Treatment Options in Distraction Osteogenesis Therapy Using a New Bidirectional Distractor System

Peter Schleier, DMD[1]/Christina Wolf, MD, DMD[2]/Hansgeorg Siebert, DMD, MD[3]/
David Shafer, MD, PhD[4]/Martin Freilich, DDS[5]/Alexander Berndt, PD, PhD[6]/Dieter Schumann, MD, DMD[7]

Purpose: *The purpose of this retrospective study was to compare a bidirectional distraction system with a unidirectional system with regard to bone height attained and the need for secondary graft procedures.* ***Materials and Methods:*** *Unidirectional and bidirectional distractor devices were used for vertical augmentation of the maxilla and mandible in 2 separate groups of patients (n = 10 and n = 11, respectively). Clinical and radiographic outcome data were collected at postoperative follow-up examinations for up to 2.5 years. The height of the augmented alveolar ridge and the sagittal location of the bone fragment were measured on panoramic radiographs or lateral cephalograms. These data were analyzed with 1-way analysis of variance. Nonparametric data, such as treatment complications, were analyzed with the Fisher exact test. The dental implant survival data were evaluated with a Kaplan-Meier survival analysis.* ***Results:*** *The difference in vertical bone gain observed between unidirectional and bidirectional groups (5.3 ± 1.8 mm vs 6.1 ± 2.3 mm) was not statistically significant. In the unidirectional group, additional autogenous bone grafting was required in 6 cases, while grafting was required in only 2 cases in the bidirectional group. This difference was due to the more precise control of the distraction process associated with the bidirectional distractor; however, it was not a statistically significant difference. Postaugmentation, 59 implants were placed in the augmented sites. These implants exhibited primary stability and were restored with good functional and esthetic results.* ***Conclusions:*** *The need for additional grafting procedures may be reduced in cases where the distraction vector is optimized, as generally seen with bidirectional distractor use.* Int J Oral Maxillofac Implants 2007;22:408–416

Key words: *augmentation, bidirectional distraction, complications, dental implants, distraction osteogenesis*

Autogenous bone grafting is a well-established method for the correction of alveolar ridge defects.[1] Distraction osteogenesis (DO) has been noted as an alternative method of vertical augmentation.[2] DO has its origins in orthopedic surgery. The first report of the lengthening of the extremities was published in 1869.[3] Ilizarov developed basic principles and equipment for external application to the extremities. He showed that distraction of bone in a transverse vector to the long axis of the bone can result in bone formation.[4] This concept has also been applied to the craniofacial region quite extensively over the past few years. The first reports describing positive outcomes in maxillofacial surgery were followed by reports that included treatment failures and unsatisfying results.[5]

Precise positioning of the crestal bony fragment during vertical distraction of the alveolar ridge is necessary to achieve optimal dental implant placement and, upon prosthetic restoration, optimal loading conditions.[6] Several methods have been described for distraction of the alveolar ridge:

[1]Associate Professor, Clinic of Maxillofacial Surgery/Plastic Surgery, Friedrich Schiller University, Jena, Germany.
[2]Resident, Clinic of Maxillofacial Surgery/Plastic Surgery, Friedrich Schiller University, Jena, Germany.
[3]Maxillofacial Surgeon, Private Practice, Jena, Germany.
[4]Professor, Head of Department, Division of Oral and Maxillofacial Surgery, University of Connecticut Health Center, Farmington, Connecticut.
[5]Professor, Department of Oral Rehabilitation, Biomaterials & Skeletal Development, University of Connecticut Health Center, Farmington, Connecticut.
[6]Associate Professor, Institute of Pathology, Friedrich Schiller University, Jena, Germany.
[7]Professor (retired), Clinic of Maxillofacial Surgery/Plastic Surgery, Friedrich Schiller University, Jena, Germany.

Correspondence to: Dr Peter Schleier, Department of Orofacial Surgery, University of Stavanger, Armauer Hansensvei 20, 4017 Stavanger, Norway. Fax: +4751518355. E-mail: schleier@online.no

- Unidirectional distraction with an endosseous device[7]
- Unidirectional distraction with a subperiosteal device[8]
- Bidirectional distraction with a subperiosteal device[9]

Clinical studies have shown that the use of subperiosteally positioned distraction devices may result in an increase in bone height of 5 to 15 mm.[10–12] The device activation screw is described as problematic because it requires continued mucosa perforation. Such perforation may result in local soft tissue infection due to oral bacteria colonization and is sometimes responsible for bone resorption around the device.[13–15]

Being "hidden" within the bone is an advantage of endosseous distraction devices. When the activation screw of such a device perforates the oral cavity, it perforates the fixed masticatory mucosa. This specialized mucosa has a barrier function to prevent infection. The downside is the difficulty of positioning the device precisely.[16]

With subperiosteal distraction, the distractor device can only be placed on the buccal side of the proximal bone fragment to maintain a blood supply from the lingual aspect. This typically results in the generation of a distraction vector that has a strong lingual component. As a consequence, dislocation of the distracted fragment to the lingual or palatal side is often seen with the use of the standard unidirectional distractor system. Such dislocation can prevent the clinician from placing implants immediately after removal of the distractor hardware (ie, in the same procedure).[17] A secondary osteotomy to correct the position of the distracted fragment or to place an additional autogenous bone graft prior to implant placement may be needed.

