Ridge Augmentation Using Mandibular Block Bone Grafts: Preliminary Results of an Ongoing Prospective Study

Ashok Sethi, BDS, DGDP, MGDSRCS, DUI[1]/Thomas Kaus, Dr Med Dent[2]

The aim of the current ongoing study is to evaluate the long-term results of endosseous implants placed into autogenous bone grafts from intraoral donor sites. Patient selection for the correction of bone deficiencies was based on biomechanical and esthetic needs. Donor site selection was dependent upon the type of deficiency and the graft shape needed. Two-stage implants were placed after a healing period of 3 to 6 months, based on an assessment of the graft viability with radiographic and clinical parameters. Thus far, 118 implants have been placed in 60 patients whose alveolar ridges were deficient in height, width, or both height and width and were augmented. The patients were observed for up to 77 months. Two implant failures were encountered before implant exposure (1.7%). No further implants have been lost in function. (INT J ORAL MAXILLOFAC IMPLANTS 2001;16:378–388)

Key words: *alveolar ridge augmentation, autogenous bone graft, esthetics, intraoral donor sites, osseointegrated dental implants*

With patients' increasing demand for implant-supported prostheses, implant dentists and surgical-prosthetic teams are faced with high patient expectations concerning optimal function and esthetics. Multiple studies have shown the predictability and excellent long-term results that can be achieved with osseointegrated implants whenever sufficient bone volume is available.[1–12]

Adequate bone volume at the future implant site is a prerequisite for good esthetic outcome and sound biomechanical support of the osseointegrated implant. However, alveolar deficiencies can often prevent ideal implant placement. Furthermore, the gingival margin and papillae, which contribute to the esthetic outcome, are dependent on support from the underlying vital bone.[13]

Predictable methods to treat osseous ridge deficiencies are therefore a necessity to achieve treatment outcomes comparable to the results seen for the uncompromised alveolar ridge. Several ridge augmentation techniques, including bone spreading,[14–18] bone grafting,[19–23] and guided bone regeneration,[24–33] have been described in the literature. Those techniques have been performed during implant placement or in stages, with implant placement being carried out some months after bone augmentation.

The main purpose of this article was to present preliminary results of the long-term clinical behavior of dental implants placed after augmentation of alveolar ridge deficiencies by means of autogenous bone grafts harvested from intraoral donor sites.

MATERIALS AND METHODS

The study was designed prospectively and performed at the Centre for Implant and Reconstructive Dentistry, London, United Kingdom. A total of 60 patients have been included in the study to date, which began in 1992. These patients have been provided with a total of 118 implants in situations where maxillary and mandibular ridges deficient in height and width were augmented using autogenous bone grafts harvested from an intraoral site. The patient group comprised 34 women and 26 men, with an age range from 18 to 69 years at the date of implant surgery (mean age was 47 years). The distribution of implants placed is given in Table 1.

[1]Senior Lecturer, Department of Maxillofacial Implants, Medical School, University of Lille 2, Lille, France.
[2]Zahnmedizinisches Fortbildungszentrum Stuttgart, Stuttgart, Germany; Senior Lecturer, Department of Prosthodontics, University of Tübingen, Germany.

Reprint requests: Dr Ashok Sethi, Centre for Implant and Reconstructive Dentistry, 33 Harley Street, London W1N 1DA United Kingdom. Fax: +44-207-436-8979. E-mail: asethi@dircon.co.uk

Table 1	Distribution of Implants		
Location	Anterior	Posterior	Total
Maxilla	88	13	101
Mandible	0	17	17
Total	88	30	118

Fig 1 *(Right)* Classification of bone deficiencies.
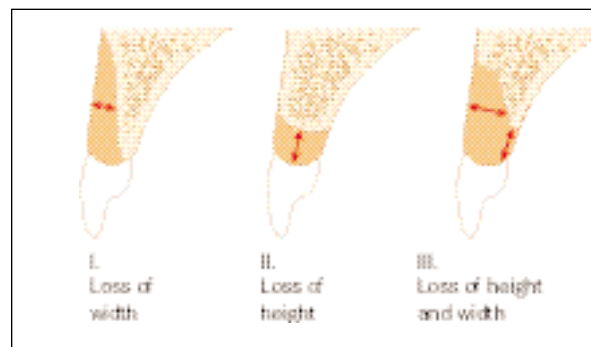
After a healing period of 3 to 6 months, 2-stage implants were placed and the sites were allowed to heal for 6 months. Implants were placed in a variety of sites in the maxilla and mandible. These have been restored with fixed cement-retained restorations.

Patient Selection

Patients selected for the study exhibited no contraindications for implant treatment. Patients were selected for augmentation with bone from an intraoral site based on recipient and donor site criteria.

Recipient Site Criteria (Figs 1 and 2). The selection criteria are summarized in Table 2.

Deficiencies in Ridge Width. This group included patients who were not suitable for maxillary ridge expansion (according to a recently published protocol[34]) because of ridge morphology (ie, labial and palatal cortical plates were fused or too narrow for expansion). These patients were treated with grafts obtained from the symphysis or the ramus. It was considered possible to increase the ridge width by 2 to 4 mm using an intraoral graft harvested from the symphysis for up to 6 implants; alternatively, bone from one ramus was considered when 1 or 2 implants were planned. If an increase in ridge width of up to 6 mm was required, bone was harvested from the ramus when up to 2 implants were planned. In situations involving multiple implants, where substantial lip support (greater than 4 mm) was required, the patient was treated with grafts from an extraoral source and therefore not included in this study.

