Fresh Frozen versus Autogenous Iliac Bone for the Rehabilitation of the Extremely Atrophic Maxilla with Onlay Grafts and Endosseous Implants: Preliminary Results of a Prospective Comparative Study

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ABSTRACT

Purpose: The purpose of this study was to compare (1) the clinical outcome of the reconstruction of extremely atrophic edentulous maxillae with fresh frozen allogeneic bone (FFB) (group A) and autogenous bone (AB) (group B) iliac blocks; and (2) the peri-implant bone resorption and the survival rate of implants in the two groups.

Materials and Methods: In a 1-year period, eight patients were treated with FFB and seven with AB iliac grafts. Five to seven months afterward, 108 implants were inserted (59 in group A and 49 in group B). Four to five months afterward, patients were rehabilitated with implant-supported prostheses. The mean follow-up was 24 months.

Results: Prior to implant placement, graft exposure occurred in two patients in group A and in one patient in group B. The mean graft resorption prior to implant placement was 0.78 mm and 0.54 mm in group A and B, respectively. After implant placement, bone graft exposures with partial loss of the graft occurred in six out of eight patients in group A and in none of the group B patients. The survival rate of implants was 90.1% and 100% in group A and B, respectively. The mean values of peri-implant bone resorption at the end of the follow-up period were 1.64 mm and 0.92 mm in group A and B, respectively.

Conclusion: Results of this study seem to demonstrate that FFB does not represent a reliable alternative to AB blocks because of the higher rate of bone exposure and partial loss of the grafts, the lower implant survival, and the higher peri-implant bone resorption in FFB patients.

KEY WORDS: allogeneic bone, autogenous bone, bone atrophy, bone graft, complication, dental prosthesis, edentulism, endosseous implant, fresh frozen

INTRODUCTION

Extreme atrophy of the edentulous maxilla (class VI according to Cawood and Howell classification)[1] still represents a challenge for oral rehabilitation by means of implant-supported prostheses because of the almost complete loss of the alveolar ridge. Maxillary sinus expansion and the presence of the nasal cavities may further reduce the quantity of bone available for implant placement. Finally, the centripetal resorption of the alveolar crest may determine not only an insufficient

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bone volume but also unfavorable vertical, transversal, and sagittal intermaxillary relationships.[1]

Well-consolidated surgical procedures such as maxillary sinus grafting,[2] if may allow the creation of adequate bone volume for implant placement in the posterior maxilla, are however insufficient to correct unfavorable intermaxillary relationships. This situation may lead to the placement of implants in an excessively apical (due to the vertical resorption of the alveolar ridge) and palatal position (due to the horizontal resorption of the ridge). As far as the anterior maxilla is concerned, extreme atrophy renders implant placement impossible because of the reduced distance between the margin of the alveolar crest of the nasal cavity (in some cases less than 1 mm). Furthermore, the unfavorable vertical and anterior–posterior intermaxillary relationship may render the final prosthetic restoration inadequate from a functional and aesthetic point of view.

In such a situation where even short, narrow diameter or tilted implants cannot be used because of the lack of available bone, more favorable conditions must be re-created prior to implant placement.

Among the different techniques proposed over the years, bone reconstruction with autogenous onlay grafts is the best documented and most versatile procedure, as it can be used to treat the vast majority of defects, irrespective of variables such as type of atrophy and extension of the defect. Clinical results are favorable and stable over time either for the reconstructed bone and for implants placed in the reconstructed areas, with a mean implant survival rate of 81.6% (range: 60–100%) and 94.2% (range: 90–100%) for machined surface and rough surface implants, respectively.[3]

Bone can be harvested both from intraoral (typically mandibular ramus or mental symphysis) or extraoral sites (typically iliac crest and/or calvarium): the choice is generally made according to the extent of the defect.[3–5]

In case of extreme atrophy of the alveolar ridge, extraoral donor sites generally represent the only option to obtain an adequate quantity of bone for the reconstruction.

Among these, the best documented results, in terms of number of patients treated, implants placed, and length of follow-up, are those reported for grafts taken from the anterior iliac crest.[3–8] The authors themselves positively experienced iliac bone for large reconstructions of atrophic jaws in the last 15 years, as reported in a number of publications.[3,9–11] The quantity of available bone in the anterior iliac crest (formed by both a cortical and cancellous component) allows a three-dimensional reconstruction of the severely atrophic maxilla with onlay grafts (including a bilateral sinus grafting procedure), which permits not only the re-creation of adequate bone volume to host endosseous implants but also the correction of vertical, anterior–posterior, and transverse intermaxillary relationships. This latter aspect can optimize the final prosthetic rehabilitation not only from a functional but also from an aesthetic point of view.

However, bone harvesting from the anterior ilium presents some drawbacks, such as the elongation of operating times, the need of general anesthesia with hospitalization, and finally, an increased postoperative morbidity, mainly represented by gait/dehambulation disturbances, albeit transient in the vast majority of cases.[3,4,6,12,13]

Other extraoral donor sites, such as the calvarium, have been proposed with very good results,[10,14–16] but the number of patients treated is limited and the quantity of bone available is lower as compared with iliac crest. Moreover, bone harvesting from the calvarium is less frequently accepted by patients, and, although extremely rare, complications in case of violation of the endocranial cavity can be relevant.[13,17]

For the aforementioned reasons, in recent years, the use of fresh frozen allogeneic bone (FFB) blocks has been introduced for the reconstruction of bone defects of the jaws, with the aim to avoid the postoperative morbidity related to iliac bone harvesting procedures and to shorten the operating times. The choice of FFB has been based on the relevant experience achieved in orthopedic surgery, where this material has been extensively used.[18–23]

However, results reported in the literature concerning the use of FFB for the reconstruction of atrophic alveolar ridges are contradictory, as some authors reported apparently good results (although frequently with short follow-up periods),[24–30] while others reported inconsistent/questionable results.[31–33]

These controversial results may be related to different factors, including (1) the small number of patients treated; (2) the extreme heterogeneity of type, site, and extension of the reconstruction (including maxillary

sinus grafting, inlay grafting, horizontal onlay grafts of limited defects, etc.); and (3) the length of follow-up after implant placement and the start of prosthetic loading, if any, thus rendering the analysis of data difficult.