A number of additional factors can alter the distraction vector. Of these, the most important is the continuous increase of forces on the distractor system directed toward the coronal aspect of the proximal bone fragment. Furthermore, distraction osteogenesis in the intraoral environment is subject to forces from the musculature of the facial aspect of the alveolar ridge, the tongue and the floor of the mouth; these forces, together with the resistance of the lingual periosteum, can alter the distraction vector.[18]

Given these problems, certain technical and surgical conditions need to be met to ensure the correct transposition of the bone fragment. Unidirectional distractor systems appear unable to meet these conditions.[19] However, a bidirectional distractor system such as that presented here may be able to address these problems. The distractor includes a second set-screw with which the distraction vector can be modified by up to 20 degrees. The purpose of this retrospective study was to compare this bidirectional distractor system with a unidirectional system with particular regard to bone height attained and the need for secondary graft procedures.

Table 1 Characteristics of Patients

	Unidirectional group	Bidirectional group
No. of patients		
Male	7	7
Female	3	4
Total	10	11
Age (y)		
Median	46.9	41.8
Range	22 to 61	19 to 68
Causes of alveolar atrophy		
Traumatic tooth loss	1	3
Caries/periodontitis	6	5
Tumors	1	2
Other	2	1
Localization of alveolar atrophy		
Mandible		
Anterior	4	5
Lateral	0	2
Anterior and lateral	3	3
Maxilla		
Anterior	2	1
Anterior and lateral	1	1

*This category included bone defects after cyst resection, gunshot injury, and aplasia.

MATERIALS AND METHODS

Patients

Twenty-one patients participated in this retrospective study. Characteristics of the patients are summarized in Table 1.

The patients had been referred to the Department of Oral and Maxillofacial Surgery/Plastic Surgery at the University of Jena by their primary dentist. All patients exhibited unilateral, bilateral, or total edentulism in the mandible or maxilla in combination with loss of alveolar ridge height and all desired implant-supported dental restorations. Faculty in the Department of Prosthetics helped plan the surgical and reconstructive treatment, including bone augmentation and dental implant positioning. The basal bone height at the surgical sites ranged from 8 to 14 mm prior to surgery. Prior to any treatment, a comprehensive intraoral and radiographic examination was carried out. The intraoral examination included an evaluation of the condition of the remaining teeth, existing prostheses, and oral mucosa. A

Table 2 Dimensions and Characteristics of the Distracted Bone Segment by Patient

Patient	Treatment causes	Distracted regions	Height of bone segment	Length of bone segment	Width of bone segment
Bidirectional group					
TW	Aplasia	Anterior maxilla	4.7	18.7	2.8
RK	Periodontal disease	Anterior mandible	13.3	55.6	3.8
NI	Periodontal disease	Anterior mandible	6.7	47.1	1.9
KF	Periodontal disease	Anterior and lateral mandible	5.7	51.2	6.0
SB	Periodontal disease	Lateral mandible	3.4	7.7	2.8
CK	Periodontal disease	Lateral mandible	8.6	18.6	2.3
KV	Traumatic tooth loss	Anterior mandible	6.8	14.1	4.4
AS	Traumatic tooth loss	Anterior and lateral mandible	7.2	18.7	2.1
MJ	Traumatic tooth loss	Anterior and lateral maxilla	12.3	34.5	3.7
RA	Tumor	Anterior mandible	5.5	25.4	3.5
AM	Tumor	Anterior mandible	6.2	46.3	5.9
Unidirectional group					
EL	Dental cyst	Anterior mandible	7.0	41.1	5.2
SF	Periodontal disease	Anterior maxilla	4.0	10.0	4.5
AS	Gunshot injury	Anterior and lateral mandible	2.3	55.6	7.3
UL	Periodontal disease	Anterior mandible	6.8	47.9	4.6
JN	Periodontal disease	Anterior mandible	3.6	26.8	6.2
GD	Periodontal disease	Anterior and lateral mandible	3.6	14.0	5.1
KW	Tumor	Anterior and lateral mandible	7.3	25.7	3.7
MB	Periodontal disease	Anterior maxilla	5.6	16.8	1.5
DG	Periodontal disease	Anterior and lateral maxilla	4.6	14.0	6.1
DF	Traumatic tooth loss	Anterior mandible	8.4	36.4	2.1

panoramic radiograph and a lateral cephalogram were obtained. Informed consent was obtained from all prospective participants upon the conclusion of a comprehensive discussion of the potential risks of and alternatives to osteogenesis distraction.

Exclusion criteria for study participation were as follows: vertical defects of the edentulous ridge associated with a history of radiotherapy in the head and neck region; chemotherapy for treatment of malignant tumors at the time of the surgical procedure; bone defects resulting from chronic infection; the systemic use of steroidal drugs; excessive tobacco use (more than 15 cigarettes per day); severe renal or liver disease; uncontrolled diabetes; active periodontal disease detected in the adjacent dentition; poor oral hygiene; and a history of noncompliance with medical or dental treatment.

