Cancellous Bone Block Allografts for the Augmentation of the Anterior Atrophic Maxilla

Joseph Nissan, DMD;* Ofer Mardinger, DMD;† Shlomo Calderon, DMD;‡
George E. Romanos, DDS, Dr.med.dent., PhD;§¶ Gavriel Chaushu, DMD, MSc**

ABSTRACT

Background: Pre-implant augmentative surgery is a prerequisite in many cases in the anterior maxilla to achieve a stable, long-term esthetic final result.

Purpose: The aim of the present study was to evaluate the outcome of ridge augmentation with cancellous freeze-dried block bone allografts in the anterior atrophic maxilla followed by placement of dental implants.

Materials and Methods: Thirty-one consecutive patients were included in the study. A bony deficiency of at least 3 mm horizontally and up to 3 mm vertically according to computerized tomography (CT) served as inclusion criteria. Sixty-three implants were inserted after a healing period of 6 months. Nineteen of sixty-three implants were immediately restored. Bone measurements were taken prior to bone augmentation, during implant placement, and at second-stage surgery.

Results: Forty-six cancellous allogeneic bone blocks were used. The mean follow-up was 34 ± 16 months. Mean bone gain was 5 ± 0.5 mm horizontally, and 2 ± 0.5 mm vertically. Mean buccal bone resorption was 0.5 ± 0.5 mm at implant placement, and 0.2 ± 0.2 mm at second-stage surgery. Mean bone thickness buccal to the implant neck was 2.5 ± 0.5 mm at implant placement, and 2.3 ± 0.2 mm at second-stage surgery. There was no evidence of vertical bone loss between implant placement and second-stage surgery. Block and implant survival rates were 95.6 and 98%, respectively. All patients received a fixed implant-supported prosthesis.

Conclusion: Cancellous block allografts appear to hold promise for grafting the anterior atrophic maxilla.

KEY WORDS: alveolar ridge augmentation, anterior atrophic maxilla, cancellous freeze-dried block bone allografts, dental implants, esthetic zone

The remarkable success of the traditional Brånemark implant protocol[1–3] revolutionized dentistry. This huge success created a need and demand for implant placement in compromised sites. Such a demand cannot be fulfilled on the expense of a good esthetic outcome. The presence of an adequate bone volume is critical for providing a predictable bony support for the gingival margin and papillae, thus contributing to an esthetic final result.[4–6]

Another crucial aspect of implant dentistry is biomechanics. Long-term results are directly related to occlusal loads exerted by the final prosthesis. Overloading can lead to biological and/or mechanical complications.[7] A force applied along the axis of an implant will be distributed around the implant, and the supporting bone will have a high load-bearing capacity. This is the situation in the posterior areas of the jaws. However, in

*Senior lecturer, Department of Oral Rehabilitation, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel; †lecturer, Department of Oral and Maxillofacial Surgery, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel; ‡professor, Department of Oral and Maxillofacial Surgery, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel; §professor, Division of Periodontology, Eastman Dental Center, University of Rochester, Rochester, NY, USA; ¶professor, Department of Oral Surgery and Implant Dentistry, Dental School Frankfurt (Carolinum), University of Frankfurt, Frankfurt, Germany; **senior lecturer, Department of Oral and Maxillofacial Surgery, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel

Reprint requests: Dr. Joseph Nissan, Department of Oral Rehabilitation, School of Dental Medicine, Tel Aviv University, P.O. Box 39040, Tel Aviv 69978, Israel; e-mail: nissandr@post.tau.ac.il

DOI 10.1111/j.1708-8208.2009.00193.x

the anterior maxillary area, the forces applied have a significant transverse direction resulting in a bending moment which can be detrimental to both implant and supporting tissues.[8] Placing narrow implants, tilted buccally, having oversized clinical crowns may result in unfavorable biomechanics, leading to severe complications in the anterior area.[9]

Therefore, pre-implant augmentative surgery is a prerequisite in many cases in the anterior maxilla.[4–6,10] A variety of bone-grafting materials have been used using wound healing mechanisms as osteogenesis, osteoinduction, and osteoconduction.[11] Autogenous bone harvested from either extraoral or intraoral sites is still the "gold standard."[12] Other sources include allogeneic, alloplastic, and xenogeneic materials.[11] The compromised alveolar ridge in the anterior maxilla does not provide a natural cavity to contain the particulated grafting material as seen in sinuses.[13] Therefore, the graft must possess strength and rigidity to allow its fixation in the recipient site, and three-dimensional stability to withstand muscular forces.[14] Consequently, a block graft is recommended in the anterior maxilla if the required augmentation exceeds 3 mm in either width, height, or both.[15]

Autogenous bone has always been the material of choice for cortical – cancellous blocks.[16–19] Preliminary reports[20–25] suggest that a block allograft in conjunction with a resorbable membrane may be an acceptable alternative to the autogenous block graft in the treatment of compromised alveolar ridges.