To the authors' knowledge, there are no publications that compare the clinical results obtained with allogeneic FFB versus AB blocks taken from the anterior iliac crest used in clinically comparable initial situations.

The aim of this prospective comparative study were therefore to compare (1) the clinical outcome of the reconstruction of extremely atrophic edentulous maxillae with FFB (group A) and autogenous bone (AB) (group B) blocks taken from the anterior ilium; and (2) the peri-implant bone resorption and the survival rate of implants placed in the reconstructed maxillae in groups A and B, respectively.

MATERIALS AND METHODS

From January to December 2010, 15 systemically healthy patients, 4 males and 11 females, aged 41 to 77 years (mean: 56 years), presenting with extreme atrophy of edentulous maxillae that determined relevant difficulty or impossibility to wear a traditional denture, were selected and consecutively enrolled for surgical treatment at the Unit of Oral Surgery, Department of Health Sciences, San Paolo Hospital, University of Milan, Italy. The treatment consisted of the reconstruction of the atrophic maxilla with vertical and horizontal onlay bone grafts in association with bilateral sinus grafting, either with fresh frozen allogeneic iliac bone (FFB – Group A, eight patients) or autogenous iliac bone (AB – Group B, seven patients), to re-create favorable intermaxillary relationship and adequate bone volume to allow the placement of endosseous implants in the proper, prosthetically driven position.

Patients were initially screened for evaluation of the clinical situation and collection of baseline data. The visit included (1) general health assessment; (2) analysis of the oral status, the evaluation of opposing arch dentition, and the intermaxillary relationships; (3) impressions for dental study casts and wax-up of the missing dentition for the fabrication of diagnostic/surgical templates with radio-opaque markers; and (4) preoperative radiographic evaluation with panoramic radiograph and computed tomography of the maxilla to be taken with the diagnostic templates in place to evaluate residual bone volume and the relationship between the ideal position of teeth and the alveolar ridge, and to exclude pathologies such as chronic sinusitis or relevant polyposis of the maxillary sinus, which may contraindicate sinus grafting procedures.

Exclusion criteria included the presence of one or more of the following conditions: (1) severe renal and/or liver disease; (2) congenital or acquired immunodeficiency; (3) ongoing bisphosphonate or antiblastic chemotherapy at the time of first examination; (4) history of radiotherapy in the head and neck area; (5) diseases of the oral mucosa, such as lichen planus; (6) tobacco (>20 cigarettes per day) or alcohol abuse; (7) non-compensated diabetes; (8) active periodontal disease of the residual mandibular dentition (if any) at the time of first examination (in this case, patients underwent etiologic therapy, education and motivation in domestic oral hygiene, and were re-evaluated for surgical treatment); and (9) maxillary sinus pathoses such as chronic sinusitis or relevant polyposis.

All patients received a thorough explanation of the planned treatment, including risks and possible complications of the surgical procedures, potential benefits, and in particular, advantages and disadvantages of using AB harvested from the anterior ilium or allogeneic FFB.

As far as AB is concerned, advantages can be summarized as follows: (1) absence of immune reaction; (2) osteogenetic, osteoinductive, and osteoconductive potential of AB; (3) well-documented procedure with more than 30 years of clinical experience.[3–6,8,34,35]

Conversely, disadvantages might be represented by (1) elongation of operating times; (2) gait/dehambulation disturbances for a variable time (up to 6–8 weeks); (3) visible scar in the skin overlying the harvesting area; and (4) paresthesia in the lateral aspect of the thigh (if the lateral femoro-cutaneous nerve is involved in the retraction of the flaps during the harvesting procedure).[3,4,6,12,13]

As far as FFB is concerned, advantages can be summarized as follows: (1) no need of bone harvesting from the patient's ilium; (2) no skin scars in the iliac region; (3) no gait/dehambulation disturbances after the reconstructive procedure; (4) no risk of damage to the lateral femoro-cutaneous nerve; (5) osteoconductive properties; and (6) practically unlimited supply of reconstructive material.[26,29]

Disadvantages might be represented by (1) risk of transmission of viruses such as hepatitis C virus (estimated 1.1×10^6), hepatitis B virus (estimated 3×10^6),

TABLE 1 Demographic and Clinical Data of Group A Patients

No.	Sex	Age	Date of Reconstruction	Date of Implant Placement	No. of Implants Placed	Type of Implant	Date of Loading	Follow-Up
1	F	56	April 2010	September 2010	8	Astra	January 2011	26 months
2	F	56	April 2010	October 2010	8	Straumann	February 2011	25 months
3	F	48	June 2010	December 2010	8	Astra	April 2011	24 months
4	F	53	July 2010	December 2010	8	Straumann	April 2011	24 months
5	M	61	October 2010	May 2011	6	Straumann	August 2011	19 months
6	F	50	November 2010	May 2011	8	Astra	September 2011	18 months
7	F	74	November 2010	May 2011	6	Straumann	September 2011	18 months
8	F	53	December 2010	May 2011	7	Astra	November 2011	17 months

F = female; M = male.

and human immunodeficiency virus (estimated 1.2×10^6); (2) immune reaction/rejection of the graft; (3) potentially reduced (and in any case still under debate) osteoinductive potential; and (4) limited patient populations and follow-ups with limited literature support (as compared with AB).[22,29,36–38]

For obvious ethical reasons, it was impossible to perform a randomization of the two reconstructive techniques: the patients themselves were the only ones who could decide which type of bone they would had liked to receive. The main reasons were represented by psychological refusal to accept allogeneic bone and the risk of transmission of viral disease, as explained in the informed consent.

Out of 15 patients treated, 8 chose FFB as reconstructive material (group A), while 7 preferred bone harvesting from their own anterior ilium (group B).

An informed consent including all information on the surgical procedures was signed by all patients before the start of treatment, with particular regard to the risks and potential complications following the reconstructive procedure, implant placement, and the outcome of the implant-supported prostheses.