Two cohorts of patients were created retrospectively. One consisted of patients in which only the unidirectional distractor system had been used; this will be referred to as "the unidirectional group." This group of 10 patients (7 men and 3 women) was treated between 2001 and 2002 . The mandible of 1 patient in this group had previously been reconstructed with a free microvascular fibula graft. All of the individuals in the other cohort were treated with the bidirectional distractor system; this cohort will be called "the bidirectional group." This group of 11 patients (7 men and 4 women) were treated in 2003 by the same group of surgeons. The mandibles of 2 patients in this group had been reconstructed after tumor resection with autogenous hip bone grafts. Table 2 illustrates the distribution of edentulous sites and the causes and magnitude of the distracted bone segment for all participants in both groups.

Surgical Protocol

Patients underwent distraction osteogenesis with either a unidirectional distractor (Martin, Tuttlingen, Germany; Figs 1a to 1e) or a bidirectional distractor (Medartis, Basel, Switzerland; Figs 2a and 2b). The surgical procedure was identical for both systems. All surgical distraction procedures were performed under general anesthesia. After local anesthesia had been administered by means of a vasoconstrictor, incisions were made at the level of the alveolar crest. Buccal mucoperiosteal flaps were elevated, while the lingual mucoperiosteum remained adherent to the bone. In the correct sagittal relation to the opposing occlusion, a vertical hole was made in the midline of the bone defect with a bur, until the basal bone was just perforated. Drilling was carried out at moderate speed (ie, 1,000 rpm) with profuse sterile saline irrigation to avoid overheating the bone. From an initial

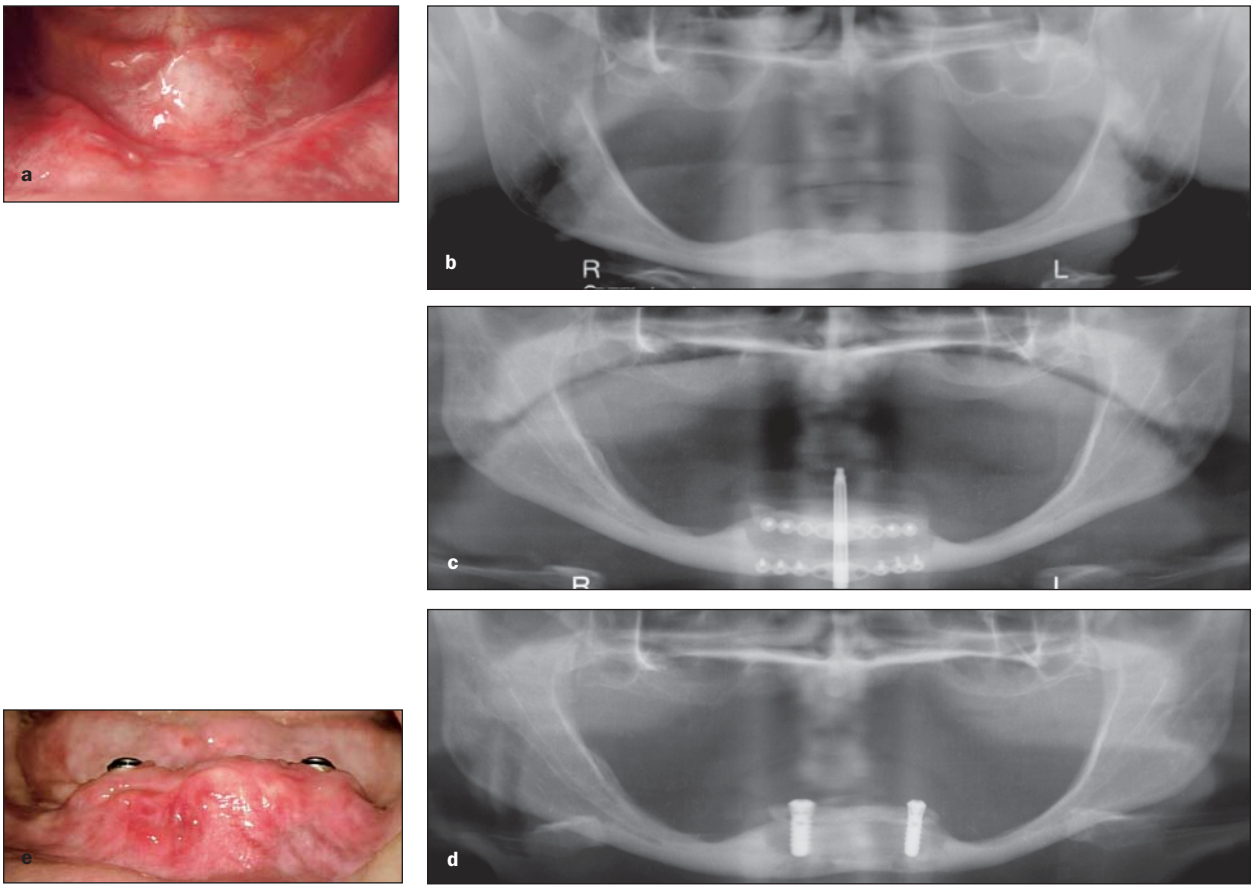
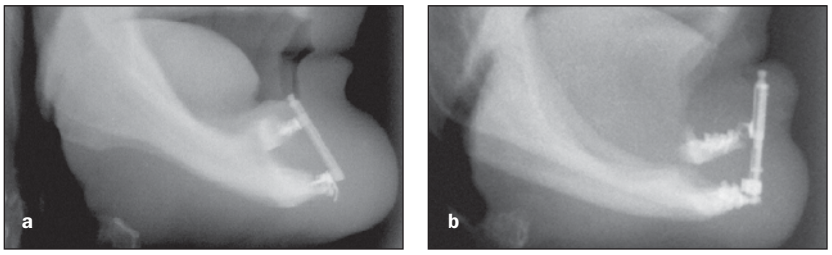