The aim of this study was to analyze the outcome of augmentation with 46 freeze-dried cancellous block allografts in the anterior atrophic maxilla followed by placement of 63 dental implants with a mean follow-up of 34 months.

MATERIALS AND METHODS

A total of 34 patients presenting with atrophic maxillary anterior alveolar ridges were originally included in the study, however, because three of those (8.8%) were lost to follow-up, they were excluded from the study. The remaining 31 patients were provided with a total of 46 (15 patients – two blocks, 16 patients – one block) freeze-dried cancellous bone block allografts and 63 (17 patients – one implant, eight patients – two implants, one patient – three implants, three patients – five implants, two patients – six implants) dental implants (33-Seven, MIS Implant Technologies Ltd, Shlomi, Israel); 18-Osseotite® (3i/Implant Innovations, Biomet®, Palm Beach Gardens, FL, USA), 12-Tapered Screw-Vent (Zimmer Dental, Carlsbad, CA, USA). In cases requiring more than two implants, several blocks were used. Reasons for tooth loss included trauma (39.1%), congenitally missing teeth (21.7%), periodontal disease (19.6%), endodontic failure (13%), and implant failure (6.6%). The patients were offered the use of both autogenous blocks from intraoral sites and allogeneic cancellous blocks for augmentation. The patient group comprised 20 women and 11 men, with an age range from 17 to 70 years (mean age 32 ± 16 years). The implants were placed after a healing period of 6 months. Nineteen implants in 14 patients were immediately loaded, while in 17 patients 44 implants were allowed to heal for 6 additional months. The implants were restored with fixed cement-retained restorations.

All patients were selected after a meticulous evaluation of their medical histories and dental examinations that included panoramic, orthoradial periapical radiographs, and dental computerized tomography (CT) scans. A bony deficiency of at least 3 mm horizontally and up to 3 mm vertically according to CT para-axial reconstruction served as inclusion criteria. Postoperative panoramic and orthoradial periapical radiographs were taken to compare with the preoperative ones. All procedures were fully explained to the patients, and the Ethics Committee of the Tel Aviv University approved the study protocol.

A staged approach was planned to reduce potential complications (wound dehiscence, block graft fracture, implant loss), which have been associated with simultaneous grafting and implant placement.[20]

One hour preoperatively, oral antibiotics of 1,000 mg amoxicillin (Moxypen® Forte, Teva Pharmaceutical Ltd., Petach Tikva, Israel) and 600 mg etodolac (Etopan, Taro Pharmaceutical Industries Ltd., Haifa Bay, Israel) were administered. Antiseptic mouthwash, 0.2% chlorhexidine gluconate (Tarodent®, Taro Pharmaceutical Industries Ltd.), was used immediately prior to surgery.

The prepared allograft was rehydrated with a solution of sterile saline for at least 45 minutes prior to initiating the procedure. Under local anesthesia (block and infiltration using 2% lidocaine with 1:100,000 epinephrine), surgery commenced at the recipient site to confirm the shape and size of the defect as previously seen on the CT para-axial reconstruction. Freeze-dried

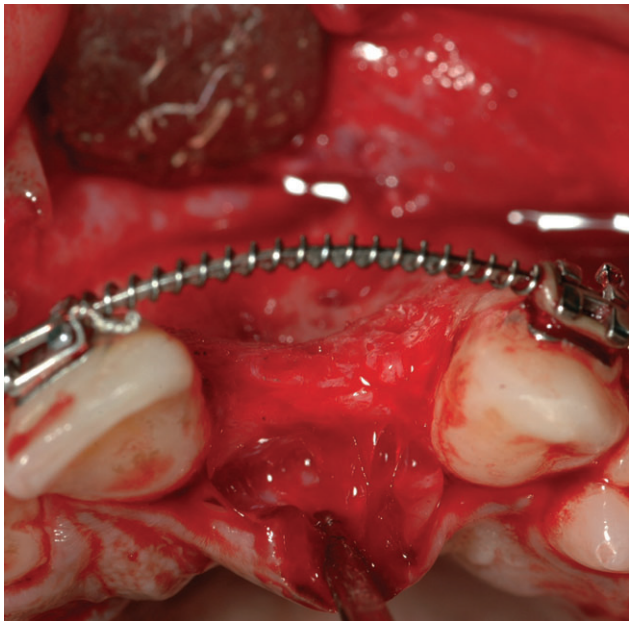

Figure 1 Preoperative clinical view.

