Vertical Alveolar Ridge Distraction with Prosthetic Treatable Distractors: A Clinical Investigation

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Alveolar ridge distraction is a recent and promising technique for ridge augmentation. Since 1997, a new distraction system incorporating a distraction implant has been in use. It can be used for alveolar ridge distraction and is not removed from the alveolar ridge. Upon completion of the distraction, it remains in the alveolar process for later prosthetic treatment. Thirty-five patients were treated with distraction implants for the correction of alveolar ridge deficiency. In 10 patients with atrophy of the mandible or maxilla, 16 patients with severe defects of the alveolar process after trauma, and 9 patients with localized alveolar ridge defects after single tooth loss, alveolar ridge distraction was carried out with the aid of 62 distraction implants. The distraction implants were loaded by prosthetic superstructures 4 to 6 months after distraction. A clinical and radiologic follow-up was carried out. Periotest values were examined, and periimplant bleeding and probing depth were registered prior to prosthetic treatment and 3, 6, and 9 months after implant loading. In 29 patients, distraction was carried out without complications or problems. Two distraction implants were lost. In 2 patients distraction was discontinued because of ankylosis of the distraction segment. In 1 patient the alveolar ridge was overcorrected, and another patient experienced a persisting hypoesthesia of the lip. For 5% of the implants, pathologic probing depth of more than 3 mm and sulcus bleeding were registered prior to prosthetic treatment. These observations decreased during the next 9 months. Periotest values were normal before the start of prosthetic treatment. There was a decrease in the Periotest values, thus an increase in implant stability, during the following 9 months. It was concluded that alveolar ridge distraction using distraction implants can be a successful technique for alveolar ridge augmentation with a low rate of complication. Acceptable esthetic and functional results can be achieved by this atraumatic technique of surgery and distraction. (Int J Oral Maxillofac Implants 2000;15:701–710)

Key words: *alveolar ridge augmentation, dental implants, distraction osteogenesis*

Distraction of the alveolar ridge was first described by Chin and Toth[1] and Block et al[2] in 1996. They used a technique from orthopedic surgery that had been used for the elongation of tubular bone in children for augmentation of the alveolar process. The technique is based on secondary osseous wound healing.[3] By osteotomy of the deficient alveolar process and slow movement of the fragment from its base, defect coverage of the alveolar bone can be achieved. The distraction gap is initially filled with callus and later with bone. Following distraction, defect coverage and a better situation for implant placement can be achieved. Chin and Toth[1] used this technique for the treatment of patients with alveolar ridge defects after trauma. Other authors have described a similar technique for distraction of the edentulous mandible in patients with severe alveolar ridge atrophy.[4,5] With distraction techniques, bone transplants for alveolar ridge augmentation can also be avoided for patients with severe alveolar ridge atrophy. Furthermore, donor site problems can be circumvented by using this technique of local bone growth induction.[6–9] Distraction is also a surgical technique for expanding the soft tissue and elongating attached gingiva by bone augmentation.[1] These are the main reasons why alveolar ridge distraction is a minimally invasive and promising technique for ridge augmentation prior to implant placement.

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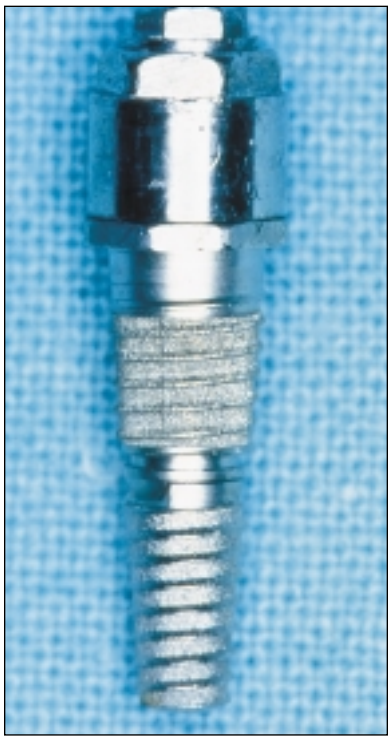