Deficiencies in Height. For an increase in ridge height of 2 to 4 mm and up to 4 planned implants, an intraoral harvest site was used. If more than 2 implants were planned, only the symphysis was considered as a donor site.

Deficiencies in Ridge Height and Width. If an increase of ridge height up to 4 mm and an increase

of ridge width up to 6 mm was required, the graft was obtained from the ramus. Up to 2 implant sites could be developed using a graft from one ramus. The increase in height was limited by the level of bone attachment to the adjacent teeth. When sufficient bone could not be harvested from the ramus, the symphysis was used in selected patients requiring only a minimal increase in height.

Donor Site Selection Criteria. These were based on available bone and assessed by means of panoramic radiographs. Calculations for the magnification were made. Lateral cephalographs were also used for assessment of the symphyseal donor site. Symphyseal donor sites were selected based on the availability of bone between the inferior border of the mandible and apices of the teeth. A 5-mm clearance between the graft site and the apices of the teeth was required to prevent injury to the teeth. Ramus donor sites were selected based on 3 main factors: the absence of third molars, the width of the ramus between the external oblique ridge and the lingual wall of the mandible, and the availability of bone above the inferior alveolar canal measured from the external oblique ridge. Only when recipient and donor site criteria could be matched was an intraoral site selected to harvest bone.

Patient Assessment

Single-tooth Replacements. When a single tooth needed to be replaced, or where there were up to 3 missing teeth, periapical radiographs in conjunction with panoramic radiographs (OPT) were considered sufficient to provide adequate diagnostic information about ridge height. Ridge width was measured using calipers under local anesthetic.[35]

Multiple-unit Restorations. Panoramic radiographs formed the primary means of ridge evaluation. However, computed tomographic (CT) scans
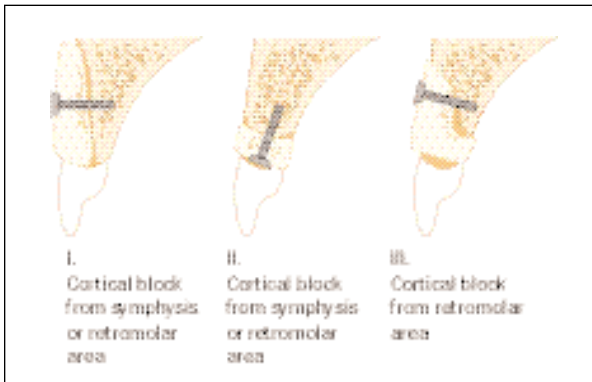
Fig 2a Diagram illustrating the type of graft required for the correction of the 3 types of deficiencies illustrated in Fig 1. Screws were the primary form of fixation, since they prevented micromovement and sequestration of the graft.

Fig 2b Labial view of cortical block graft from the ramus repairing a deficiency in width (classification I according to Fig 1).
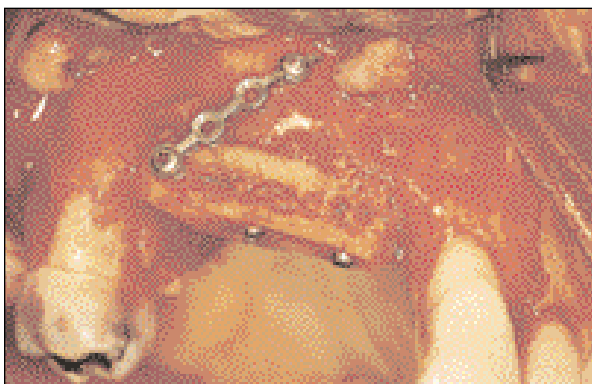

Fig 2c Labial view of symphyseal block graft being used to augment a deficiency in height (classification II according to Fig 1). Additional stability was gained by the use of titanium bone plates.
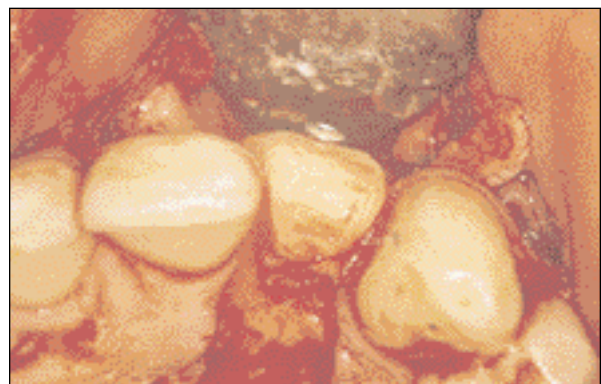

Fig 2d Occlusal view of bone graft reconstructing the alveolar ridge. The graft from the ramus is particularly suited for reconstruction of defects in width and height (classification III in Fig 1) because of donor site morphology.

Table 2	Criteria for Selection of Bone Grafting Procedure			
Donor site	No. of implants	Increase in width	Increase in height	Increase in width and height
Symphysis	1–6 implants	2–4 mm (1–6 implants)	2–4 mm (1–4 implants)	
Ramus	1–2 implants	2–6 mm	Up to 4 mm	Up to 6 mm width and 4 mm height

were used as the method of choice because of the comprehensive diagnostic data provided. The ridge dimensions could be measured accurately in the cross-sectional images; furthermore, orientation of the ridge angulation could be seen. Tooth position was revealed in the cross-sectional images by means of radiopaque markers.[36–38]

Treatment Planning

Ideal tooth form and position were determined by arrangement of teeth in wax on a diagnostic cast and transferred to the mouth for patient approval. Careful assessment of the crown in relation to the residual ridge was made to determine the need for augmentation, particularly if the tooth was in the

esthetic zone. A hard, clear, acrylic resin template was fabricated over a duplicate plaster cast of the diagnostic arrangement. This provided a hollow envelope identifying the position of the teeth to be replaced.[39] It was used to relate future tooth position to the deficient ridge and as a guide for the assessment of contours achieved by the bone graft. The template was used to identify implant sites when multiple implants were placed.