Fig 1 The treatment of patient JN with a unidirectional distractor device. The original situation *(a)* shows the lack of attached mucosa in the anterior mandible. The first radiograph *(b)* shows the atrophic mandible; the second *(c)* shows the distractor device in situ, and the third *(d)* was obtained after removal of the distractor device, after the placement of 2 implants. *(e)* A clinical view of the newly formed alveolar ridge.

Fig 2 Radiographs demonstrating the treatment of patient NI with a bidirectional distractor device. *(a)* Postdistraction, the dislocation of the crestal bone fragment toward the lingual was obvious. *(b)* The distraction vector was corrected up to 20 degrees to the labial with the bidirectional distractor device.



landmark, the line of horizontal osteotomy was identified. The bone was prepared to allow for good adaptation of the distractor. After that, the distractor was adapted and fixed by monocortical screws. The distraction vector was controlled, and afterward all screws and the distractor device removed.

Vertical cuts were made in the upper third of the bone with an oscillating saw. These saw-cuts were connected with a horizontal cut also made with an oscillating saw. After all saw-cuts were made, the mobility of the segment was tested. The survival of the trans-

Table 3 Protocol for Distraction

Time	Length (mm)	Times per day
Intraoperative	3	1
7 days postsurgery	0.25	1
8 days postsurgery	0.25	1
9 days postsurgery	0.25	2
10 days postsurgery	0.25	2
11 days postsurgery	0.25	4
12 days postsurgery	0.25	4
13 days postsurgery	0.25	4
14 days postsurgery	0.25	4

Table 4 Transversal Movement in mm in Relation to the Number of Screw Turns and Height of the Proximal Bone Fragment

Vertical distraction height	Anterior angulation (degrees)						Posterior angulation (degrees)								
	20	16.5	13	9.5	6	3	2.5	4.5	6.5	8.5	10.5	12.5	14.5	16.5	18.5
15.0	+8.75	+7.25	+5.75	+4.25	+2.5	+1.25	−1.0	−2.0	−2.75	−3.75	−4.75	−5.5	−6.25	−7.25	−8.0
13.5	+8.25	+6.75	+5.5	+4.0	+2.5	+1.25	−1.0	−2.0	−2.75	−3.5	−4.25	−5.25	−5.75	−6.75	−7.5
12.0	+7.75	+6.25	+5.0	+3.75	+2.25	+1.25	−1.0	−1.75	−2.5	−3.25	−4.0	−5.0	−5.5	−6.25	−7.0
10.5	+7.25	+5.75	+4.75	+3.5	+2.25	+1.25	−1.0	−1.5	−2.25	−3.0	−3.75	−4.5	−5.25	−5.75	−6.5
9.0	+6.5	+5.5	+4.25	+3.25	+2.0	+1.0	−0.75	−1.5	−2.25	−3.0	−3.5	−4.25	−4.75	−5.5	−6.0
7.5	+6.0	+5.0	+4.0	+3.0	+1.75	+1.0	−0.75	−1.5	−2.0	−2.75	−3.25	−4.0	−4.5	−5.0	−5.5
6.0	+5.5	+4.75	+3.25	+2.75	+1.75	+0.75	−0.75	−1.25	−1.75	−2.5	−3.0	−3.5	−4.25	−4.5	−5.0
4.5	+5.0	+4.25	+3.25	+2.5	+1.5	+0.75	−0.5	−1.0	−1.75	−2.25	−2.75	−3.25	−3.75	−4.25	−4.75
3.0	+4.5	+3.75	+3.0	+2.25	+1.5	+0.75	−0.5	−1.0	−1.5	−2.0	−2.5	−2.75	−3.5	−3.75	−4.25
1.5	+4.0	+3.25	+2.75	+2.0	+1.25	+0.5	−0.5	−1.0	−1.25	−1.75	−2.25	−2.5	−3.0	−3.25	−3.75
0	+3.5	+3.0	+2.25	+1.75	+1.0	+0.5	−0.5	−0.75	−1.25	−1.5	−2.0	−2.25	−2.75	−3.0	−3.25
No. of turns	3	2 ½	2	1 ½	1	½	½	1	1 ½	2	2 ½	3	3 ½	4	4 ½

port bone (distracted bone segment) is dependent on the preservation of contact between the lingual/palatal aspect of this segment and the lingual/palatal mucoperiosteal flap. Bone segments with different length and height measurements were osteotomized. The region, length, and height of the distracted bone segments are shown in Table 2. The distractor was permanently fixed to the bone with titanium screws after inspection of the vector of distraction.