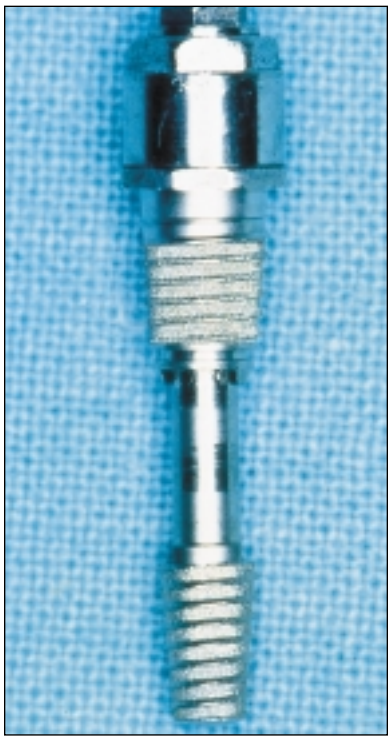

Fig 1a *(Left)* The distraction implant is a self-cutting conical titanium screw implant with a laser-roughened surface. Here, the implant is not distracted.

Fig 1b *(Right)* The distraction implant partially distracted. The distraction is carried out by activation of the central distraction screw, which causes the distraction cylinder to move out of the coronal implant component.

For all of these previously described techniques, a 2- to 3-stage procedure for distraction and implant placement is necessary, because the distractor must be removed from the alveolar process and implantation cannot be carried out before optimal conditions are present. Therefore, additional surgical treatment and a second removal of the periosteum is necessary after alveolar ridge augmentation by distraction. Removal of the distractor can endanger the newly formed callus and bone. Additional surgery can cause more scarification, which is especially objectionable in the anterior area of the arches.

Since 1997, another distractor system has been in use, which remains in the alveolar ridge after distraction and can be incorporated into prosthetic treatment after osseous healing.[10] The distractor is designed as a dental implant that is not removed from the alveolar process. Thus, a single-step procedure for distraction and implant placement is possible with this distraction system.[11]

MATERIAL AND METHODS

Since 1997, 35 patients with alveolar ridge deficiency have been treated by alveolar ridge distraction with the aid of distraction implants (SIS Trade Systems, Klagenfurt, Austria) (Figs 1a and 1b). In this investigation, 7 patients with severe atrophy of the edentulous mandible, 3 patients with severe atrophy of the edentulous maxilla, 16 patients with an alveolar ridge defect after trauma with the loss of more than 2 teeth, and 9 patients with an alveolar ridge defect after single tooth loss, all with a residual ridge of 7 mm or more, were examined. The average age of patients with atrophy was 60 years, of patients with extended defects 34 years, and of patients after single tooth loss 22 years (Table 1). All trauma patients had penetrating defects of the alveolar ridge involving the buccal and lingual cortical layers (Table 2).

Distraction was started no earlier than 4 months after the trauma. Preoperative planning was carried out with the aid of panoramic radiographs, dental radiographs, plaster casts, and computed tomogram–based milling models (Fig 2). Combined segmental osteotomy and distraction implant placement was carried out during surgical treatment. After crestal incision and mobilization of the mucoperiosteal flap, the remaining crestal bone was removed with the use of a milling cutter to create a plateau for implant placement. Then a horizontal osteotomy was performed at a distance of 4.5 mm from the crestal bone plateau (Fig 3). One or 2 distraction implants were placed in the alveolar ridge after pilot and core drilling. The distraction implant

Table 1 Patient Data

Patient	Sex	Age	Cause	Location	Complications
Alveolar ridge atrophy (mandible)					
1	Male	63		Mandible	None
2	Female	69		Mandible	Implant loss
3	Male	66		Mandible	None
4	Male	62		Mandible	None
5	Male	58		Mandible	None
6	Female	56		Mandible	None
7	Male	63		Mandible	None
Single tooth loss					
1	Female	21	Trauma	Central incisor	Implant loss
2	Female	24	Trauma	Central incisor	None
3	Male	18	Trauma	Central incisor	None
4	Male	20	Trauma	Central incisor	None
5	Female	26	Trauma	Central incisor	None
6	Female	17	Trauma	Lateral incisor	None
7	Male	27	Trauma	Central incisor	None
8	Female	23	Trauma	Central incisor	None
9	Female	19	Trauma	Central incisor	None
Alveolar ridge defect					
1	Male	39	Trauma	Anterior mandible	None
2	Male	43	Trauma	Anterior mandible	None
			Trauma	Anterior maxilla	None
3	Male	26	Trauma	Anterior maxilla	None
4	Female	32	Trauma	Anterior mandible	None
5	Male	43	Trauma	Anterior mandible	None
6	Male	37	Trauma	Anterior mandible	None
7	Male	23	Trauma	Anterior maxilla	None
8	Female	29	Trauma	Anterior mandible	None
9	Male	21	Trauma	Anterior maxilla	None
10	Female	47	Trauma	Anterior mandible	None
11	Male	41	Trauma	Anterior mandible	None
12	Male	39	Tumor	Anterior mandible	None
13	Male	19	Trauma	Anterior mandible	None
14	Female	28	Trauma	Anterior mandible	None
15	Female	34	Trauma	Anterior maxilla	None
16	Male	47	Trauma	Anterior maxilla	None
Alveolar ridge atrophy (maxilla)					
1	Male	56		Maxilla	None
2	Female	53		Maxilla	None
3	Female	49		Maxilla	None