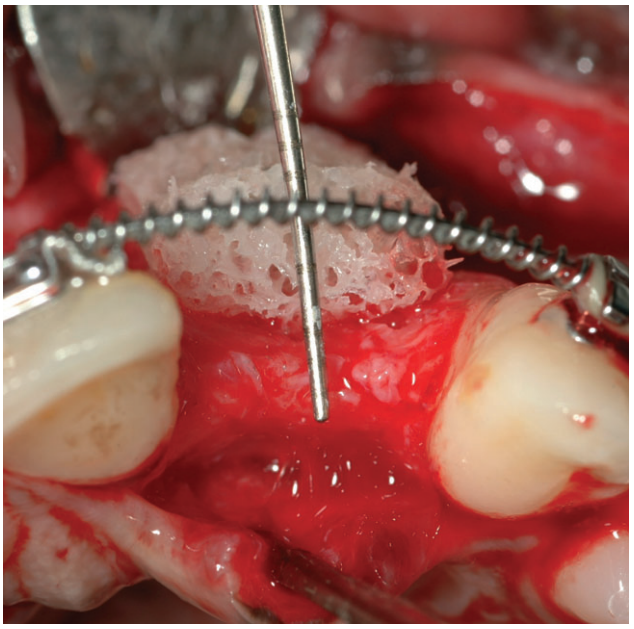

Figure 2 Graft is fixed in place to augment the anterior maxillary alveolus.

cancellous block allograft (ReadiGraft®, Canblock 1.5, LifeNet, Virginia Beach, VA, USA) was shaped with a fissure bur in a high-speed handpiece with copious irrigation. The end point was a block graft that closely approximated the recipient bed and provided adequate width and height to accomplish the restorative treatment plan. It was then thoroughly rinsed with sterile saline to remove residual bone particles.

A midcrestal incision based on the missing teeth was made. The incision was extended intrasulcularly around the cervical margins of the adjacent teeth up to the canines. Two vertical releasing incisions were made on the labial aspect distal to the canines, away from the recipient site to include the papilla between the canine and the first premolar. The vertical releasing incisions were thus extended away from the esthetic zone into the mobile mucosa. The buccal aspect of the alveolar ridge was then exposed to allow three-dimensional visualization of the defect (Figure 1).

Several modalities were applied in order to expose native bone to the bone graft, ensuring possible communication between grafted bone and the recipient site bone marrow cavity. The most frequent technique used in cases with a noticeable cortical bone was multiple perforations, made through the cortical plate with a round bur. In cases with dense cortical bone, decortication was carried out. Cases presenting after recent trauma or surgery without evident cortex and profound bleeding were left as is without additional preparation.

The cancellous block graft was refined to fit into the defect. Once the graft was seated and stable, it was fixed with 1.6×10 mm bone screws (OsteoMed Corporation, Addison, TX, USA) (Figure 2). A high-speed, water-cooled, large round bur was used to round the sharp cortical edges and shape it to completely conform to the defect site. Measurements of the initial and post-augmentation ridge width and height were taken with a periodontal probe scaled in millimeters and bone changes calculated. Measurements were taken from the edge of the alveolar crest in the position of implant site. Implant site was verified by the aid of a periodontal probe relative to the distance from the adjacent teeth. Measurements were enabled by the different clinical view of the cancellous block and the corticated original bone. Deficiencies at the edges of the graft were filled with either particulate bone, mineralized freeze-dried bone allograft (OraGraft®, LifeNet, Virginia Beach, VA, USA) or bovine bone mineral (Bio-Oss®, Geistlich Biomaterials, Wolhousen, Switzerland). One of either three resorbable membranes (Bio Gide®, Geistlich Biomaterials; Ossix™, 3i/Implant Innovations, Biomet; Ossix Plus™, OraPharma Inc., Warminster, PA, USA) were used.