A second informed consent related to the risks of receiving FFB (in particular, the transmission of viral disease) was also signed by all patients who decided to receive this type of bone for the reconstruction.

Demographic data and clinical features of groups A and B patients are reported in Tables 1 and 2, respectively.

Approval for this study was obtained from the Ethics Committee, Department of Health Sciences, San Paolo Hospital, University of Milan, Italy.

Surgical Procedure – Reconstructive Phase

All patients underwent a professional oral hygiene treatment 1 to 2 weeks before the date scheduled for the reconstructive surgery, even if no signs of periodontal disease were present. Patients were also asked to start chlorhexidine (0.2%) mouthrinses 2 days before surgery, three times per day.

TABLE 2 Demographic and Clinical Data of Group B Patients

No.	Sex	Age (Years)	Date of Reconstruction	Date of Implant Placement	No. of Implants Placed	Type of Implant	Date of Loading	Follow-Up
1	F	41	January 2010	June 2010	8	Straumann	September 2010	31 months
2	M	66	February 2010	July 2010	8	Astra	October 2010	30 months
3	M	58	March 2010	July 2010	8	Straumann	October 2010	29 months
4	F	77	April 2010	August 2010	6	Straumann	December 2010	27 months
5	F	47	May 2010	November 2010	5	Straumann	January 2011	26 months
6	M	42	July 2010	December 2010	6	Straumann	March 2011	24 months
7	F	60	October 2010	February 2011	8	Astra	April 2011	24 months

F = female; M = male.

All patients were treated under general anesthesia with nasotracheal intubation and operated on under controlled blood hypotension during surgery. All patients received 2 g of ceftriaxone intravenously at the time of anesthesia induction.

Regardless of the type of bone used, the surgical technique for the reconstruction of the atrophic maxillae was the same for both groups.

In group A patients (FFB), a tricortical bone block as well as corticocancellous granules obtained from the anterior ilium of human cadavers was provided by the local musculoskeletal tissue bank (Gaetano Pini Orthopaedics Institute, University of Milan, Milan, Italy). FFB is harvested aseptically from cadaveric donors and then frozen, with no additional preparation, and it is available for human recipients after at least 6 months of quarantine at −80°C.

Before its use, FFB must be defrosted by keeping the block in a warm (40°C) solution of sterile saline and rifamycin (500 mg/L) for 45 minutes. Once defrosted, any residual portion of connective tissue attached to the surface of the bone block was carefully removed with a sharp blade. Finally, the bone block was cut in pieces to be precisely adapted to the recipient site.

In group B patients (AB), an incision of the skin and subcutaneous tissues was performed along the anterior iliac crest, starting approximately 2 cm posterior to the anterior iliac spine and extending posteriorly according to surgical needs (quantity of bone necessary and local anatomy). After a subperiosteal dissection, the medial side of the anterior iliac crest was exposed and a corticocancellous bone block including the iliac crest and the medial side of the ilium was outlined with oscillating saws and detached with chisels. With a surgical curette, cancellous bone particles were also collected. No attempt was done to detach the muscular insertions (tensor fascia latae muscle and gluteal muscles) on the outer cortex of the anterior ilium to reduce postoperative gait disturbances. Surgical access was closed in layers after hemostasis with collagen sponge (Spongostan®, Ferrosan Medical Devices, Søborg, Denmark) and/or bone wax (Ethicon Bone Wax®, Johnson & Johnson Medical, Amersfoort, the Netherlands) and positioning of a vacuum drainage.

The following phase was represented by the maxillary reconstruction, and the procedure did not differ between the two groups. A midcrestal incision from the maxillary tuberosity on one side to the opposite one was performed and a mucoperiosteal flap elevated until the maxillary bone was completely exposed. Because of severe atrophy, care was taken to identify and protect the branches of the infraorbital nerve on both sides.

A sinus grafting procedure with lateral approach, as described by Boyne and James,[2] on both the right and left maxillary sinus was the first part of the reconstructive procedure in all patients. Briefly, a bony window was outlined in the lateral aspect of the right and left maxilla either with piezoelectric instruments (Piezosurgery®, Mectron Medical Technology, Carasco, Genova, Italy) or with a round diamond bur mounted on a straight handpiece, and careful elevation of the sinusal membrane was performed. The void created between the floor of the sinus and the elevated Schneiderian membrane was then packed with particulated bone: corticocancellous allogeneic chips were used in group A patients, while autogenous iliac bone chips were used in group B patients.

The severely atrophic maxilla was then reconstructed by means of onlay bone grafts (FFB in group A and AB in group B). Grafts were used to correct both the vertical, transverse, and anterior–posterior deficits. Careful modeling of the blocks was performed to optimize the contact between the recipient site and the blocks and to obtain a correct morphology of the reconstructed alveolar crest. The blocks were then rigidly fixed to the recipient bed by means of titanium microscrews (MF cortex screw, Synthes GmbH, Zuchwil, Switzerland), 1.5 mm in diameter and 8–16 mm in length according to surgical needs. Any residual space between the recipient sites and the blocks was carefully packed with particulated bone (allogeneic in group A and autogenous in group B) to avoid connective tissue ingrowth during the healing phases, which might compromise the integration of the grafts with the recipient bed.

After the completion of the reconstructive phase, periosteal releasing incisions were performed to allow for a tension-free and water-tight closure of the flaps.

Antibiotic therapy (2 g ceftriaxone per day for the following 7 days) was prescribed to all patients, and postoperative instructions included liquid/soft diet for 2 weeks, thorough oral hygiene with toothbrush on the residual dentition, and 0.2% chlorhexidine mouthwashes until suture removal, which was performed 12 to 14 days after the reconstruction.

During the postoperative period, patients were not allowed to wear prostheses that could stress the reconstructed ridges for a minimum of 8 weeks. In the

following period, and until implant placement, prostheses relined with soft materials were allowed only for "cosmetic use," with the prohibition to use them for chewing hard food.