serves as a self-cutting screw. After the implants were placed, the lateral osteotomy was carried out with a small oscillating saw (Fig 4), and an attempted distraction was performed to determine whether the distraction segment could be moved without impedance during actual distraction (Fig 5). Following this determination, the distraction implants were retracted to their starting position and wounds were closed with sutures.

In patients with atrophy of the edentulous mandible, 2 implants were placed in the interforaminal area. The segment osteotomy was performed as a sandwich osteotomy[12] in 3 patients and as a combined sandwich (anterior part) and lateral visor osteotomy[13] in 4 patients.[14] The lingual soft tissue was treated carefully without removing the lingual periosteum during soft tissue preparation. In patients with severe atrophy of the edentulous maxilla, 2 distraction implants were used in the anterior maxilla. The osteotomy was carried out as a sandwich osteotomy without injuring the maxillary sinus. Patients with severe alveolar ridge defects were also treated with 2 distraction implants. The implants were positioned in the mesial and distal parts of the defect. The vertical osteotomy was carried out near the neighboring teeth without injuring the

Table 2 Defect Dimensions and Planned Distraction

Patient	Defect diameter: Mesiodistal direction	Defect diameter: Apicocoronal direction	Planned distraction	No. of distractors	Location of distractors*	Distraction height achieved
Alveolar ridge atrophy (mandible)						
1	37 mm		6 mm	2	34 and 44	6 mm
2	42 mm		6 mm	2	34 and 44	4 mm
3	41 mm		6 mm	2	34 and 44	6 mm
4	52 mm		6 mm	2	34 and 44	6 mm
5	49 mm		6 mm	2	34 and 44	6 mm
6	54 mm		6 mm	2	34 and 44	6 mm
7	50 mm		6 mm	2	32 and 42	6 mm
Single tooth loss						
1	10 mm	4 mm	4 mm	1	11	3 mm
2	10 mm	4 mm	4 mm	1	21	4 mm
3	12 mm	5 mm	5 mm	1	11	5 mm
4	11 mm	5 mm	5 mm	1	11	5 mm
5	11 mm	3 mm	3 mm	1	21	4 mm
6	8 mm	4 mm	4 mm	1	12	5 mm
7	12 mm	5 mm	5 mm	1	22	5 mm
8	11 mm	5 mm	5 mm	1	21	6 mm
9	11 mm	5 mm	5 mm	1	11	4 mm
Alveolar ridge defect						
1	22 mm	5 mm	5 mm	1	31 and 41	5 mm
2	27 mm	6 mm	6 mm	2	32 and 41	6 mm
	24 mm	5 mm	5 mm	2	11 and 21	5 mm
3	27 mm	5 mm	5 mm	2	11 and 22	4 mm
4	23 mm	5 mm	5 mm	2	32 and 41	5 mm
5	23 mm	5 mm	5 mm	2	33 and 41	5 mm
6	19 mm	5 mm	5 mm	2	31 and 41	5 mm
7	26 mm	5 mm	5 mm	2	12 and 21	5 mm
8	28 mm	5 mm	5 mm	1	11 and 22	5 mm
9	29 mm	3 mm	3 mm	2	12 and 22	5 mm
10	27 mm	5 mm	5 mm	2	32 and 42	4 mm
11	28 mm	6 mm	6 mm	2	33 and 41	6 mm
12	27 mm	5 mm	5 mm	2	32 and 35	5 mm
13	30 mm	6 mm	6 mm	2	31 and 42	5 mm
14	24 mm	4 mm	4 mm	2	32 and 41	4 mm
15	27 mm	5 mm	5 mm	2	12 and 21	5 mm
16	28 mm	4 mm	4 mm	2	11 and 22	4 mm
Alveolar ridge atrophy (maxilla)						
1	47 mm	6 mm	6 mm	2	13 and 23	6 mm
2	56 mm	6 mm	6 mm	4	14 and 25	6 mm
3	54 mm	5 mm	5 mm	2	13 and 23	5 mm