Surgical Protocol

Surgery commenced at the recipient site to identify the shape of the defect. This enabled determination of the donor site based on the precise shape of the graft that was required.

Maxilla as Recipient Site. A remote palatal incision was made in the maxilla based on the incidence of bony defects on the labial aspect of the ridge (Fig 3). The incision was made with a conventional scalpel with a number 15 blade for the vertical component. The vertical component consisted of 2 parallel incisions extending approximately 10 mm into the palate, and the horizontal component of the incision was made using a Blake's knife, connecting the 2 vertical components. The horizontal incision was beveled toward the crest of the ridge. The flap was designed to include the papillae to ensure that coverage of the graft could be achieved. This provided a labially based flap. The incision was then extended around the cervical margins of each of the adjacent teeth. A vertical release incision on the labial aspect was then made 1 tooth away from the recipient site to include the papilla. The vertical release incision was extended into the unattached mucosa. The periosteal flap was reflected carefully to ensure that there were no tears and that the gingival margins and papillae were not traumatized. The labial aspect of the ridge was then exposed to allow measurement of the defect in all 3 dimensions. Based on the shape of the defect, the decision regarding the donor site was confirmed.

Mandible as Recipient Site. Crestal incisions bisecting the attached gingiva were used in the mandible to expose the labial and lingual aspects of the ridge. The incisions were extended around the cervical margin of one adjacent tooth on either side. A vertical release incision on the labial aspect was made to include the papillae. Care was taken not to sever any branches of the mental nerve while working in the proximity of the mental foramen, which was visualized by exposure to prevent any damage. The site of the deficiency was measured as in the maxilla.

Symphysis as Donor Site. Access to the symphysis was obtained via 2 types of incisions. In one approach, a labial incision was made in the sulcus between the
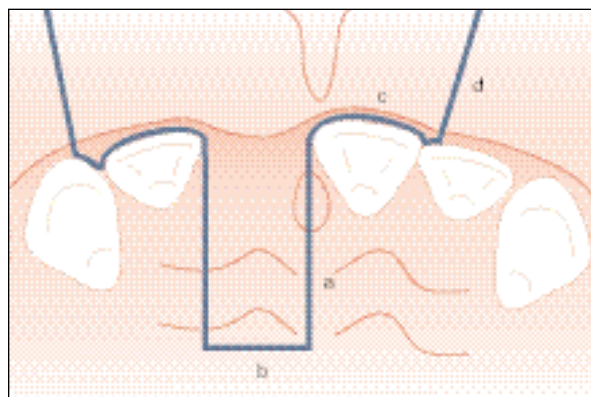

Fig 3 Remote palatal incision. The incision was made in the following sequence: a = vertical component, approximately 10 mm; b = horizontal beveled component made with Blake's knife; c = intrasulcular incision; d = vertical releasing incision including the papilla.

canines and the tissues were dissected toward the coronal aspect of the ridge, resulting in a split-thickness flap. Then a periosteal incision was made at the insertion of the muscles and a full-thickness flap was reflected. Access to the symphysis was obtained by reflecting the periosteum with the muscle attachments toward the inferior border of the mandible and extended distally toward the mental foramen.

Alternatively, a cervical incision was made that extended from premolar to premolar, with vertical release incisions being made distal to the mental foramen. The periosteal reflection was carried out, exposing the mental foramen and extending the reflection to the inferior border of the mandible.

The size and shape of the graft required was marked with a straight handpiece using fissure burs and abundant irrigation. The superior horizontal osteotomy was made with a minimum distance of 5 mm from the apices of the mandibular incisors and canines. To avoid damage to the nerve and vascular supply to the teeth, the osteotomy was beveled away from the apices. The vertical components of the osteotomy were performed through the cortical bone only.

The inferior horizontal osteotomy was made parallel to the inferior border of the mandible and was not extended beyond the maximum convexity (Fig 4). The graft required was then elevated from the symphysis with bone chisels or elevators.

Wound closure for the sulcular incision was done in 2 layers. Deep periosteal sutures with resorbable polyglactin 910 were used to approximate the periosteal edges; the mucosa was closed using interrupted sutures. Whenever a cervical incision was used, care was taken to reposition the
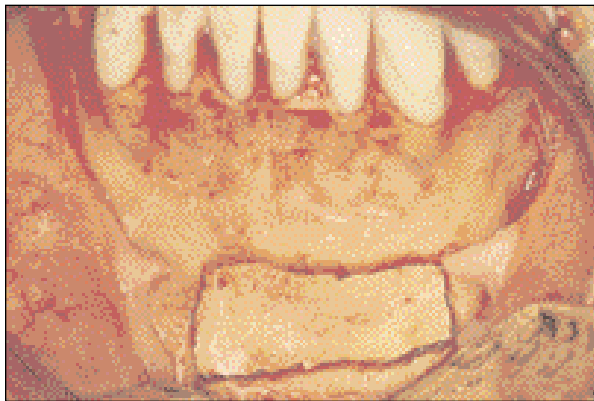
Fig 4 Symphyseal donor site exposed via a full-thickness flap, made using a cervical incision, showing the graft prior to elevation. The superior cut, beveled to avoid the apices, was made more than 5 mm from the apices of the teeth.
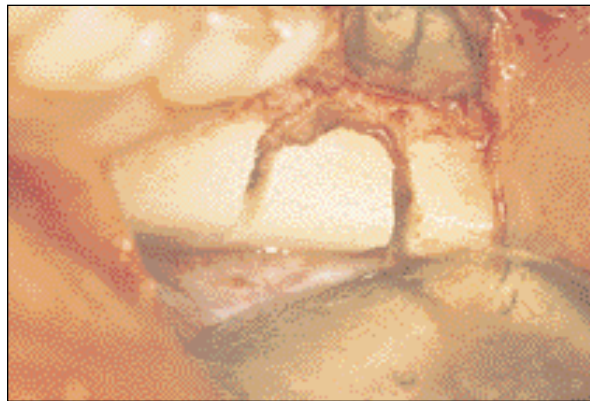