Surgical Procedure – Implant Phase

Five to seven months after the reconstruction, the second surgical session was scheduled for screw removal and implant placement. The surgical procedure started with the elevation of a full-thickness flap along the same incision line used for the reconstructive surgery and the removal of the titanium microscrews used to fix the grafts; when the position of the screws did not interfere with implant insertion, the screws were left in place to avoid any unnecessary graft exposure.

A total of 108 implants were placed (Astra Tech Dental Implant System®, Dentsply, Mölndal, Sweden; Straumann Implant System, Straumann Institut, Basel, Switzerland), 59 in group A and 49 in group B patients: length and diameter of the implants were chosen according to prosthetic indications and to the bone volume available at each implant site. Implant positions were chosen according to the prosthetic planning reproduced by surgical templates based on the ideal wax-up of the missing dentition. After implant placement, cover screws were placed on the implants to achieve a submerged healing, sutures were applied, and the patients were discharged with the same postoperative instructions given for the reconstructive phase. Anagraphic and clinical data of group A and B patients are reported in Tables 1 and 2, respectively.

Prosthetic Phase

Four to five months after placement, implants were uncovered, healing abutments connected, and the prosthetic rehabilitation started (see Tables 1 and 2 for details). Patients were then scheduled for periodical clinical and radiographic controls.

Parameters Evaluated in the Follow-Up Period

In order to obtain data concerning the clinical outcome of the reconstructive procedure and implants in the two groups, the following parameters were evaluated: (1) the complication rate following the reconstruction; (2) the graft resorption rate before implant placement; (3) the complication rate after implant placement and loading; (4) the survival rate of implants; and (5) and the peri-implant bone resorption in groups A and B, respectively.

The resorption of the grafts before implant placement was measured with a periodontal probe mesial and distal to each microscrew used for graft fixation at the time of screw removal and implant placement. The distance between the head of the screw and the first screw-to-implant bone contact was measured. The initial distance between the screw head and the bone graft surface was considered equal to 0 mm at the end of the reconstructive procedure, as the screw heads were always at the level of the more superficial part of the bone blocks. Values were rounded to the nearest millimeter.

Radiographic controls were performed: (1) immediately after the reconstruction and immediately prior to implant placement with panoramic radiographs; and (2) immediately after implant placement, at the time of prosthetic loading, and annually thereafter with periapical radiographs to evaluate peri-implant bone resorption.

As far as peri-implant bone resorption was concerned, the distance between the implant shoulder and the most coronal point of bone-to-implant contact, mesial and distal to each implant, was measured on intraoral radiographs by two independent investigators. Measurements were performed using a dedicated software (ImageJ® 1.38v, National Institutes of Health, Bethesda, MD, USA) after digitalization of radiographs with a Nikon D90 camera (Nikon Corp., Tokyo, Japan) and were rounded to the nearest half millimeter. Dimensional distortion was corrected by knowing the actual dimensions of the implants. Again, the distance between the implant shoulder and the most coronal part of the graft was considered as the baseline for the following measurements.

For each implant, a mathematical mean between the value measured on the mesial and distal aspects was calculated to obtain a mean resorption value.

Peri-implant bone resorption values in the two groups were compared using a two-tailed, unpaired *t*-test. A p value of .05 was considered to be statistically significant.

Life table method (standard actuarial method) was used to compute cumulative survival proportions and hazard rates of implants.

RESULTS

Postoperative recovery after the reconstructive surgery was uneventful in the majority of cases. Patients were

discharged between 24 (group A) and 48 hours (group B) after the end of the surgical session.

Patients of group A treated with FFB had, of course, no morbidity in the anterior iliac area, as no harvesting procedure was performed. On the contrary, patients of group B reported dehambulation/gait disturbances lasting from 1 to 6 weeks postoperatively (mean: 2.6 weeks), but all of them finally recovered completely with no further sequelae.

As far as the complication rate following the reconstruction and prior to implant placement was concerned, a spontaneous dehiscence of the surgical flap with graft exposure, but without clinical signs of infection, occurred in two patients (patient 1 and 8) in group A, 4 and 14 weeks after the reconstructive procedure, respectively (see Table 3). The same problem was detected 16 weeks after the reconstruction in one patient in group B (patient 2) (see Table 4). All early dehiscences were successfully treated with local curettage and perforation of the grafts with round burs assembled on straight handpieces in association with saline solution irrigation to promote local bleeding, formation of granulation tissue, and secondary healing, which occurred in all of these patients; no relevant bone loss was recorded at the time of local curettage.

The mean resorption of the graft at the time of microscrews removal and implant placement was 0.78 mm (range: 0–3 mm; standard deviation [SD]: 0.64) in group A, and 0.54 mm (range: 0–2 mm; SD: 0.59) in group B patients. All data (frequency distribution, medians, and interquartile ranges) related to graft resorption are reported in Table 5.

All patients received the planned number of implants in the reconstructed maxillae (59 implants in group A and 49 implants in group B patients) following the indications of preformed surgical templates: all implants were left to integrate with a submerged protocol.

However, a dehiscence of soft tissues with bone exposure occurred before implant uncovering in two out of eight patients in group A (patients 5 and 7), 3 and 11 weeks after implant placement, respectively. In both patients, local curettage with removal of some fragments of clinically nonvascularized graft and application of an antibiotic solution (Rifocin®, Sanofi Aventis, Milan, Italy) were performed, and a spontaneous soft tissue healing by secondary intention occurred with complete coverage of the exposed areas in both patients (see Table 3 for details).

