucoperiosteal flaps were raised to expose the structure and the underlying bony defect. The remaining fibrous tissue was removed from the recipient site and corticalization of the medullary space was performed using small round surgical drills to improve the vascularization of the recipient bed. In all cases, bone particulate was collected from the mandibular ramus using a bone bur. At the same time, the dental implants were positioned according to the standard protocol of the implant system for a total of 35 implants in 18 patients. After preparation of the implant osteotomy sites, the implants were screwed into place at low speed (10 rpm) using a contra-angle handpiece. All implants showed good primary stability after insertion with a torque of 35 Ncm.

For each segment to be rehabilitated, a Ti-mesh was cut and fixed in place with three or more titanium micro-screws in the buccal and lingual/palatal portion of the native bone to maintain and protect the graft. Subsequently, it was covered by making periosteal release incisions to extend the flap as coronally as possible to the metal mesh. Horizontal mattress sutures were used to achieve tension-free soft tissue closure.

The postoperative regimen included amoxicillin plus clavulanic acid, 1 g every 12 hours for 6 days, ibuprofen 600 mg every 8 hours for 7 days, and 0.2% chlorhexidine mouthwash rinses every 12 hours for 1 week. Patients were asked to avoid brushing the surgical site and to avoid smoking for a few days after surgery. The sutures were removed after 15 days. The patients were called for a check-up after 1 month and for the oral hygiene session 3 months after implant insertion.

In all cases, between 3 and 5 months after implant insertion, the Ti-mesh was removed with a second surgical operation and the implants were rehabilitated. Nineteen fixed partial prostheses were inserted. The definitive screw-retained prostheses were made of titanium and ceramic or composite resin. All patients were provided with careful oral hygiene instructions at the time of denture placement and were enrolled in a maintenance care program every 6 months during the 5-year monitoring period.

Radiographic analysis of bone augmentation

All patients underwent intraoral radiographs and cone-beam CT at baseline (T0), removal of the titanium Ti-mesh and prosthesis after 4 months (T1) and after a 5 years of follow-up (T2). To verify the vertical bone augmentation and, therefore, the size of the residual bone defect at restoration and follow-up, measurements were performed on periapical radiographs using the DbSwin dental imaging software from Dürr Dental (Muggiò, MB, Italy). For each implant, the vertical bone defect on both the mesial and distal sides was calculated at T0, T1, and T2 in terms of mm, starting from the most coronal point of the bone defect up to the most coronal point of the implant neck. Below are the radiological (Fig.1a-d) and clinical (Fig.2a-c) images of a case.

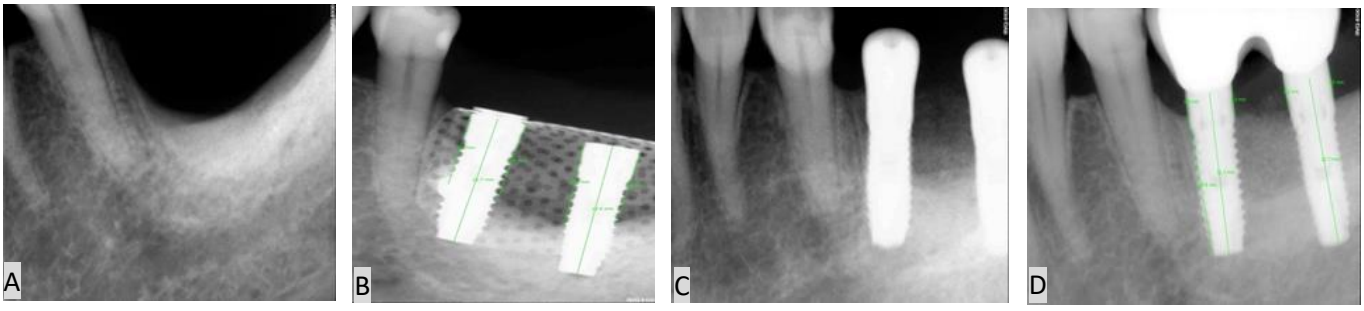

Fig. 1. A): *Initial bone defect;* ***B****): X-ray post vertical bone augmentation with autologous material, implant insertion and positioning of the Ti-Mesh secured with pins (****T0****);* ***C****): X-ray 4 months after removal of the Ti-Mesh and insertion of abutment onto the implants (****T1****);* ***D****): X-ray at a minimum follow-up of 5 years after prosthesis and implant loading (****T2****).*