Fig 5 Retromolar donor site with graft outlined prior to elevation. The morphology of the external oblique ridge is particularly suited to augment a ridge deficient in height and width.

papillae accurately. Either interrupted sutures or continuous sutures were used. Maintenance of papillary height was enhanced by the use of vertical mattress sutures.

Large donor site defects were filled with beta-tricalcium phosphate (Augmen, Miter, Warsaw, IN). On 2 occasions, bone obtained from a bone filter was used.

Ramus as Donor Site. The incision to expose the external oblique ridge was made approximately 1 cm distal to the second molar. It was made over the ridge and extended mesially toward the buccal of the second molar. Care was taken to ensure that the incision was not extended too far lingually, which would risk damage to the structures on the lingual aspect of the mandible. The external oblique ridge was exposed by reflecting the periosteum, which also exposed the retromolar region and the lateral aspect of the ramus. The donor site was selected using the measurements obtained from the defect in the recipient site. Fissure and round burs were used to mark and section the cortical bone to obtain the 3-dimensional shape required to restore the defect. A fissure bur was used to outline the graft dimensions on the superficial surface of the retromolar region to provide the width of bone required at the recipient site (Fig 5). Care was taken not to extend the osseous incisions too far lingually. A large round bur (#8) was used to create a longitudinal groove to connect the vertical cuts made on the lateral wall of the ramus. This was done to limit the extent of the graft obtained by creating a fracture line. The groove did not extend through the cortical plate and was located above the level of the inferior alveolar canal as measured from the OPT. This

ensured that the inferior alveolar nerve was not damaged. The graft was removed and then transferred to the recipient site. Closure of the wound was done following graft fixation with continuous sutures.

Graft Fixation. The graft was refined to fit into the defect. Occasionally, modifications to the recipient site were carried out to produce a bed into which the graft fitted accurately. Once the graft was seated and stable, it was fixed with screws, which attached it to the remaining bone at the recipient site (Figs 2a to 2d). Rigid fixation of the graft was considered mandatory to ensure healing. Where dense cortical bone was present at the recipient site, decortication was carried out to establish an early blood supply. Deficiencies at the edge of the graft were filled with particulate cortical or cancellous bone. If autogenous bone was not available to fill the defects, beta-tricalcium phosphate (Augmen, Miter) was packed loosely around the edges.

To ensure a tension-free wound closure, an adequate periosteal reflection was performed. A periosteal releasing incision was made when passive closure could not be achieved.

Wound Closure of the Recipient Site. Maxillary palatal flaps were secured using interrupted sutures. The interdental papillae were secured using interrupted or vertical mattress sutures, as appropriate. The vertical release incisions were normally closed using interrupted sutures.

The crestal portions of the mandibular flaps were sutured using horizontal mattress sutures to appose the everted edges and supplemented with interrupted sutures. Papillae and vertical release incisions were closed in a manner similar to the maxilla.

Figs 6a and 6b Periapical radiographs used to evaluate changes in bone patterns.
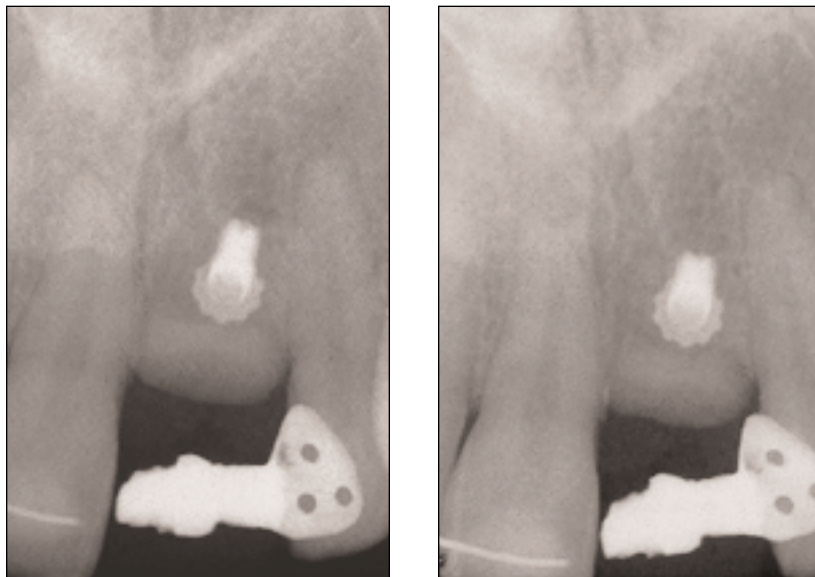

Fig 6a *(Left)* Postoperative periapical radiograph used as a baseline reference. The sharp outline of the horizontal portion of the grafted cortical bone is visible.