The mobility of the bone segment was checked prior to wound closure. The wound was closed in 2 layers to obtain a tension-free closure. The submucosa was sutured with resorbable Vicryl 4-0 sutures (Johnson & Johnson/Ethicon, Somerville, NJ). The mucosa was closed with a nonresorbable suture (Ethibond Excel; Ethicon), which were left in place for 7 days. After this time the mucosal sutures were removed.

Patients were not allowed to wear a denture while the distraction device was in place. Only soft foods and fluids were allowed during the active distraction time (generally approximately 14 days). All patients received broad-spectrum antibiotics intravenously for 7 days prior to the surgical procedure.

One week after fitting the distractor hardware, distraction was initiated according to the protocol shown in Table 3. The aim was to increase the height of the alveolar ridge by 8 to 10 mm or to achieve a level of bone growth commensurate with the bone level of the adjacent teeth. In the bidirectional group, the optimal distraction vector could be changed during the distraction period by adjusting an additional exposed set screw (Table 4). Once optimal bone growth had been achieved, the distractor was left in place for 3 months to ensure bony consolidation. Whenever possible, dental implants (Straumann, Basel, Switzerland) were placed at the time of distractor hardware removal. On a number of occasions, the direction of bone growth achieved through distraction was too far lingual, and additional autogenous graft procedures were performed at distraction device removal to increase the alveolar bone width at the buccal aspect of the ridge. This was necessary to accommodate subsequent implant placement in a prosthetically useful location. Fixed partial prostheses were fabricated 10 weeks after implant placement.

Clinical and Radiographic Examination

Postoperative follow-up ranged from 6 months to 2.5 years (mean ± SD). Radiographic and clinical measurements were made at 0, 6, 18, and 30 months following implant placement. All measurements were made by the same postdoctoral fellow in the department of oral surgery, who performed calibration exercises with the distractor device. The following clinical parameters were evaluated:

- Pain or inflammation around the screws
- Movement of the distractor system
- Change of the distraction vector/proximal bone fragment
- Loss of distraction screws
- Need for autogenous bone grafting prior to implant placement
- Loss of implants
- Sensory changes of mucosa and facial skin

The height of the augmented alveolar ridge was measured with the use of panoramic radiographs after the active distraction period and before implant placement. Metal balls (5 mm in diameter) were embedded into custom radiographic guides, which allowed for the correction of magnification errors.

Table 5 Complications and (Where Relevant) Region of Bone Harvesting by Patient

Patient	Complications during implantation	Region of bone harvesting
Bidirectional group		
TW	Mucosa retraction	
RK		
NI		
KF		
SB		
CK		
KV		
AS		
MJ	Need for bone graft	Anterior nasal spine
RA		
AM	Need for bone graft	Ramus mandibulae
Unidirectional group		
EL		
SF	Need for bone graft	Palate
AS	Infection, bone fracture	
UL	Need for bone graft	Chin
JN	Need for bone graft	Mandibular ramus
GD		
KW	Need for bone graft, mucosa retraction	Mandibular ramus
MB	Need for bone graft, mucosa retraction	Mandibular ramus
DG		
DF	Need for bone graft, mucosa retraction	Anterior nasal spine

The radiographs made prior to the surgical procedures were compared with radiographs made before placement of the implants and during the follow-up examinations to detect bone augmentation as well as possible resorption. The sagittal location of the bone fragment was demonstrated by lateral cephalograms. The measurements of transversal bone movement through the activation of the second screw were correlated to the amount of turns, as shown in Table 4.

The mean follow-up after insertion of the prosthesis was 8 ± 4 months.

Data Analysis

The retrospective clinical data obtained at the recall examinations were entered into an MS Excel database (Redmond, WA) and transferred to StatXact (Cytel, Cambridge, MA) for statistical analysis. Data derived from continuous measures, such as bone height and transverse bone movement, were analyzed with 1-way analysis of variance, and nonparametric data were analyzed with the Fisher exact test. The dental implant survival data were evaluated with a Kaplan-Meier survival analysis. Data on the survival analysis were collected up to 30 months postsurgery. The threshold for statistical differences observed between comparisons was set at $P < .05$.

RESULTS

A consecutive series of 21 alveolar segmental distraction procedures was carried out prior to implant placement and prosthetic restoration. In all cases, natural teeth or prosthetic tooth replacements were present in the opposing jaw.

The mean bone gain resulting from the use a unidirectional distractor system was 5.3 ± 1.8 mm; the mean bone gain with use of a bidirectional distractor system was where 6.1 ± 2.3 mm was attained.