Periosteal releasing incisions were made. The midcrestal incision was initially closed using interrupted or horizontal mattress sutures as needed. The interdental papillae and the vertical incisions were secured with

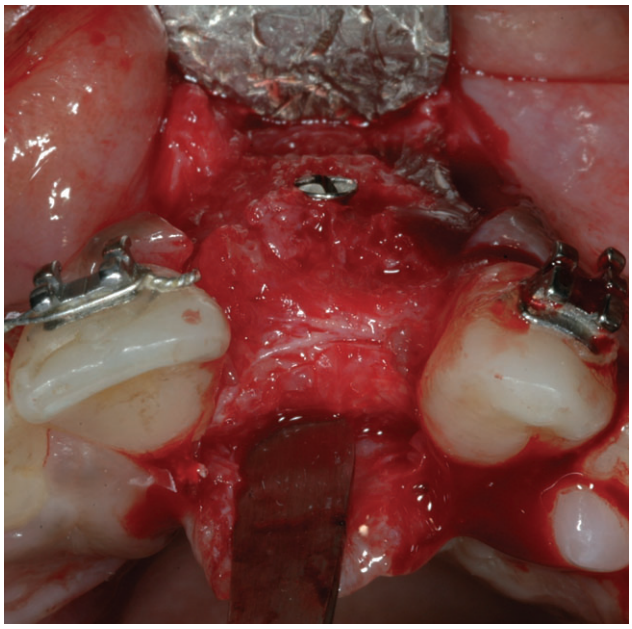

Figure 3 Exposure of graft at 6 months.

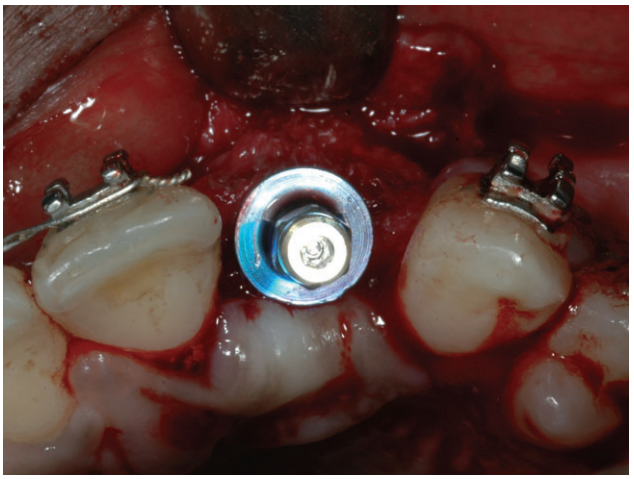

Figure 4 Placement of implant in augmented ridge.

interrupted sutures. Amoxycillin (Moxypen Forte) 500 mg three times daily (tid) and 600 mg etodolac (Etopan) twice daily (bid) were prescribed for 5 days postoperatively. As an antiseptic solution, 0.2% chlorhexidine gluconate mouthwash (Tarodent) was used for 45 seconds, tid for 2 weeks.

Provisional restorations were modified to prevent the application of any pressure to the healing tissues. All provisional restorations were fitted and delivered to the patient immediately after surgery. The grafted sites were allowed to heal for 6 months. The patients were seen weekly during the first month following surgery, and monthly thereafter until second-stage surgery. Periapical radiographs were taken immediately postoperatively and prior to implant placement. The clinical evaluation included a thorough search for soft tissue dehiscence and an overall view of the grafted ridge contour.

Access to the augmented ridge was obtained after 6 months via an incision similar to the one used during graft placement. The augmented site was evaluated. Surgical exposure of the augmentation site revealed well-integrated block grafts that were incorporated into the surrounding bone (Figure 3). The fixation screws were removed. Measurements of post-augmentation ridge width and height were taken to assess bone gain followed by implant placement (Figure 4). Bone thickness buccal to the implant was measured at the time of implant placement and uncovering.

The implants were either nonfunctionally immediately loaded (non-occlusal contacts present) or exposed 6 months later. For all the nonfunctionally immediately loading cases, the provisional acrylic crowns were prefabricated in the laboratory prior to surgery. The occlusion was adjusted and finalized without contacts in protrusive excursions or intercuspal position. The temporary acrylic-fixed restorations were adjusted over temporary abutments.

In cases with two-stage healing period, the soft tissues were allowed to mature for 3 weeks following implant exposure. Cement-retained restorations were then fabricated. In cases that were immediately loaded, 6 months after implant placement, radiographs of the implant sites were taken. The implants were restored with cement-retained fixed ceramic prostheses (Figure 5). Temporary cement (TempBond™, Kerr Italia, Salerno, Italy) was used to enable future maintenance and follow-up. Clinical and radiographic examinations were carried out at the time of restoration, and every 6 months follow-up during the first year and once a year thereafter (Figure 6).