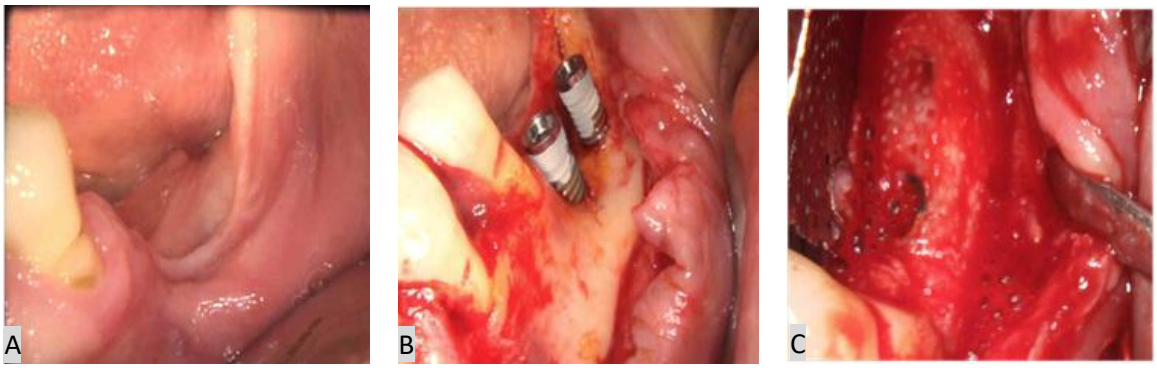

Fig. 2. ***A)****: Initial bone defect;* ***B)****: Vertical bone augmentation with autologous material, implant insertion, and positioning of the pin-locked Ti-Mesh (****T0****);* ***C)****: Four months after removal of the Ti-Mesh and abutment of the implants (****T1****).*

Peri-implant clinical parameters

For a period of 5 years, all patients were recalled for professional hygiene sessions and evaluated according to a standard protocol every 6 months from the moment of implant insertion. The health and stability of the soft tissues around the implants were assessed using the modified plaque index (MPI) (33) and modified bleeding index (MBI) (34) recorded at the mesial, distal, buccal, and lingual/palatal aspects of each implant. At the same time, the peri-implant probing depth (PD) was recorded at the nearest millimeter using a calibrated mechanical probe with a constant probing force. An MPI, MBI, and PD value was calculated for each implant based on the average of the four values obtained. All clinical measurements were performed by a single investigator.

Implant survival and success rates

The success criteria for this study were chosen based on Alberktsson et al. (1) and included the following: the absence of persistent subjective complaints, such as pain, foreign body sensation, and/or dysesthesia; absence of peri-implant infection with suppuration; lack of mobility; absence of continuous radiolucency around the implant and mean bone resorption (MBR) <1.5 mm in the first year of operation and <0.2 mm per year in subsequent years. Implants that had all of the above criteria, but showed MBR above established parameters, were considered survivors.

Statistical analysis

The measurements were collected at T0, T1 (i.e., at the restoration of the implants), and T2 (i.e., at a minimum follow-up of 5 years). The values were obtained using the DbSwin dental imaging software from Dürr Dental and were entered into the tables in the results. Subsequently, it was possible to calculate the average value of resorption and, therefore, the remaining bone defect on the mesial and distal sides of each implant.

RESULTS

All 18 patients completed the study and demonstrated satisfactory function of the implant-supported prosthesis at the minimum 5-year examination. The clinical results of the study are summarized in Table II.

At all but 3 augmented sites, postoperative healing was uneventful and complication-free. In 2 out of 18 patients (11%) medium-level post-operative pain occurred and was kept under control by a higher dose of ibuprofen compared to other patients who did not need to take painkillers. One patient out of 18 (5%) showed post-operative swelling that resolved spontaneously in 3-4 days.

Radiographic results of bone augmentation and resorption

Upon removal of the titanium mesh, which took place in a time varying from 3 to 5 months (T1), the use of autologous bone in the form of particulate with the GBR Ti-Mesh technique led to an average percentage of bone resorption equal to zero. The GBR Ti-Mesh technique in association with autologous bone in particulate form, allowed an average bone height gain of 5.6 ± 0.65 mm upon removal of the titanium mesh and an average resorption after 5 years of 1.06 ± 0.45 mm. This corresponds to an average resorption after 5 years of 19% of the autogenous bone grafted at T0. The results of the individual measurements are presented in the tables below (Table II-IV).