Resorption of the crestal portion of the alveolar bone was not observed during the observation period. No significant difference between the 2 groups was detected regarding bone height ($P = .4$). It was necessary to place 6 autogenous grafts following removal of the unilateral distractor, while grafts were needed in 2 cases after the use of the bidirectional distractor ($P = .08$). Although the 2 groups did not differ significantly in this respect, this indicated a tendency toward a significant difference between the 2 distraction methods for this particular outcome. For the graft procedures, the bone was harvested from chin or ramus region of the mandible or anterior nasal spine in the maxilla (Table 5).

Overall, 10 of the 21 procedures led to a complication. Seven of these resulted from the use of the uni-

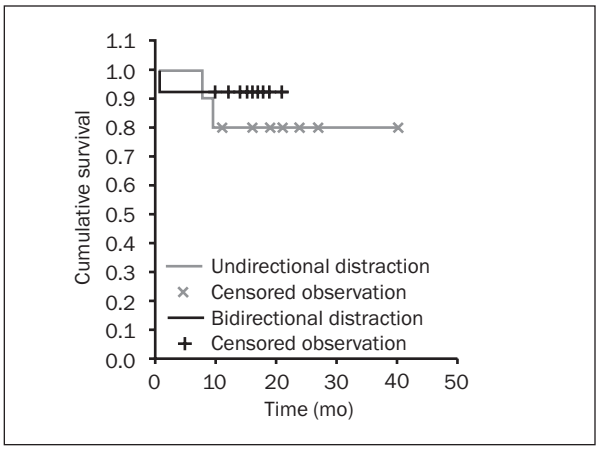


Fig 3 The Kaplan-Meier survival analysis curve demonstrates no significant difference ($P = .6$) between the 2 systems in regard to implant success.

directional distractor, while 3 were associated with the bilateral distractor ($P = .08$). Again, the difference between the 2 groups was insignificant. One severe complication (bone fracture) occurred in the patient who had received nonvascular bone transplants from the iliac crest months before the procedure.

A total of 59 implants (4.1 mm or 3.3 mm in diameter; lengths of 10 to 14 mm) were placed in the augmented areas with good primary stability. One implant was removed between the 3rd and 4th week postoperatively. Sixteen patients received removable prostheses, while 4 received fixed prostheses. A survival analysis of the implants placed in this study (Fig 3) demonstrated that 94% of the implants placed into bone augmentation via osteogenesis distraction survived for up to 30 months, with no significant difference ($P = .6$) between the 2 methods of distraction.

DISCUSSION

Distraction osteogenesis offers an option for the treatment of vertical alveolar bone deficiencies while also enhancing the width of the ridge and the band of keratinized soft tissue at the alveolar ridge crest (Figs 1a to 1e).[20] Vertical distraction generally results in less resorption than autogenous bone graft techniques and eliminates possible disease transmission when compared with the use of allogeneic materials.[21]

This surgical approach is not without drawbacks, such as the discomfort caused by the distractor, which may interfere with eating and speaking. The absolute compliance of the patient and family is of utmost importance, and close and frequent follow-up is essential. The patient cannot wear prostheses during the distraction osteogenesis procedure and for at least 2 weeks afterward.[22] Usually distractor systems are able to augment bone in only a single direction. The distractor needs to be firmly embedded in the bone, and a correct primary vector for the transposition needs to be established. Continuous force from muscles such as the *genioglossus* or *orbicularis oris* frequently dislocates the proximal bone fragment to the lingual direction (Figs 1d and 2b). When this occurs, the placement of dental implants immediately upon removal of the distractor device is not possible; instead, bone grafting procedures to augment the buccal aspect of the site are required prior to implant placement.

In the cases reported here, the use of a unidirectional distractor was more frequently associated with a need for additional autogenous hard tissue grafting (6 of 10 cases). The expectation that bidirectional distraction would eliminate the need for additional bone grafting was not realized. Grafting was, however, needed less frequently. While the difference between the 2 groups with respect to the need for grafting was not significant ($P = .08$), this lack of statistical significance may be a function of the modest sample size, which resulted in low statistical power. Autogenous grafting was generally accomplished at the time of distractor removal. In almost all cases, the vertical bone gain extended to the level of adjacent alveolar bone. It has been shown in the literature that distraction osteogenesis results in an increase of bone height of 5 to 15 mm.[23] Lack of bone width can be corrected with slight overdistraction of the bone and reduction of small edges at the coronal aspect; thus, distraction osteogenesis can eliminate the need for grafting even in cases where both bone height and width are deficient. The subgroup of patients requiring grafting procedures did not significantly differ with respect to the number of implant failures, but some compromised esthetic results were noted. Others have found that the combination of bone grafting and implant placement procedures postdistraction may be problematic. In a study by Jensen et al, all failed implants (8 of 84 placed) required grafting of bone dehiscences.[24] These failures may be attributed to the temporary decrease of blood supply to the newly augmented bone resulting in a reduction of nutrition. The need for additional augmentation procedures may be eliminated in cases where the distraction vector is optimized (Fig 2a). As long as the bone fragment is mobile, this can be accomplished through a secondary alteration of the vector with the use of a bidirectional distractor such as that used in the present study.