Fig 6b *(Right)* Periapical radiograph taken 3 months postoperatively. A more diffuse appearance of the cortex was considered to be indicative of metabolic activity.

Provisional restorations were modified to prevent the application of any undue pressure to the healing tissues. All patients who had a provisional restoration were fitted with it directly postoperatively. The grafted sites were allowed to heal for 3 to 6 months.

Evaluation of Graft Healing. Periapical radiographs were taken immediately postoperatively (Fig 6a) and 2 to 3 months after surgery (Fig 6b). These radiographs were taken with Rinn x-ray holders (Rinn, Elgin, IL) using a paralleling long-cone technique. Changes in the cortical and trabecular patterns were considered indicative of integration of the graft. The radiographic assessment was used in conjunction with a clinical evaluation of changes in the contour of the grafted ridge. In the event that no changes were visible, additional radiographs were taken 1 to 2 months later. Assessment was facilitated whenever fixed transitional restorations were present, because the contact between the pontic and the ridge was used to evaluate remodeling. Implant placement was performed after integration of the graft took place.

Implant Placement and Exposure. Access to the augmented ridge was obtained via remote palatal incisions in the maxilla and crestal incisions in the mandible. The implant sites were selected with a diagnostic template whenever appropriate. Internally irrigated osteotomy burs were used in the mandible and maxilla.[40] Bone taps were used as needed to create threads in the dense grafted cortical bone. The primary provisional prosthesis was modified to compensate for any alteration in the gingival contours. Implant exposure was carried out 6 months later. The definitive abutment was attached and the transitional acrylic resin restoration was adjusted, bringing the implant into function.

Restorative Phase

The soft tissues were allowed to mature for a minimum of 1 month prior to the definitive restorative phase. Conventional cement-retained restorations were fabricated. Soft cement (Temp Bond, Kerr Italia, Salerno, Italy) was used to enable the removal of restorations for monitoring and maintenance.

Radiographic and Clinical Monitoring

Clinical monitoring of the implants was carried out and recorded immediately after restoration, at 6 months and 12 months after restoration, and annually thereafter. The clinical examination involved visual examination of the crown margins for any signs of inflammation, percussion and manual manipulation to check for mobility or pain, and probing of the permucosal site to determine probing depth. Radiographic monitoring of the implants occurred immediately after first-stage surgery, on completion of the restoration, 6 months after completion of the restoration, and annually for those restorations that have been functional for longer than 6 months.
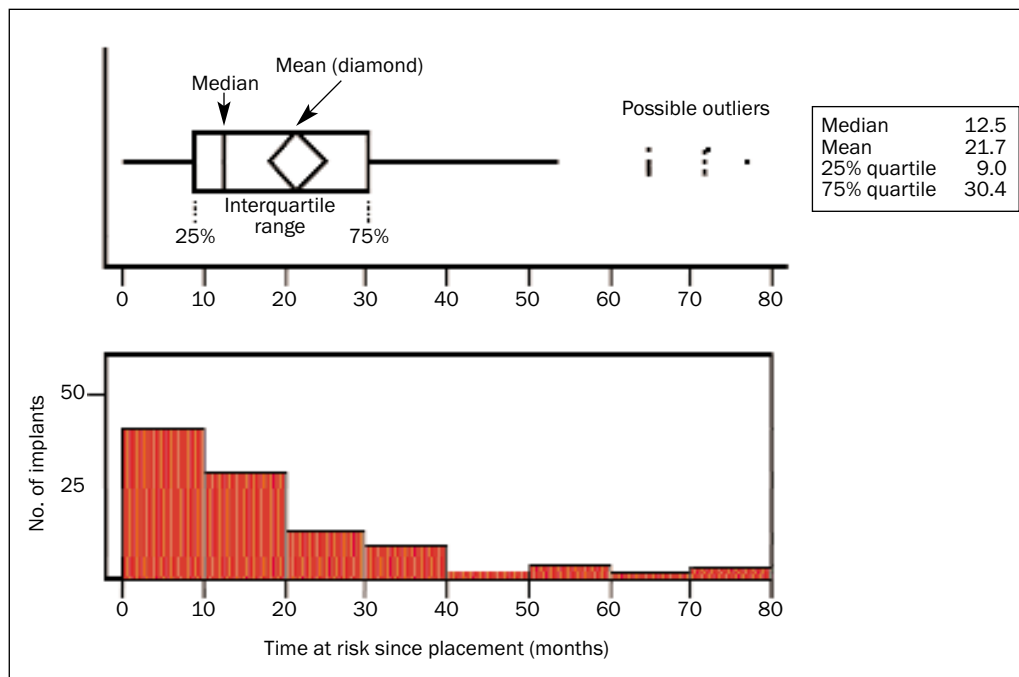
Fig 7 Distribution of implants regarding time since placement (outlier box plot at top and histogram at bottom).

Calculations and Statistics

Data concerning the source of the bone graft and the site and classification of the ridge deficiency were recorded. The location and number of implants per grafted site as well as the times of grafting, placement, exposure, and prosthodontic treatment were recorded. Subsequently, clinical monitoring as described was performed.

All patient-related data were transferred into a database format (Access, Microsoft, Redmond, WA). Calculations were carried out using a personal computer. Descriptive statistical analyses, such as the distribution of intraoral grafts and implants placed, were made with a statistical program (JMP, SAS Institute, Cary, NC).