Table II. *Measurements of the distance from the apex of the fixture to the most coronal point of the regeneration, of the mesial bone defect M, and of the distal bone defect D to the implant in mm upon insertion (T0).*

T0 - FIXTURE POSITIONING										
PATIENT INFORMATION		FIXTURE N°1			FIXTURE N°2			FIXTURE N°3		
	TYPE OF RX	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT
PATIENT 1	PERIAPICAL X-RAY	12.7	7.2	7.8	13	8.2	7.2	*	*	*
PATIENT 2	PERIAPICAL X-RAY	10.4	1.6	3.9	10.5	4.7	6.2	*	*	*
PATIENT 3	PERIAPICAL X-RAY	14.5	5.1	6.1	14.8	5.7	4.2	*	*	*
PATIENT 4	PERIAPICAL X-RAY	6	3.5	3.3	6.3	3.5	3.2	*	*	*
PATIENT 5	PERIAPICAL X-RAY	13	2.1	7.7	15	10.4	8.7	*	*	*
PATIENT 6	PERIAPICAL X-RAY	11	3.5	6.1	12	6.4	0	*	*	*
PATIENT 7	PERIAPICAL X-RAY	14.6	4.2	6.6	14	5.5	-1.2	*	*	*
PATIENT 8	PERIAPICAL X-RAY	8.1	2.9	1.9	9.3	2.1	0.7	*	*	*
PATIENT 9	PERIAPICAL X-RAY	8.4	3.5	4.2	9.6	5.3	3.7	*	*	*
PATIENT 10	PERIAPICAL X-RAY	10	3.2	3.7	10.1	3.2	3.2	*	*	*
PATIENT 12	PERIAPICAL X-RAY	8.6	4.2	5.1	*	*	*	*	*	*
PATIENT 13	PERIAPICAL X-RAY	10	0	2.3	12	4	4.3	12.5	4.5	2.2
PATIENT 15	PERIAPICAL X-RAY	15	8.8	9.4	14.2	5.7	5.7	9.9	1.8	2.2
PATIENT 16	PERIAPICAL X-RAY	7.5	4	3.7	10.5	6	6.8	13.9	8	3.4
PATIENT 17	PERIAPICAL X-RAY	15.4	7.4	7.5	*	*	*	*	*	*
PATIENT 18	PERIAPICAL X-RAY	13.2	3.8	2.7	*	*	*	*	*	*
PATIENT 20	PERIAPICAL X-RAY	12.3	8.8	8.9	*	*	*	*	*	*
PATIENT 23	PERIAPICAL X-RAY	14	3.2	8.7	15	9.9	7.7	*	*	*

Table III. *Measurements of the distance from the apex of the fixture to the most coronal point of the regeneration of the mesial bone defect M and the distal bone defect D in mm at implant restoration 4 months after grafting (T1).*

T1 - implant prosthesis										
PATIENT INFORMATION		FIXTURE N°1			FIXTURE N°2			FIXTURE N°3		
	TYPE OF RX	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT
PATIENT 1	PERIAPICAL X-RAY	11.5	0	0	11.5	0	0	*	*	*
PATIENT 2	PERIAPICAL X-RAY	10	1.3	0	9.9	0	0	*	*	*
PATIENT 3	PERIAPICAL X-RAY	14.5	0	0	14.8	0	0	*	*	*
PATIENT 4	PERIAPICAL X-RAY	6.1	1.5	0.6	6.2	0.6	1	*	*	*
PATIENT 5	PERIAPICAL X-RAY	13	0	0	15	0	0	*	*	*
PATIENT 6	PERIAPICAL X-RAY	10.1	-0.7	-0.5	12	0	-1.4	*	*	*
PATIENT 7	PERIAPICAL X-RAY	14.9	0	0	14.8	0	-1.4	*	*	*
PATIENT 8	PERIAPICAL X-RAY	8.1	-1.6	-1.7	9.3	-0.6	-0.7	*	*	*
PATIENT 9	PERIAPICAL X-RAY	8.4	0	0	9.6	0	0	*	*	*
PATIENT 10	PERIAPICAL X-RAY	9.8	0	0	9.4	-1.4	-0.9	*	*	*
PATIENT 12	PERIAPICAL X-RAY	7.9	0.9	2	*	*	*	*	*	*
PATIENT 13	PERIAPICAL X-RAY	10	-0.7	-1.5	12	1.2	0	12.5	0	0
PATIENT 15	PERIAPICAL X-RAY	14.8	1.2	2.1	14.3	1.9	1.4	10.1	0.9	1.5
PATIENT 16	PERIAPICAL X-RAY	7.9	0	0	10.5	0	0	13.9	0	0
PATIENT 17	PERIAPICAL X-RAY	15.1	0	-0.7	*	*	*	*	*	*
PATIENT 18	PERIAPICAL X-RAY	13.2	0	0	*	*	*	*	*	*
PATIENT 20	PERIAPICAL X-RAY	12	0	-0.6	*	*	*	*	*	*
PATIENT 23	PERIAPICAL X-RAY	14.8	0	0	15	0	0	*	*	*