TABLE 3 Group A: Incidence of Graft Exposure, Treatment, and Outcome

No.	Prior to Implant Placement (Weeks)			Between Implant Placement and Abutment Connection (Weeks)			After Implant Loading (Weeks)		
	Area Involved	Management	Healing	Area Involved	Management	Healing	Area Involved	Management	Healing
1	(4 weeks) 25–26 bucc	Cur, perf	Yes	No	—	—	No	—	—
2	No	—	—	No	—	—	(60 weeks) 24–26 bucc	Cur, perf	Yes
3	No	—	—	No	—	—	No	—	—
4	No	—	—	No	—	—	(23 weeks) 14–16 pal (25 weeks) 24–25 pal	Cur, perf	No
5	No	—	—	(3 weeks) 12–13 bucc	Cur, perf, rem	Yes	(10 weeks) 14–15 bucc	Cur, perf	No
6	No	—	—	No	—	—	(13 week) 24–25 bucc	Cur, perf	Yes
7	No	—	—	(11 weeks) 24–26 bucc	Cur, perf, rem	Yes	(52 weeks) 24–26 bucc	Cur, perf, rem	Yes
8	(14 weeks) 24–25 bucc	Cur, perf	Yes	No	—	—	(8 weeks) 24 25 bucc	Cur, perf	No

Bucc = buccal side; cur = local curettage; pal = palatal side; perf = perforations; rem = removal of partial bone.

TABLE 4 Group A: Incidence of Graft Exposure, Treatment, and Outcome

No.	Prior to Implant Placement (Weeks) Area Involved	Management	Healing	Between Implant Placement and Uncovering (Weeks) Area Involved	Management	Healing	After Implant Loading (Weeks) Area Involved	Management	Healing
1	No	—	—	No	—	—	No	—	—
2	(16 weeks) 24–26 bucc	Cur, perf	Yes	No	—	—	No	—	—
3	No	—	—	No	—	—	No	—	—
4	No	—	—	No	—	—	No	—	—
5	No	—	—	No	—	—	No	—	—
6	No	—	—	No	—	—	No	—	—
7	No	—	—	No	—	—	No	—	—

Bucc = buccal side; cur = local curettage; perf = perforations.

TABLE 5 Data Concerning Graft Resorption before Implant Placement

Frequency Distribution of Graft Resorption	Group A (104 Microscrews)	Group B (85 Microscrews)
0 mm	33 (31.7%)	43 (50.6%)
1 mm	63 (60.6%)	38 (44.7%)
2 mm	6 (5.8%)	4 (4.7%)
3 mm	2 (1.9%)	0
>4 mm	0	0
Graft resorption	Group A	Group B
Mean (SD)	0.78 (0.64)	0.54 (0.59)
Median	1	0
First quartile	0	0
Third quartile	1	1
Minimum	0	0
Maximum	3	2

Microscrews mentioned in the second and third columns indicate the titanium microscrews used for graft fixation.
SD = standard deviation.

Conversely, in group B patients, no complications occurred prior to implant uncovering (Table 4).

In 2 patients in group A (patients 3 and 7), 2 implants out of 59 were not osseointegrated at the time of abutment connection and were removed. It was however possible to complete the rehabilitation with fixed, implant-supported prostheses, although the planned prosthetic suprastructure had to be modified.

The follow-up after the start of prosthetic loading ranged from 17 to 31 months, with a mean follow-up of 24 months.

At different times after the start of prosthetic rehabilitation, a dehiscence of soft tissues with bone exposure occurred in six patients (patients 2, 4, 5, 6, 7, and 8) in group A.

Dehiscences were treated again with local curettage, bone graft perforations, and local antibiotic therapy. A complete soft tissue healing by secondary intention occurred however in only two patients (patients 2 and 6) and no other complications were reported. Conversely, in patients 4, 5, and 8, despite curettage and graft perforations, the grafted bone remained exposed, although the patients did not report any pain and/or sign and symptoms of infection and both implants and prosthetic suprastructures are still in function at the end of the observation period.

In patient 7, the exposed bone surrounding two implants in the left premolar area underwent

sequestration 13 months after the start of prosthetic loading. Both the bone fragment and the implants were removed, and a spontaneous healing of soft tissue with complete closure of the bone exposure occurred (see Table 3 for details). The two failed implants were substituted with two new implants placed in the remaining bone in the molar area. The final prosthetic suprastructure had to be modified, and the new implants were connected to the survived ones on the right side.

Finally, in one patient (patient 1), one implant lost osseointegration 1 year after the start of prosthetic loading and had to be removed, together with some fragments of sequestrated bone.

In group B patients, no complications were reported after the start of prosthetic loading and none of the implants were removed.

Therefore, the cumulative survival rate of implants was 90.1% (54 out of 59 implants) and 100% in group A and B, respectively (see Table 6).

The mean peri-implant bone resorption at the time of prosthetic loading were 0.45 mm (range: 0–1.8 mm; SD: 0.48) in group A (59 implants) and 0.35 mm (range: 0–1 mm; SD: 0.32) in group B (49 implants). The difference between the two groups was not statistically significant ($p = .19$).

One year after the start of prosthetic loading, these values were 1.45 mm (range: 0.25–8 mm; SD: 1.42) in group A and 0.77 mm (range: 0–2.7 mm; SD: 0.79) in group B. The difference between the two groups was statistically significant ($p = .004$).

Two years after, these values were 1.64 mm (range: 0.5–3 mm; SD: 0.69) and 0.92 mm (range: 0–3.6 mm; SD: 0.88) in group A and B, respectively. The difference between the two groups was statistically significant ($p = .0005$).

Descriptive statistics related to peri-implant bone resorption (mean, median, frequency distribution, interquartile ranges) are reported in Table 7.

All patients in group A (despite the loss of five implants) and group B are wearing fixed, implant-supported prostheses at the end of the observation period.

Two clinical cases, one in group A and one in group B, are presented in Figures 1A–K and 2A–J.

DISCUSSION

The use of FFB for the reconstruction of atrophic edentulous ridges has been proposed to reduce morbidity related to AB harvesting, in particular when extraoral donor sites, such as the ilum, are used. However, results reported in the literature concerning the use of FFB for the reconstruction of atrophic alveolar ridges are contradictory, as some authors reported apparently good results (although frequently with short follow-up periods),[24–30] while others reported inconsistent/questionable results.[31–33]

These controversial results may be related to different factors, including (1) the number of patients treated; (2) the extreme heterogeneity of type, site, and extension of the reconstruction (including maxillary sinus grafting, inlay grafting, horizontal onlay grafts of limited defects, etc.); and (3) the length of follow-up after implant placement and the start of prosthetic loading (if any), thus rendering the analysis of data difficult to be evaluated.