Distributions were depicted by means of frequency tables, histograms, or outlier box plots. The outlier box plot visualizes the sample distribution and helps to identify points with extreme values or outliers (Fig 7). The ends of each box are the 25th and 75th quartiles, and the difference between the quartiles is the interquartile range. The line inside the box represents the median sample value. The ends of the whiskers are the outermost data points from their respective quartiles that fall within the distance computed as 1.5 times the interquartile range. The mean value of the distribution is represented by the diamond. The width of the diamond represents the 95% confidence interval for the group.

RESULTS

Patients Lost to Follow-up

Sixty patients were included in the study. A total of 118 implants were placed in grafted ridges. Nine patients (15%) with a total of 29 implants (25%) were lost to follow-up. Seven were referred patients who did not attend the recall program and have been monitored by their referring dentist; 1 patient did not comply with requests to attend for monitoring, and 1 patient was deceased.

Postoperative Complications

Donor Site. Two complications were noted in the ramus donor site. One patient had an infection of the graft material, which was collected from the bone trap and used to fill the defect.[34] The infection was observed 1 week postoperatively and healed well following drainage and irrigation of the site with sterile saline and antibiotic therapy.

Another patient complained of sensory disturbances in the buccal mucosa adjacent to the molar teeth. Altered sensation was noted on probing. Partial resolution of the affected area was noted following the definitive restoration. However, complete recovery of the subjective perception by the patient has not taken place, 18 months after implant placement.

Two additional complications were noted in relation to the symphysis as a donor site. In one patient,

Table 3 Distribution of Intraoral Grafts and Implants Placed

Donor site	Anterior region	Posterior region	Maxilla	Mandible	No. of implants placed
Ramus	35	15	42	8	50
Symphysis	53	15	59	9	68
Total	88	30	101	17	118

Table 4 Source of Graft Related to Type of Augmentation

Type of augmentation	Ramus				Symphysis				Total n	Total %
	n	% of total	% of ramus grafts	% of augmentation type	n	% of total	% of symphysis grafts	% of augmentation type		
Width	4	3.4	8.0	7.0	53	44.9	77.9	92.9	57	48.3
Height	34	28.8	68.0	85.0	6	5.1	8.8	15.0	40	33.9
Height and width	12	10.2	24.0	57.1	9	7.6	13.2	42.9	21	17.8
Total	50	42.4			68	57.6			118	

gingival recession around the cervical margins of the teeth was observed; this did not cause the patient any distress. There was no sensitivity of the teeth. The incision had been made around the cervical margins of the teeth in this patient. The second patient was originally treated with an incision in the labial sulcus. Dehiscence of the wound was noted, which healed spontaneously. No permanent sensory disturbances of the skin or the teeth were noted, although there was a transient alteration in sensation to both regions, which was attributed to the postoperative edema.

Recipient Site. No major complications that led to failure of the graft were noted at the recipient sites. There was no soft tissue breakdown, and none of the grafts became exposed.

Implants and Grafts

The ridges of 33 patients (55%) were grafted with bone from the ramus. In 27 patients (45%), the symphysis was chosen as the donor site. To date, 88 (78%) implant sites in the anterior region and 30 (22%) implant sites in the posterior region have been augmented by means of intraoral bone grafts. Table 3 summarizes the distribution of intraoral bone grafts and the number of corresponding implants placed.

Table 4 details the use of grafts to augment height, width, or both height and width. Thirty-four implant sites were augmented to gain height using a graft from the ramus. Only 4 implants were placed in sites where the graft of the ramus was used to increase width, whereas 12 implant sites were augmented from the ramus to gain height and width. The ramus was used predominantly to gain height. Width was gained mainly with grafts from the symphysis (53 implant sites). With bone from the symphysis, 9 sites were augmented to gain width and height and only 6 sites were augmented to gain height. Of the grafts, 33.9% were used to gain height, 48.3% were used to gain width, and 17.8% were used to gain both height and width.

Implant Losses

Two implants (1.7%) have failed thus far; both implants were lost because of premature exposure and infection. Furthermore, both autogenous grafts from the symphysis were supplemented with beta-tricalcium phosphate to fill irregularities into which the implants were placed. Table 5 summarizes the essential details of the lost implants. No implants have been lost in function after exposure so far. The period of observation since placement of the implants ranged from 0 to 77 months, with a mean observation time of 22 months. Figure 7 depicts the distribution of implants with regard to time since placement. Fifty percent (median) of all implants had been placed within 12.5 months of the last observation. The box plot additionally shows the 25% quartile (9 months) as well as the 75% quartile (30 months).

Table 5   Analysis of Implant Losses

Implant no.	Position	Smoker	Source of graft	Time (mo)	Cause
1	Maxillary left central incisor	No	Symphysis	2.3	Premature exposure
2	Maxillary right central incisor	Yes	Symphysis	4.0	Premature exposure

DISCUSSION

The grafting technique evaluated in this study showed an acceptable clinical outcome for both integration of the grafts and survival of the implants. To date, only 2 of 118 implants (1.7%) have failed (98.3% survival rate). All of the bone grafts have integrated and no complications were noted. No further survival analysis or survival estimation has been performed at this stage of the study, since both implant failures occurred before exposure and no more failures were observed during the observation period of up to 77 months.

Misch compared the use of different intraoral donor sites for onlay grafting prior to implant placement.[22] However, that report did not address survival of the implants, but focused on benefits and complications of the grafting procedures. A 2-stage approach was considered preferable. Tolman carried out a review of the literature, which described a very broad range of techniques with graft materials in different forms from a variety of sites.[41] Because of the broad range of techniques covered, it is difficult to compare the studies and develop valuable clinical guidelines. Few papers deal with the long-term results of intraoral bone grafts in combination with implant survival.