RESULTS

Forty-six ridges of 31 patients were grafted. Sixty-three implants were placed in the augmented sites. Of the grafts, 9% were used to gain height, 40% were used to gain width, and 51% to gain both height and width. Bone gain (Table 1) in horizontal (4–6 mm, mean 5 ± 0.5 mm, 50–75%, mean $62.5 \pm 6.3\%$ of final width) dimension exceeded bone gain in vertical dimension (0–3 mm, mean 2 ± 0.5 mm). Buccal bone resorption

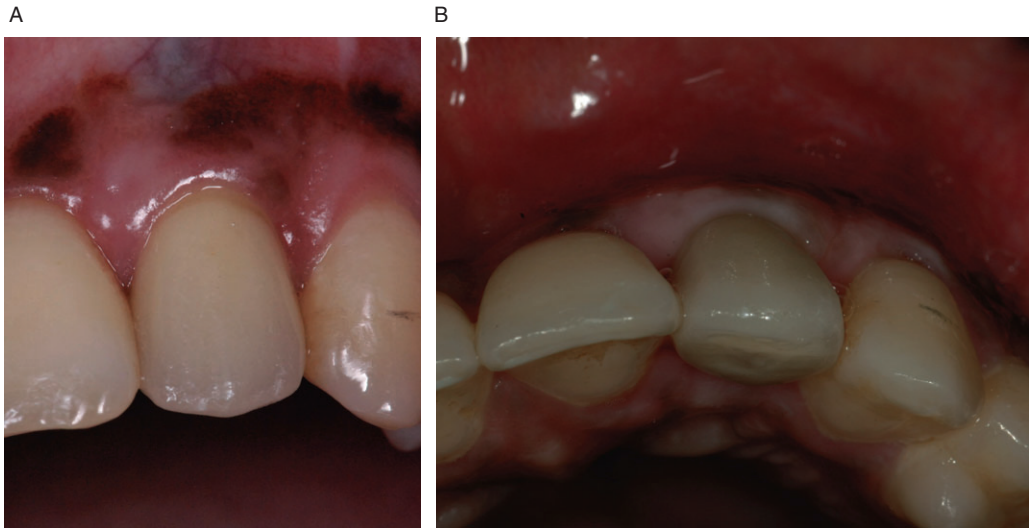

Figure 5 Final clinical view: (A) anterior and (B) occlusal.

(Table 2) was 0–1 mm, mean 0.5 ± 0.5 mm, 0–20%, mean 10 ± 1% of bone graft at implant placement and 0–0.5 mm, mean 0.2 ± 0.2 mm, 0–10%, mean 4% ± 4% of bone graft at second-stage surgery. Bone thickness buccal to the implant neck (Table 3) was 2–3 mm, mean 2.5 ± 0.5 mm at implant placement and 2–2.5 mm, mean 2.3 ± 0.2 mm at second-stage surgery. There was no evidence of vertical bone loss between implant placement and second-stage surgery.

Soft tissue breakdown and graft exposure occurred in 13 (28%) cases. Necrotic soft tissue was removed; the bone was leveled with the soft tissue by the aid of a high-speed bur. Bone resorption was most significant in those cases. Two blocks failed; in five cases soft tissue dehiscence did not prevent bone formation, and in six cases soft tissue closure was achieved within 4 weeks. Two block grafts failed because of soft tissue breakdown, infection, and loss of fixation resulting in 95.6% survival rate. One out of the 19 immediately loaded implants (98% survival rate) failed following automobile accident

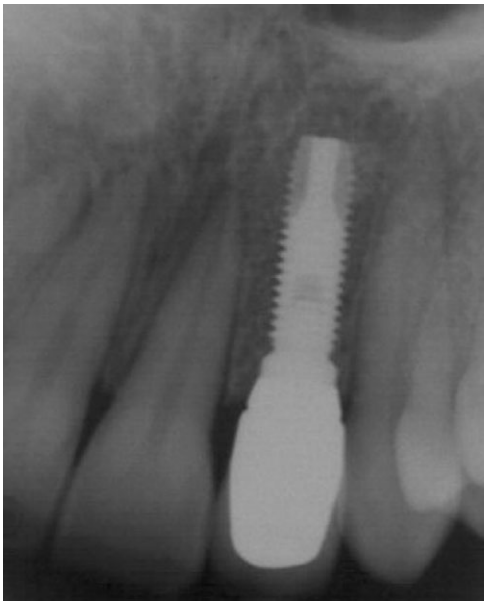

Figure 6 Follow-up radiograph at 42 months.