Possible complications of the distraction procedure are fracture of the mandible, wound dehiscence, and nerve disturbance. Osteomyelitis, lack of

bone formation, and bone resorption of the crestal segment are other potential problems.[25] The severely resorbed mandible is prone to complications because of its poor blood supply.[26] As with the need for postdistraction grafting, there was a clear tendency toward a higher rate of complications in the unidirectional group ($P = .08$). Again, the lack of statistical significance is likely a function of poor statistical power because of the modest sample size.

At the time of distractor removal, generally 10 weeks after the cessation of distraction, areas of poor ossification or scar tissue were seen, mostly adjacent to the distractor spindle. This mostly occurred in distractions of greater than 5 mm, which still showed patches of radiolucency months after the osteotomy was completed. These findings, however, did not appear to significantly influence the overall results. In other comparable studies, thinning of the alveolus in the facial regenerate zone has been observed.[27] The infection rate associated with distraction osteogenesis in general has reportedly ranged from 5% to 30%.[28] Infection is nevertheless mentioned as the most common complication during alveolar distraction.[29] Bacterial contamination is possible during the insertion of distractor systems and the weeks of distraction and consolidation. The prophylactic administration of antibiotics during the first 7 days, along with good oral hygiene and an antimicrobial rinse, appears to reduce the infection rate to an acceptable level.

Vertical distraction osteogenesis performed in healthy patients and healthy bone should result in fewer postoperative complications compared with other osseous surgical procedures.[30] The distraction of previously irradiated and nonvascular transplanted bone requires a different approach. Several experimental investigations have studied the effects of irradiation on bone healing. The damaging effects of radiotherapy on bone tissue are believed to result from direct damage to the osteogenic cells, but vascular injury to the area is also important.[31] The loss of regenerative function increases the rate of failures and makes severe complications such as fractures and bone necrosis more likely.[32] Hyperbaric oxygenation may be necessary in such cases.[33]

A recent investigation comparing distraction osteogenesis and onlay bone grafting for the treatment of vertical bone deficiencies of the alveolar ridge demonstrated no difference between the 2 methods in terms of bone gained.[34] The advantage of distraction osteogenesis is that the bone is gained without first harvesting bone from a donor site. Most of the morbidity and complications associated with grafting occur at the donor site. The primary disadvantage of distraction is the large number of complications that can occur at the augmentation site.[35]

CONCLUSION

In this retrospective clinical report on 10 patients receiving distraction osteogenesis using a unidirectional device and 11 patients treated with a bidirectional distractor, no statistically significant difference between the 2 groups was realized with respect to bone gain. Although the patients treated with the bidirectional device needed subsequent bone grafting less often, this difference was also not significant.

REFERENCES

1. Peled M, El-Naaj IA, Lipin Y, Ardekian L. The use of free fibular flap for functional mandibular reconstruction. J Oral Maxillofac Surg 2005;63:220–224.
2. Jensen OT, Cockrell R, Kuhike L, Reed C. Anterior maxillary alveolar distraction osteogenesis: A prospective 5-year clinical study. Int J Oral Maxillofac Implants 2002;17:52–68.
3. Bertram C, Nielander KH, König DP. Pioneers in the lengthening of the extremities. Chirurg 1999;70:1374–1378.
4. Ilizarov GA. The principles of the Ilizarov method. 1988. Bull Hosp Jt Dis 1997;56:49–53.
5. Altuna G, Walker DA, Freeman E. Rapid orthopedic lengthening of the mandible in primates by sagittal split osteotomy and distraction osteogenesis: A pilot study. Int J Adult Orthodon Orthognath Surg 1995;10:59–64.
6. Enislidis G, Fock N, Millesi-Schobel G, et al. Analysis of complications following alveolar distraction osteogenesis and implant placement in the partially edentulous mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:25–30.
7. Kunkel M, Wahlmann U, Reichert TE, Wegener J, Wagner W. Reconstruction of mandibular defects following tumor ablation by vertical distraction osteogenesis using intraosseous distraction devices. Clin Oral Implants Res 2005;16:89–97.
8. Hidding J, Zoller JE, Lazar F. Micro- and macrodistraction of the jaw. A sure method of adding new bone. Mund Kiefer Gesichtschir 2000;(suppl 2):432–437.
9. Iizuka T, Hallermann W, Seto I, Smolka W, Smolka K, Bosshardt DD. Bi-directional distraction osteogenesis of the alveolar bone using an extraosseous device. Clin Oral Implants Res 2005;16:700–707.
10. Mazzonetto R, Serra E Silva FM, Ribeiro Torezan JF. Clinical assessment of 40 patients subjected to alveolar distraction osteogenesis. Implant Dent Jun 2005;14:149-153.
11. Cano J, Campo J, Moreno LA, Bascones A. Osteogenic alveolar distraction: A review of the literature. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101:11–28.
12. Alkan A, Bas B, Inal S. Alveolar distraction osteogenesis of bone graft reconstructed mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:39–42.
13. Uckan S, Haydar SG, Dolanmaz D. Alveolar distraction: analysis of 10 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:561–565.
14. Chiapasco M, Consolo U, Bianchi A, Ronchi P. Alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: A multicenter prospective study on humans. Int J Oral Maxillofac Implants 2004;19:399–407.
15. Oda T, Sawaki Y, Ueda M. Alveolar ridge augmentation by distraction osteogenesis using titanium implants: An experimental study. Int J Oral Maxillofac Surg 1999;28:151–156.