Lekholm and colleagues published a retrospective multicenter study with 150 patients in whom 48 grafts were taken from intraoral sites.[42] Most patients were treated using a 1-stage approach. No analysis of implant survival in intraoral grafts alone was performed, and an overall survival rate of 80% after 3 years was described. More implants were lost in conjunction with a 1-stage procedure (23%) than when they were placed in a second stage after healing of the graft (10%).

Schliephake and associates[43] found no difference between intraoral and extraoral grafts or 1-stage and 2-stage placement procedures. A low overall 5-year survival rate of 68% was calculated based on a 1-implant-per-patient analysis (154 implants). Interestingly, an association between graft viability, determined by [99]Tc (technetium) scintigrams, and implant failure has been noted.[44]

Block grafts have been used in combination with barrier membranes, with implants being placed after 7 to 13 months.[45] Lateral ridge augmentation only was carried out, and only 1 complication (exposure of the membrane) was reported in 40 patients. This is in contrast to Fugazzotto, who reported a very high incidence of membrane exposure in treatments carried out with particulate, non-autogenous grafts.[46]

The present study was performed with the use of bone grafts alone, because it was possible to predictably recreate the desired ridge form to achieve the contours desired for esthetic restoration. It further precluded the need for membranes, with their associated risk of early exposure and infection. This also reduced the expense, both in terms of the costs of materials and in clinical time in dealing with fixation and complications associated with membranes.

Although the viability of bone grafts has been addressed, no clinical guidelines have been recommended. Buser and coworkers placed implants at times ranging from 7 to 13 months after grafting, presumably because of the longer healing time required secondary to the reduced vascularity resulting from the membranes used.[45] Misch described variations in healing time of 4 months for the maxilla and 5 to 6 months for the mandible. No evidence for this rationale was presented.[22]

The protocol for the present study was based on the observation that resorption of the grafts took place at varying rates, as measured from the head of the fixation screw. Therefore, assessment of graft maturation was instituted based on radiographic observations of trabecular pattern changes, as well as the degree of resorption (as measured between the mucosa and the pontic of the fixed provisional restoration, when present). A variation in bone maturation times between 3 and 6 months was noted. More sophisticated techniques, such as serial bone scintigraphy or densitometry, to investigate signs of viability of the bone graft and thereby pinpoint the optimum time for implant placement prior to resorption of the graft seem to be necessary. The favorable clinical outcome to date seems to support the protocol for assessing the viability of the bone graft prior to implant placement. Other studies

comparing 1-stage and 2-stage procedures have also demonstrated that viability of the bone graft is different and has an influence on the survival of the implants.[42,47]

An increase in the current use of bone grafts—50% of the implants in this study have been placed within 12.5 months prior to the last observation—has been demonstrated. This reflects higher patient expectations in terms of achieving an esthetic result, where the gingival contours are at a level harmonious with the adjacent teeth.

ACKNOWLEDGMENTS

REFERENCES

1. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347–359.
2. Albrektsson T, Dahl E, Enbom L, et al. Osseointegrated oral implants. A Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. J Periodontol 1988;59:287–296.
3. Albrektsson T. A multicenter report on osseointegrated oral implants. J Prosthet Dent 1988;60:75–84.
4. Babbush CA, Shimura M. Five-year statistical and clinical observations with the IMZ two-stage osteointegrated implant system. Int J Oral Maxillofac Implants 1993;8:245–253.
5. Block MS, Kent JN. Long-term follow-up on hydroxylapatite-coated cylindrical dental implants: A comparison between developmental and recent periods. J Oral Maxillofac Surg 1994;52:937–943.
6. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants. Clin Oral Implants Res 1997;8:161–172.
7. D'Hoedt B, Schulte W. A comparative study of results with various endosseous implant systems. Int J Oral Maxillofac Implants 1989;4:95–105.
8. Gomez-Roman G, Schulte W, d'Hoedt B, Axman-Krcmar D. The Frialit-2 implant system: Five-year clinical experience in single-tooth and immediately postextraction applications. Int J Oral Maxillofac Implants 1997;12:299–309.
9. Grunder U, Polizzi G, Goene R, et al. A 3-year prospective multicenter follow-up report on the immediate and delayed-immediate placement of implants. Int J Oral Maxillofac Implants 1999;14:210–216.
10. Higuchi KW, Folmer T, Kultje C. Implant survival rates in partially edentulous patients: A 3-year prospective multicenter study. J Oral Maxillofac Surg 1995;53:264–268.
11. Nevins M, Langer B. The successful application of osseointegrated implants to the posterior jaw: A long-term retrospective study. Int J Oral Maxillofac Implants 1993;8:428–432.
12. Wheeler SL. Eight-year clinical retrospective study of titanium plasma-sprayed and hydroxyapatite-coated cylinder implants. Int J Oral Maxillofac Implants 1996;11:340–350.
13. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 1992;63:995–996.
14. De Wijs FL, Cune MS. Immediate labial contour restoration for improved esthetics: A radiographic study on bone splitting in anterior single-tooth replacement. Int J Oral Maxillofac Implants 1997;12:686–696.
15. Duncan JM, Westwood RM. Ridge widening for the thin maxilla: A clinical report. Int J Oral Maxillofac Implants 1997;12:224–227.
16. Sethi A, Sochor P, Hills G. Implants and maxillary ridge expansion. Indep Dent 1998;80–90.
17. Simion M, Baldoni M, Zaffe D. Jawbone enlargement using immediate implant placement associated with a split-crest technique and guided tissue regeneration. Int J Periodontics Restorative Dent 1992;12:462–473.
18. Tatum HJ. Maxillary and sinus implant reconstructions. Dent Clin North Am 1986;30:207–229.
19. Breine U, Brånemark P-I. Reconstruction of alveolar jaw bone. An experimental and clinical study of immediate and preformed autologous bone grafts in combination with osseointegrated implants. Scand J Plast Reconstr Surg 1980;14:23–48.
20. Misch CM, Misch CE. The repair of localized severe ridge defects for implant placement using mandibular bone grafts. Implant Dent 1995;4:261–267.
21. Misch CM. Ridge augmentation using mandibular ramus bone grafts for the placement of dental implants: Presentation of a technique. Pract Periodont Aesthet Dent 1996;8:127–135.
22. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. Int J Oral Maxillofac Implants 1997;12:767–776.
23. Nystrom E, Kahnberg KE, Gunne J. Bone grafts and Brånemark implants in the treatment of the severely resorbed maxilla: A 2-year longitudinal study. Int J Oral Maxillofac Implants 1993;8:45–53.
24. Bahat O, Fontanesi RV, Preston J. Reconstruction of the hard and soft tissues for optimal placement of osseointegrated implants. Int J Periodontics Restorative Dent 1993;13:255–275.
25. Buser D, Brägger U, Lang NP, Nyman S. Regeneration and enlargement of jaw bone using guided tissue regeneration. Clin Oral Implants Res 1990;1:22–32.
26. Buser D, Dula K, Belser U, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. I. Surgical procedure in the maxilla. Int J Periodontics Restorative Dent 1993;13:29–45.
27. Buser D, Dula K, Belser UC, Hirt HP, Berthold H. Localized ridge augmentation using guided bone regeneration. II. Surgical procedure in the mandible. Int J Periodontics Restorative Dent 1995;15:10–29.