TABLE 1 Bone Gain Characteristics (mm)

Bone gain	*n*	Range	Mean	SD	SE
Horizontal	42	4–6	5	0.5	0.08
Vertical	27	0–3	2	0.5	0.1

TABLE 2 Buccal Bone Resorption (mm)

	n	Range	Mean	SD	SE
Implant placement	63	0–1	0.5	0.5	0.06
Second stage	44	0–0.5	0.2	0.2	0.03

TABLE 3 Buccal Bone Thickness (mm)

	n	Range	Mean	SD	SE
Implant placement	63	2–3	2.5	0.5	0.06
Second stage	44	2–2.5	2.3	0.2	0.03

trauma. After 3 months of waiting, the implant was reinserted and successfully osseointegrated. All patients received a fixed implant-supported prosthesis.

The mean follow-up was 34 ± 16 months (range 6–59 months). All implants remained clinically osseointegrated at the end of the follow-up examination. There was no crestal bone loss around the implants beyond the first implant thread.

DISCUSSION

The use of dental implants in the anterior maxilla is well documented in the literature, and numerous controlled clinical trials show that the respective overall implant survival and success rates are high (91.1–100%), and similar to those reported for other segments of the jaws.[5] Initial patient evaluation must assess buccolingual ridge anatomy as one of the most important for treatment planning. Bone augmentation procedures are indicated in cases of deficient alveolar crest to allow implant placement in a correct buccolingual position. The extent and morphology of the alveolar crest deficiency dictate a simultaneous or staged approach.[26] The presence of bone is also the first determining factor for the soft tissue contour. Therefore, the bone volume is also essential from an esthetic perspective.[6] Photoelastic and finite-element analysis studies demonstrate stress concentration at the buccal aspect in the anterior maxilla. Those studies suggest that significant buccal bone volume is desirable to obtain a physiological modeling response which will support long-term esthetics. Insufficient bone volume may result in buccal fenestration or dehiscence resulting in biomechanical and esthetic deterioration.[27–29] To achieve a long-term anterior esthetic result, the available bone thickness buccal to the implant neck should be at least 2 mm, preferably 4 mm.[30] When this is not taken into consideration, the buccal bone is resorbed resulting in loss of buccal bone height followed by gingival recession and an esthetic failure. Because such bony thickness dimensions cannot be found bone normally on the buccal side, augmentation procedures are indicated in almost every esthetically demanding case. Thus, even if the entire implant bony envelope is intact without thread exposure, bone grafting will still be needed.[6] The use of cancellous block allografts in the present study maintained a 2–3 mm buccal bone thickness at second-stage surgery. Therefore, the esthetic requirements are fulfilled by this modality of bone grafting.

Reports of implants in grafted bone of the anterior maxilla compare favorably with the results of implants placed in nongrafted bone. A report of 10 implants placed in nine patients, following a graft healing period of 3 to 5 months, revealed that one implant had not integrated at the time of abutment surgery.[31] Another article reported on 27 patients with 31 maxillary implants placed after grafting with bone from a variety of intraoral sites, including the mandibular symphysis, with 100% success.[32] The survival of 35 implants of 17 patients following mandibular symphysis buccal onlay bone grafting in the anterior maxilla was 97.1%.[33]

The present study has focused on the outcome of loaded implants for a mean follow-up period of 34 ± 16 months (range 6–59 months). The survival rates of cancellous allogeneic blocks (95.6%), two-stage implants (100%), and immediately loaded implants (98%) compare favorably with the literature regarding implant outcome in the anterior maxilla.[5]

Several advantages of the described technique should be emphasized. The area, size, and contour of the bone regeneration are dictated by the size and shape of the compromised alveolar ridge. The cancellous block allograft can be modified to comply with the desired height and width of the new generated bone. In contrast, the contour and size of the autogenously harvested block grafts are very difficult to control because of the inherent shape of the cortical bone graft itself, which must be reshaped to fit the contours and curves of the anterior maxilla.

Esthetic demands are provided by the cancellous block allograft without donor site morbidity and discomfort to the patient. The patients define the morbidity of such procedures as severe. Each intra- or extraoral donor site has its own inherent problems and potential complications. For example, morbidity after iliac crest bone harvesting techniques occurs during physical activity, and discomfort in the oral cavity especially in the donor sites after intraoral surgical procedures.[34]

Autogenous block graft harvesting may result in up to 43% of some paresthesia.[34] Although such disturbances can recover spontaneously,[35] the best way is to avoid them. Therefore, the patients must be informed about the risks of sensory disturbance in the various autogenous donor regions.