TABLE 6 Life Table Analysis (Standard Actuarial Method) of Implants Placed in Group A and B Patients

	No. of Implants at Start of Interval	Dropout Implants	No. of Removed Implants	No. of Implants at End of Interval	Cumulative Survival Rate (%)
Group A					
Plc to load	59	0	2	57	96.6
Load to 1 year	57	0	0	57	96.6
1 to 2 years	57	24	3	30	90.1
Group B					
Plc to load	49	0	0	49	100
Load to 1 year	49	0	0	49	100
1 to 2 years	49	0	0	49	100

Plc = placement; load = prosthetic loading.

TABLE 7 Data on Peri-Implant Bone Resorption

Frequency Distribution of Peri-Implant Bone Resorption	Group A			Group B		
	At Loading (59 Implants)	1 Year (57 Implants)	2 Years (30 Implants)	At Loading (49 Implants)	1 Year (49 Implants)	2 Years (49 Implants)
0 mm	24 (40.7%)	0	0	18 (36.7%)	13 (26.5%)	6 (12.2%)
<0.9 mm	21 (35.6%)	22 (38.6 %)	1 (3.3%)	26 (53.1%)	19 (38.8%)	26 (53.1%)
1–1.9 mm	14 (23.7%)	21 (36.8%)	19 (63.3%)	5 (10.2%)	12 (24.5%)	10 (20.5%)
2–2.9 mm	0	9 (15.8%)	8 (26.7%)	0	5 (10.2%)	6 (12.2%)
3–3.9 mm	0	1 (1.8%)	2 (6.7)	0	0	1 (2%)
>4 mm	0	4 (7%)	0	0	0	0
Peri-implant bone resorption		Group A			Group B	
Mean (SD)	0.45 (0.48)	1.45 (1.42)	1.64 (0.69)	0.35 (0.32)	0.77 (0.79)	0.92 (0.88)
Median	0.5	1	1.5	0.5	0.8	0.82
First quartile	0	0.75	1	0	0	0.25
Third quartile	0.7	1.5	2.25	0.5	1.35	1.45
Minimum	0	0.25	0.5	0	0	0
Maximum	1.8	8	3	1	2.7	3.6

SD = standard deviation.