28. Nevins M, Mellonig JT. Enhancement of the damaged edentulous ridge to receive dental implants: A combination of allograft and the GORE-TEX membrane. Int J Periodontics Restorative Dent 1992;12:96–111.

29. Shanaman RH. The use of guided tissue regeneration to facilitate ideal prosthetic placement of implants. Int J Periodontics Restorative Dent 1992;12:256–265.

30. Shanaman RH. A retrospective study of 237 sites treated consecutively with guided tissue regeneration. Int J Periodontics Restorative Dent 1994;14:292–301.

31. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. Int J Periodontics Restorative Dent 1994;14:496–511.

32. Simion M, Jovanovic SA, Trisi P, Scarano A, Piattelli A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. Int J Periodontics Restorative Dent 1998;18:8–23.

33. Von Arx T, Hardt N, Wallkamm B. The TIME technique: A new method for localized alveolar ridge augmentation prior to placement of dental implants. Int J Oral Maxillofac Implants 1996;11:387–394.

34. Sethi A, Kaus T. Maxillary ridge expansion with simultaneous implant placement: 5-year results of an ongoing clinical study. Int J Oral Maxillofac Implants 2000;15:491–499.

35. Wilson DJ. Ridge mapping for determination of alveolar ridge width. Int J Oral Maxillofac Implants 1989;4:41–43.

36. Sethi A. Precise site location for implants using CT scans: A technical note. Int J Oral Maxillofac Implants 1993;8:433–438.

37. Jacobs R, Adriansens A, Verstreken K, Suetens P, van Steenberghe D. Predictability of a three-dimensional planning system for oral implant surgery. Dentomaxillofac Radiol 1999;28:105–111.

38. Jacobs R, Adriansens A, Naert I, Quirynen M, Hermans R, van Steenberghe D. Predictability of reformatted computed tomography for pre-operative planning of endosseous implants. Dentomaxillofac Radiol 1999;28:37–41.

39. Sethi A, Sochor P. Predicting esthetics in implant dentistry using multiplanar angulation: A technical note. Int J Oral Maxillofac Implants 1995;10:485–490.

40. Lavelle C, Wedgwood D. Effect of internal irrigation on frictional heat generated from bone drilling. J Oral Surg 1980;38:499–503.

41. Tolman DE. Reconstructive procedures with endosseous implants in grafted bone: A review of the literature. Int J Oral Maxillofac Implants 1995;10:275–294.

42. Lekholm U, Wannfors K, Isaksson S, Adielsson B. Oral implants in combination with bone grafts. A 3-year retrospective multicenter study using the Brånemark implant system. Int J Oral Maxillofac Surg 1999;28:181–187.

43. Schliephake H, Neukam FW, Wichmann M. Survival analysis of endosseous implants in bone grafts used for the treatment of severe alveolar ridge atrophy. J Oral Maxillofac Surg 1997;55:1227–1233.

44. Schliephake H, Berding G, Neukam FW, Bothe KJ, Gratz KF, Hundeshagen H. Use of sequential bone scintigraphy for monitoring onlay grafts to grossly atrophic jaws. Dentomaxillofac Radiol 1997;26:117–124.

45. Buser D, Dula K, Hirt HP, Schenk RK. Lateral ridge augmentation using autografts and barrier membranes: A clinical study with 40 partially edentulous patients. J Oral Maxillofac Surg 1996;54:420–432.

46. Fugazzotto PA. Report of 302 consecutive ridge augmentation procedures: Technical considerations and clinical results. Int J Oral Maxillofac Implants 1998;13:358–368.

47. Lundgren S, Rasmusson L, Sjostrom M, Sennerby L. Simultaneous or delayed placement of titanium implants in free autogenous iliac bone grafts. Histological analysis of the bone graft–titanium interface in 10 consecutive patients. Int J Oral Maxillofac Surg 1999;28:31–37.