Radiographically, complete healing of the donor requires around 6 months[36] even in successful cases.

Moreover, radiographic evidence of incomplete bony regeneration in donor sites has been also reported in elderly patients.[35]

Another major drawback for using autogenous bone blocks is its inability to withstand long-term, three-dimensional stability. Resorption rates of 0 to 25% at the time of implant placement, and up to 60% at abutment connection were documented with the use of autogenous block grafts.[11] Thus, many clinicians and patients are confronted with dilemma of whether the risk (morbidity)/benefit of autogenous bone block harvesting is worth taking. In the present study, resorption rates at the time of implant placement were 10 and 14% at second-stage surgery. This demonstrates the potential of cancellous block allografts to minimize bone resorption and allow a long-term stable esthetic result compared to autogenous block grafts. This of course awaits future long-term studies for the validation of the present data. In the present study, the considerations of risk (morbidity)/benefit were in favor of grafting because the parameter of risk and morbidity was minimized while the surgical techniques have been improved.

All the above-mentioned advantages of using cancellous block allografts allow the implementation of an esthetic implant-supported fixed prosthesis in the anterior atrophic maxilla, even in cases that would have been impossible to be performed previously because of lack of patient willingness to undergo complex harvesting procedures.

Until more data are gathered and published, the surgeon, prosthodontist, and patient must be aware of potential complications, and treatment alternatives should be thoroughly emphasized to the patient. Further clinical and histological studies are necessary in order to promote routine clinical application of this treatment alternative.

CONCLUSION

Within the limits of the present study, the data indicate that implant placement in the anterior atrophic maxilla following augmentation with freeze-dried cancellous block allograft can result in successful implant integration up to 59 months. Future studies should focus on bone gain and resorption in both dimensions in every stage, compare cases with single blocks to multiple, and cases with soft tissue dehiscence to those without through statistical analysis.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981; 10:387–416.
2. Albrektsson T, Branemark P-I, Hansson HA, Lindström J. Osseointegrated titanium implants: requirements for ensuring a long lasting, direct bone to implant anchorage in man. Acta Orthop Scand 1981; 52:155–170.
3. Branemark P-I. Osseointegration and its experimental background. J Prosthet Dent 1983; 50:399–410.
4. Palacci P, Ericsson I. Anterior maxilla classification. In: Palacci P, Ericsson I, eds. Esthetic implant dentistry. Soft and hard tissue management. Hanover Park, IL: Quintessence Publishing Co, Inc, 2001:89–100.
5. Belser UC, Schmid B, Higginbottom F, Buser D. Outcome analysis of implant restorations located in the anterior maxilla: a review of the recent literature. Int J Oral Maxillofac Implants 2004; 19:30–42.
6. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. Int J Periodontics Restorative Dent 2005; 25:113–119.
7. Rangert B, Krogh PHJ, Langer B, van Roekel N. Bending overload and implant fracture: a retrospective clinical analysis. Int J Oral Maxillofac Implants 1995; 10:326–334.
8. Rangert B, Jemt T, Jörneus L. Forces and moments on Branemark implants. Int J Oral Maxillofac Implants 1989; 4:241–247.
9. Hsu ML, Chen FC, Kao HC, Cheng CK. Influence of off-axis loading of an anterior maxillary implant: a 3-dimensional finite element analysis. Int J Oral Maxillofac Implants 2007; 22:301–309.
10. Sethi A, Kaus T. Ridge augmentation using mandibular block bone grafts: preliminary results of an ongoing prospective study. Int J Oral Maxillofac Implants 2001; 16:378–388.
11. McAllister BS, Haghighat K. Bone augmentation techniques. J Periodontol 2007; 78:377–396.
12. Lundgren S, Sjostrom M, Nystrom E, Sennerby L. Strategies in reconstruction of the atrophic maxilla with autogenous bone grafts and endosseous implants. Periodontol 2000 2008; 47:143–161.
13. Chaushu G, Mardinger O, Calderon S, Moses O, Nissan J. The use of cancellous block-allograft for sinus floor augmentation with simultaneous implant placement in the posterior atrophic maxilla. J Periodontol 2009; 80:422–428.
14. Moy P, Palacci P. Minor bone augmentation procedures. In: Palacci P, Ericsson I, eds. Esthetic implant dentistry. Soft and hard tissue management. Hanover Park, IL: Quintessence Publishing Co, Inc, 2001:137–158.
15. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. Clin Oral Implants Res 1999; 10:278–288.