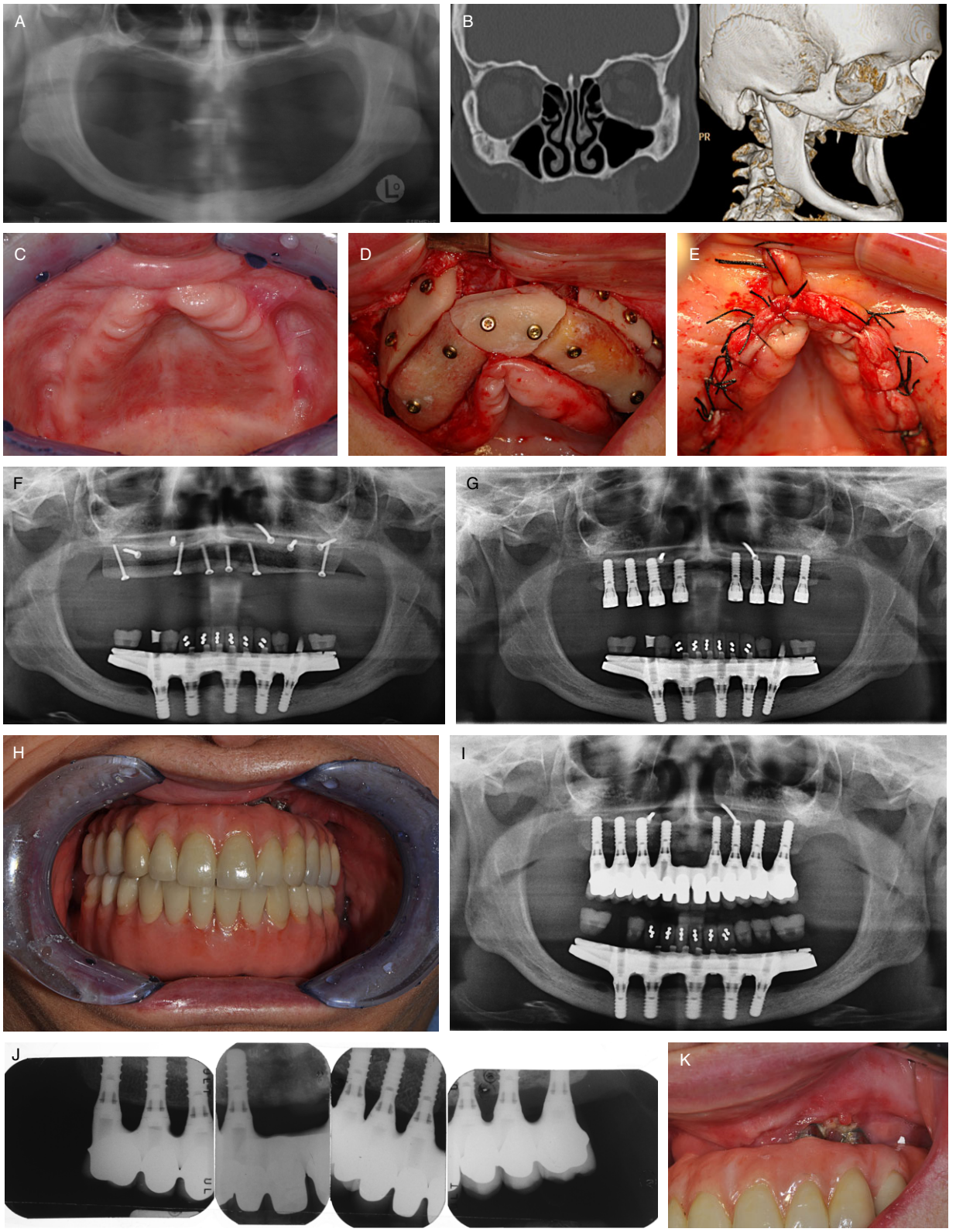

Figure 1 *A*, Preoperative panoramic radiograph showing extreme atrophy of the edentulous maxilla. *B*, Preoperative computed tomography showing extreme atrophy of the edentulous maxilla. *C*, Preoperative intraoral view showing the extreme maxillary atrophy. *D*, Reconstruction of the maxilla with FFB onlay grafts in association with bilateral sinus grafting procedures. *E*, Water-tight closure of the flaps at the end of surgery. *F*, Postoperative radiographic control showing the relevant increase in bone volume. *G*, Panoramic radiograph after installation of eight implants in the reconstructed areas. *H*, Final prosthetic restoration. *I*, Panoramic radiograph at the end of prosthetic restoration. *J*, Intraoral radiographs 1 year after the start of prosthetic loading. *K*, Intraoral view showing exposed bone surrounding the buccal aspect of two implants in the left anterior maxilla. FFB = fresh frozen bone.

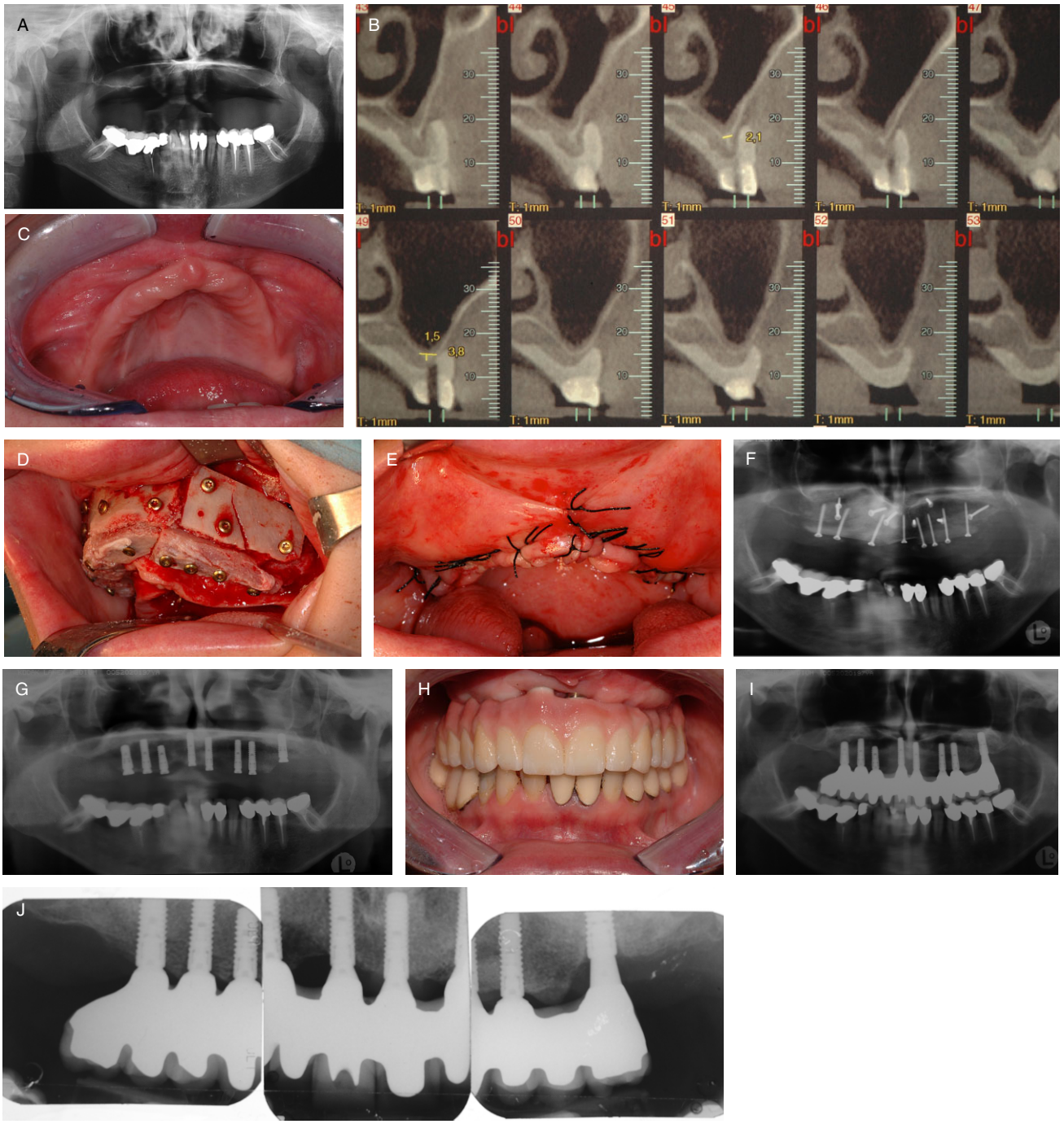

Figure 2 *A*, Preoperative panoramic radiograph showing extreme atrophy of the edentulous maxilla. *B*, Preoperative computed tomography showing extreme atrophy of the edentulous maxilla. *C*, Preoperative intraoral view showing the extreme maxillary atrophy. *D*, Reconstruction of the maxilla with AB onlay grafts in association with bilateral sinus grafting procedures. *E*, Water-tight closure of the flaps at the end of surgery. *F*, Postoperative radiographic control showing the relevant increase in bone volume. *G*, Panoramic radiograph after installation of eight implants in the reconstructed areas. *H*, Final prosthetic restoration. *I*, Panoramic radiograph at the end of prosthetic restoration. *J*, Intraoral radiographs 2 years after the start of prosthetic loading. AB = autogenous bone.

To the authors' knowledge, this is the first article where the clinical outcome of allogeneic FFB and autogenous iliac bone blocks used for the three-dimensional reconstruction of severely atrophic edentulous maxillae, as well as the survival rate of implants in the reconstructed areas are compared.