16. Garcia Garcia A, Somoza Martin M, Gandara Vila P, Lopez Maceiras J. Alveolar ridge osteogenesis using 2 intraosseous distractors: Uniform and nonuniform distraction. J Oral Maxillofac Surg 2002;60:1510–1512.
17. Uckan S, Haydar SG, Dolanmaz D. Alveolar distraction: Analysis of 10 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:561–565.
18. Klug CN, Millesi-Schobel GA, Millesi W, Watzinger F, Ewers R. Preprosthetic vertical distraction osteogenesis of the mandible using an L-shaped osteotomy and titanium membranes for guided bone regeneration. J Oral Maxillofac Surg 2001;59:1302–1310.
19. Chiapasco M, Romeo E, Casentini P, Rimondini L. Alveolar distraction osteogenesis vs vertical guided bone regeneration for the correction of vertically deficient edentulous ridges: A 1–3-year prospective study on humans. Clin Oral Implants Res 2004;15:82–95.
20. Rachmiel A, Srouji S, Peled M. Alveolar ridge augmentation by distraction osteogenesis. Int J Oral Maxillofac Surg 2001;30:510–517.
21. Stricker A, Schramm A, Marukawa E, Lauer G, Schmelzeisen R. Distraction osteogenesis and tissue engineering—New options for enhancing the implant site. Int J Periodontics Restorative Dent 2003;23:297–302.
22. van Strijen PJ, Breuning KH, Becking AG, Perdijk FB, Tuinzing DB. Complications in bilateral mandibular distraction osteogenesis using internal devices. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:392–397.
23. Mazzonetto R, Serra E Silva FM, Ribeiro Torezan JF. Clinical assessment of 40 patients subjected to alveolar distraction osteogenesis. Implant Dent 2005;14:149–153.
24. Jensen OT, Cockrell R, Kuhike L, Reed C. Anterior maxillary alveolar distraction osteogenesis: A prospective 5-year clinical study. Int J Oral Maxillofac Implants 2002;17:52–68.
25. Oda T, Sawaki Y, Ueda M. Alveolar ridge augmentation by distraction osteogenesis using titanium implants: An experimental study. Int J Oral Maxillofac Surg 1999;28:151–156.
26. Raghoebar GM, Liem RS, Vissink A. Vertical distraction of the severely resorbed edentulous mandible: A clinical, histological and electron microscopic study of 10 treated cases. Clin Oral Implants Res 2002;13:558–565.
27. Lin Y, Wang X, Li J, Qiu L, Chen B. Clinical study of alveolar vertical distraction osteogenesis for implant. Zhonghua Kou Qiang Yi Xue Za Zhi 2002;3:253–256.
28. Gaggl A, Schultes G, Karcher H. Vertical alveolar ridge distraction with prosthetic treatable distractors: A clinical investigation. Int J Oral Maxillofac Implants 2000;15:701–710.
29. Garcia-Garcia A, Somoza-Martin M, Gandara-Vila P, Saulacic N, Gandara-Rey JM. Alveolar distraction before insertion of dental implants in the posterior mandible. Br J Oral Maxillofac Surg 2003;41:376–379.
30. Keller EE, Tolman DE, Eckert SE. Maxillary antral-nasal inlay autogenous bone graft reconstruction of compromised maxilla: A 12-year retrospective study. Int J Oral Maxillofac Implants 1999;14:707–721.
31. Arnold M, Kummermehr J, Trott KR. Radiation-induced impairment of osseous healing: Quantitative studies using a standard drilling defect in rat femur. Radiat Res 1995;143:77–84.
32. Fukuda M, Iino M, Ohnuki T, Nagai H, Takahashi T. Vertical alveolar distraction osteogenesis with complications in a reconstructed mandible. J Oral Implantol 2003;29:185–188.
33. Johnsson AA, Jacobsson M, Granstrom G, Johansson CB, Strid K, Turesson I. A microradiographic investigation of cancellous bone healing after irradiation and hyperbaric oxygenation: A rabbit study. Int J Radiat Oncol Biol Phys 2000;4:555–563.
34. Saulacic N, Gandara-Vila P, Somoza-Martin M, Garcia-Garcia A. Distraction osteogenesis of the alveolar ridge: A review of the literature. Med Oral 2004;9:321–327.
35. Enislidis G, Ewers R. Vertical augmentation of atrophic mandibles-pedicled sandwich-plasty or distraction osteogenesis? Br J Oral Maxillofac Surg 2005;18:26–31.