16. Misch CM, Misch CE, Resnik RR, Ismail YH. Reconstruction of maxillary alveolar defects with mandibular symphysis grafts for dental implants: a preliminary procedural report. Int J Oral Maxillofac Implants 1992; 7:360–366.
17. Verhoeven JW, Cune MS, Terlou M, Zoon MA, de Putter C. The combined use of endosteal implants and iliac crest onlay grafts in the severely atrophic mandible: a longitudinal study. Int J Oral Maxillofac Surg 1997; 26:351–377.
18. Hunt D, Jovanovic S. Autogenous bone harvesting: a chin technique for particulate and monocortical bone blocks. Int J Periodontics Restorative Dent 1999; 19:165–173.
19. D'Addona A, Nowzari H. Intramembranous autogenous osseous transplants in aesthetic treatment of alveolar atrophy. Periodontol 2000 2001; 27:148–161.
20. Leonetti JA, Koup R. Localized maxillary ridge augmentation with a block allograft for dental implant placement: case reports. Implant Dent 2003; 12:217–226.
21. Lyford RH, Mills MP, Knapp CI, Scheyer ET, Mellonig JT. Clinical evaluation of freeze-dried block allografts for alveolar ridge augmentation: a case series. Int J Periodontics Restorative Dent 2003; 23:417–425.
22. Keith JD Jr. Localized ridge augmentation with a block allograft followed by secondary implant placement: a case report. Int J Periodontics Restorative Dent 2004; 24:11–17.
23. Petrungaro PS, Amar S. Localized ridge augmentation with allogeneic block grafts prior to implant placement: case reports and histologic evaluations. Implant Dent 2005; 14:139–148.
24. Keith JD Jr, Petrungaro P, Leonetti JA, et al. Clinical and histologic evaluation of a mineralized block allograft: results from the developmental period (2001–2004). Int J Periodontics Restorative Dent 2006; 26:321–327.
25. Nissan J, Romanos GE, Mardinger O, Chaushu G. Immediate nonfunctional loading of single-tooth implants in the anterior maxilla following augmentation with cancellous freeze-dried block allograft: a case series. Int J Oral Maxillofac Implants 2008; 23:709–716.
26. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. Int J Oral Maxillofac Implants 2004; 19:43–61.
27. Gross MD, Arbel G, Hershkovitz I. Three-dimensional finite element analysis of the facial skeleton on simulated occlusal loading. J Oral Rehabil 2001; 28:684–694.
28. Gross MD, Nissan J, Samuel R. Stress distribution around maxillary implants in anatomic photoelastic models of varying geometry. Part I. J Prosthet Dent 2001; 85:442–449.
29. Gross MD, Nissan J. Stress distribution around maxillary implants in anatomic photoelastic models of varying geometry. Part II. J Prosthet Dent 2001; 85:450–454.
30. Spray RJ, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone responses: stage 1 placement through stage 2 uncovering. Ann Periodontol 2000; 5:119–128.
31. Widmark G, Andersson B, Ivanoff CJ. Mandibular bone graft in the anterior maxilla for single-tooth implants. Presentation of a surgical method. Int J Oral Maxillofac Surg 1997; 26:106–109.
32. Raghoebar GM, Batenburg RH, Vissenk A, Reintsema H. Augmentation of localized defects of the anterior maxillary ridge with autogenous bone before insertion of implants. J Oral Maxillofac Surg 1996; 54:1180–1185.
33. McCarthy C, Patel RR, Wragg PF, Brook IM. Dental implants and onlay bone grafts in the anterior maxilla: analysis of clinical outcome. Int J Oral Maxillofac Implants 2003; 18:238–241.
34. Raghoebar GM, Louwerse C, Kalk WWI, Vissink A. Morbidity of chin bone harvesting. Clin Oral Implants Res 2001; 12:503–507.
35. Jensen J, Sindet-Pedersen S. Autogenous mandibular bone grafts and osseointergrated implants for reconstruction of the severely atrophied maxilla: a preliminary report. J Oral Maxillofac Surg 1991; 48:1277–1287.
36. Sindet-Pedersen S, Enemark H. Mandibular bone grafts for reconstruction of alveolar clefts. J Oral Maxillofac Surg 1988; 46:533–537.