Notwithstanding the fact that the patient population, the number of implants placed, and the

follow-up are limited, the following considerations can be made:

- Patients of the AB group were discharged from the hospital later than those of the FFB group (2–3 days vs 1 day after surgery, respectively).
- Postoperative morbidity/discomfort was higher in the AB group, as they reported dehambulation/gait problems lasting from 1 to 6 weeks postoperatively, with a mean 2.6 weeks; nevertheless, it is worth noting that all of them finally recovered completely with no further sequelae. This problem was obviously absent in the FFB group.
- Apparently, both AB and FFB undergo a favorable integration in the recipient site, despite the occurrence of one graft exposure in one patient of the AB group and two graft exposures in two patients of the FFB group.
- The mean resorption of the grafts at the time of implant placement was limited and without relevant differences between the two groups (0.78 mm and 0.54 mm in the FFB and AB group patients, respectively).
- All patients in both groups could receive the planned number of implants in the reconstructed areas.
- The implant-supported prosthetic restorations are still in function in all patients of both groups at the end of the follow-up period.

Preliminary conclusions derived from the observation of these data apparently seem to indicate that FFB might represent an alternative to AB, as it allows reduction of hospitalization times, reduction of morbidity, and completion of the rehabilitation with implant-supported fixed prostheses.

However, this study showed that patients treated with FFB (group A) presented with a definitely higher rate of complications, particularly after implant placement, thus raising doubts concerning the reliability of this material for the reconstruction of severely atrophic edentulous maxillae. Ten spontaneous soft tissues dehiscences occurred in group A patients (two before implant placement, two before healing abutment connection, and six after the start of prosthetic loading). It is worth noting that 4 of the 10 dehiscences are still present at the end of the observation period, despite several attempts to obtain secondary healing with local curettage and antibiotic irrigation (the number of dehiscences exceeds the number of patients because some patients experienced more than one dehiscence). On the other hand, only one dehiscence occurred in group B patients, before implant placement, while no other complications were registered after implant placement and prosthetic loading.

The mean peri-implant bone resorption was higher in group A as compared with group B, with statistically significant differences at all observation times (0.45 mm vs 0.35 mm at the time of abutment connection and start of prosthetic loading, 1.45 mm vs 0.77 mm 1 year after the start of prosthetic loading, and finally 1.64 mm vs 0.92 mm 2 years after).

The survival rate of implants placed in group B patients (100%) was consistent not only with data reported by other authors for implants placed in reconstructed maxillary with autogenous iliac graft[3,4,6–8] but also with data related to implants placed in native, non-reconstructed bone.[39–43]

Conversely, the survival rate of implants placed in group A patients was lower (90.1%) at the end of the observation period. This and the high incidence and persistence of bone exposures around implants placed in this group, as well as the removal of fragments of non-vital bone around and between the implants, raise many doubts regarding the possibility of long-term implant survival and the subsequent prosthetic restorations in these patients.

Histologic analysis of the removed FFB bone fragments demonstrated the presence of extremely limited or no presence of vital cells.

Strangely enough, these results are quite in contrast with a previous histologic and histomorphometric study recently published by the same group of authors.[44] In this preliminary study, bone specimens were taken with a trephine bur during implant site preparation in partially or totally edentulous patients reconstructed either with FFB or with AB. Although patients treated with FFB showed slower bone remodeling and revascularization, at the time of implant placement, the FFB grafts appeared well integrated and normal bleeding was observed from the prepared implant sites, apparently demonstrating a good revascularization of the grafts. These findings encouraged the authors to rely on FFB as a grafting material.

Yet, as already stated, a much higher incidence of bone exposures after abutment connection and the start of prosthetic loading was observed in group A patients

in the present study, together with the presence of necrotic bone on the surface of the FFB grafts.

These findings are not easily explainable. The authors can only speculate that the grafted FFB is still not completely revascularized (in particular in the outer part) even 1 year after the reconstruction (at the time of implant loading). Once put in contact with the oral cavity, due to the presence of transmucosal abutments, FFB grafts undergo dehiscences with variable areas of bone exposures, with all the connected risks for graft and implant survival (six out of eight patients treated with FFB grafts present apparently integrated implants supporting fixed prostheses but with an unpredictable prognosis).

Our findings are therefore in contrast with those reported in other studies in which apparently favorable results have been obtained with FFB,[24,25,27–29,45] while they confirm the inconsistent results reported by other authors.[31–33]

Furthermore, it is worth noting that an in vitro study by Simpson and colleagues published in 2007[22] demonstrated that FFB, despite the freezing process at –80°C and after at least 6 months of quarantine in a bone bank, still maintains vital cells. In fact, it has been shown that osteoblast-related cells can be grown in vitro from fresh frozen allograft specimens. The cells derived from frozen grafts were morphologically indistinguishable from those grown out of freshly harvested trabecular bone and the authors concluded that a frozen autograft will resemble an allograft. The detrimental effects of preservation and the immune response to the allografts contribute to failure of these grafts in vivo.[46] In allograft recipients, growth of donor cells may be one aspect of a whole spectrum of immunological reactions occurring following implantation, which may lead to a localized host/graft immune response and explain the inconsistent behavior of allografts. Therefore, at present, FFB should be used with extreme caution.

CONCLUSION

Within the limits represented by the small patients' sample and the relatively short follow-up period, observations from this study seem to demonstrate that results obtained in patients treated with iliac autografts (in terms of implant survival and peri-implant bone resorption) are consistent with those reported in the literature for implants placed in native, non-reconstructed bone. The only drawback is the higher morbidity associated to the need of harvesting bone from the anterior ilium.

On the contrary, results obtained in patients reconstructed with fresh frozen allogeneic onlay grafts demonstrate a high incidence of graft exposures, particularly after implant placement and loading, the presence of areas of non-vital bone, and a lower survival rate of implants. The only advantage was represented by the lower morbidity following the reconstruction because of the absence of the harvesting procedure. Moreover, the presence of immunological reactions occurring following implantation, which may lead to a localized host/graft immune response,[22] suggests that at present, fresh frozen allogeneic iliac grafts do not represent a safe and reliable alternative to autogenous iliac grafts. Further studies are needed to investigate the behavior of FFB allograft, with both clinical and in vitro studies.

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