Table IV. *Measurements of the distance from the apex of the fixture to the most coronal point of the regeneration of the mesial bone defect M and the distal bone defect D in mm at a 5-year follow-up (T2).*

T2 - follow-up at 5 years										
PATIENT INFORMATION		FIXTURE N°1			FIXTURE N°2			FIXTURE N°3		
	TYPE OF RX	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT	T0 MEASURE OF GBR	T0 MEASURE OF THE MESIAL DEFECT	MEASURE OF THE DISTAL DEFECT
PATIENT 1	PERIAPICAL X-RAY	12.30	1.80	2.30	12.70	2.50	2.50	*	*	*
PATIENT 2	PERIAPICAL X-RAY	10.10	1.20	1.40	10.20	1.00	1.80	*	*	*
PATIENT 3	PERIAPICAL X-RAY	12.80	0.60	0.10	13.80	1.50	0.00	*	*	*
PATIENT 4	PERIAPICAL X-RAY	6.20	2.10	0.90	6.20	1.20	1.20	*	*	*
PATIENT 5	PERIAPICAL X-RAY	12.80	0.00	0.00	14.70	-0.80	-1.60	*	*	*
PATIENT 6	PERIAPICAL X-RAY	10.40	0.00	1.00	12.40	0.90	0.70	*	*	*
PATIENT 7	PERIAPICAL X-RAY	14.40	4.00	2.30	14.20	2.40	3.20	*	*	*

PATIENT 8	PERIAPICAL X-RAY	7.90	-0.80	-0.50	9.80	0.00	1.00	*	*	*
PATIENT 9	PERIAPICAL X-RAY	8.40	1.10	0.90	9.80	1.60	0.60	*	*	*
PATIENT 10	PERIAPICAL X-RAY	10.10	1.40	1.90	9.90	1.00	0.80	*	*	*
PATIENT 12	PERIAPICAL X-RAY	8.40	1.10	2.20	*	*	*	*	*	*
PATIENT 13	PERIAPICAL X-RAY	10.10	1.60	1.30	13.00	2.10	1.50	12.90	1.00	0.60
PATIENT 15	PERIAPICAL X-RAY	15.10	1.30	2.40	14.60	2.00	2.40	10.40	1.70	2.10
PATIENT 16	PERIAPICAL X-RAY	10.10	0.00	-0.90	12.70	1.70	1.50	12.30	1.40	0.20
PATIENT 17	PERIAPICAL X-RAY	15.40	1.70	1.50	*	*	*	*	*	*
PATIENT 18	PERIAPICAL X-RAY	13.30	1.40	0.90	*	*	*	*	*	*
PATIENT 20	PERIAPICAL X-RAY	11.80	0.00	-0.80	*	*	*	*	*	*
PATIENT 23	PERIAPICAL X-RAY	14.80	0.00	0.00	15.00	0.00	0.00	*	*	*

Results of peri-implant clinical parameters

The mean MPI values at 6 months, 1 year, and up to 5 years after the start of prosthetic loading were 0.25±0.39, 0.31±0.35, and 0.36±0.27, respectively. The mean MBI values were 0.48±0.46, 0.52±0.41, and 0.6±0.45, respectively. No statistically significant increase in MPI or MBI was observed between baseline and subsequent years for implant sites.

The mean PD values at 6 months, 1 year, and at least 5 years after the start of prosthetic loading were 2.55±0.34 mm, 2.91±0.68 mm, and 3.02±0.61 mm, respectively. At the 5-year examination, 67% of all implants had PD <3 mm, and only 8.3% had PD >5 mm.

Implant survival results and success rate

Osseointegration was achieved in all 35 implants at the time of abutment connection. After a minimum of 5 years of functional loading, all 35 implants included in this study caused no pain, sensitivity, or mobility and maintained stable osseointegration. However, 4 of the 35 implants (11.4%) had MBR values higher than those proposed by Albrektsson et al. (1) as an index of the success of the implant. Therefore, the cumulative implant survival and success rates at the end of the follow-up period were 100% and 88.6%, respectively.

DISCUSSION

From the study carried out, it emerged that the use of autologous bone in the form of particulates in association with the GBR Ti-Mesh technique guarantees excellent results. Autologous bone in particulate form is, therefore, a material that allows regeneration of large bone defects to be achieved with predictable, reproducible, stable results over time and with almost no incidence of complications. This is clearly due to the better osteogenetic, osteoinductive, osteoconductive, and low resorption properties of autologous bone compared to heterologous material. In terms of implant survival, the use of autologous bone has determined results that are completely comparable to those of implants positioned in regenerated bone with heterologous bone (2).

The most important question that arises after alveolar ridge augmentation with the titanium mesh technique is whether the augmented bone can support functional loading through restored prosthetic implants and whether bone resorption occurs. This study demonstrated the possibility of achieving osseointegration with good conditions of the peri-implant tissues and satisfactory MBR values for implants positioned in atrophic ridges previously augmented with exclusively autogenous bone and Ti-mesh networks after 5 years of loading.

Pre- and post-augmentation CT measurements demonstrated significant bone regeneration. These results are comparable to those reported in other studies. Matsui et al. (35) evaluated the combined use of autografts and titanium mesh in a series of 15 patients with cleft lip and palate and reported a mean height increase of 4.4 mm.

A CT scan performed before and after the bone grafting procedure, as performed in this study, provided accurate and reliable measurements of bone gain. However, the high cost and risk of radiation exposure with this method limit its routine application. For this reason, we used low-dose cone beam CT in this study.

Follow-up examinations were performed every 6 months on each of the 35 implants placed in the augmented bone, and several clinical and radiographic parameters were evaluated at 5 years. All implants showed satisfactory osseointegration, and no patient suffered from inflammation, pain, or discomfort except 3 patients (16.6%) who presented swelling or pain immediately after the implant insertion procedure (Table I). The conditions of the peri-implant soft tissues

were evaluated. All abutments were surrounded by healthy and stable peri-implant soft tissues, probably due to rigorous periodontal monitoring and effort to maintain good oral hygiene. These data were confirmed by the values shown for the periodontal parameters used to evaluate the condition of the peri-implant tissues (i.e., MPI, MBI, and PD). The literature indicates that successful implants generally allow probe penetration <3 mm (36).

Furthermore, pockets >5 mm deep should be viewed as a sign of peri-implantitis and may be related to progressive crestal bone resorption and implant failure (37-39). In the present study, only 4 of 35 implants (11.6%) had PD >5 mm and 2.5 mm MBR after 5 years of loading. Since plaque control compliance was adequate and the load on the implant-supported prosthesis was carefully assessed during follow-up visits, eliminating any possible occlusal interference, we hypothesized that the cause of bone resorption could be attributed to parafunctional habits. These habits can generate tensile or compressive forces on the bone-implant surface, resulting in rapid crestal bone loss in the absence of mucosal inflammation.

Caution should be used when interpreting data relating to peri-implant clinical parameters and when correlating these results with marginal changes in bone level. Furthermore, follow-up studies are needed to clarify the long-term influence of these factors on implant success.

CONCLUSIONS

From our study, it emerged that the 100% autogenous bone graft in the form of particulates, in association with the GBR Ti-Mesh technique, allows for the regeneration of large bone defects and over a long period of time (minimum 5 years), the volume of the autologous bone grafted in the form of particulate remains stable, except for minimal and completely physiological resorption (1.06+-0.45 mm). The use of only autologous bone together with Ti-Mesh resulted in vertical bone resorption comparable to that of implants positioned in regenerated bone with heterologous biomaterial, a reduction in post-operative healing times, a reduction in costs compared to heterologous biomaterials and a bone remodeling that made it indistinguishable from native bone. Further studies with the same parameters could be useful to expand the number of cases and consequently expand the number of data available.

Following this retrospective observational study, however, it is already possible to outline how autologous bone is a material that has excellent regenerative properties, and that over a long period of time it undergoes minimal physiological volume reabsorption, allowing stable results to be obtained over time and predictable.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contributions

Gianluca Porcaro made substantial contributions to the conception and design of the manuscript as well as the acquisition, analysis, and interpretation of the data. All the authors participated in the drafting of the manuscript, and Fabrizio Carini reviewed it critically. All authors have read and approved the final version of the manuscript. All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

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