*Maxilla: 11 = R central incisor; 12 = R lateral incisor; 13 = R canine; 14 = R first premolar; 21 = L central incisor; 22 = L lateral incisor; 23 = L canine; 25 = L second premolar. Mandible: 31 = L central incisor; 32 = L lateral incisor; 33 = L canine; 34 = L first premolar; 35 = L second premolar; 41 = R central incisor; 42 = R lateral incisor; 44 = R first premolar.

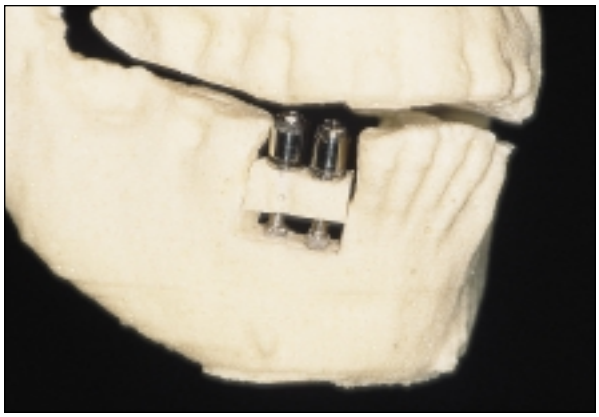

Fig 2 Operative planning with the aid of a computed tomography–based milling model in a patient with an alveolar ridge defect.

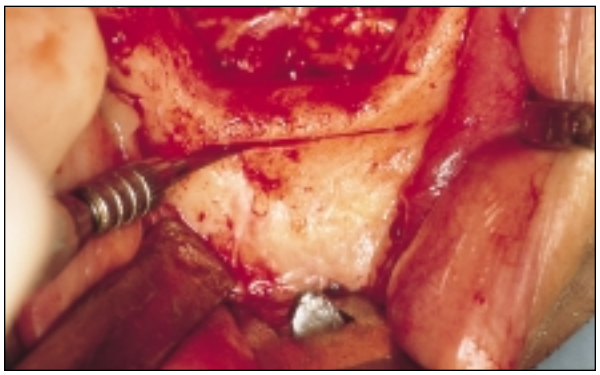

Fig 3 Intraoperative situation during horizontal osteotomy.

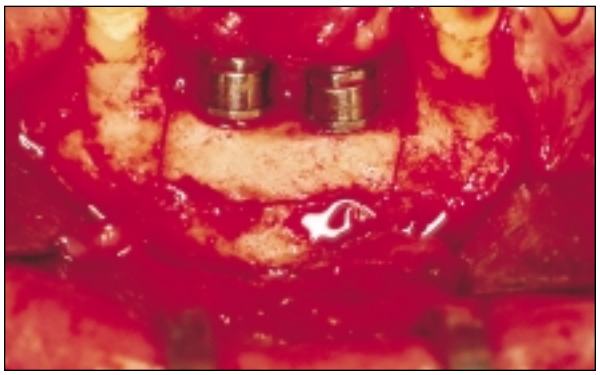

Fig 4 Intraoperative situation after implant placement and vertical osteotomy.

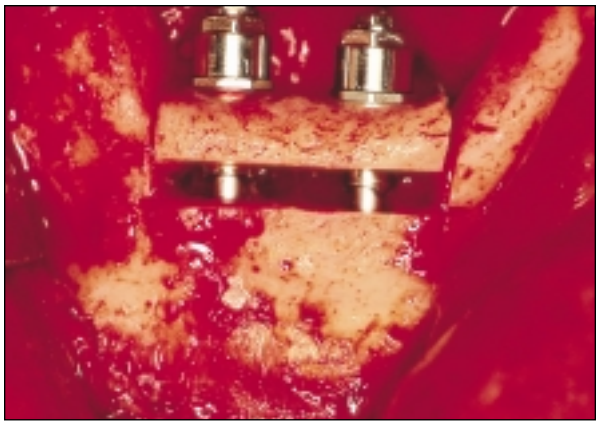

Fig 5 Intraoperative trial run of distraction.

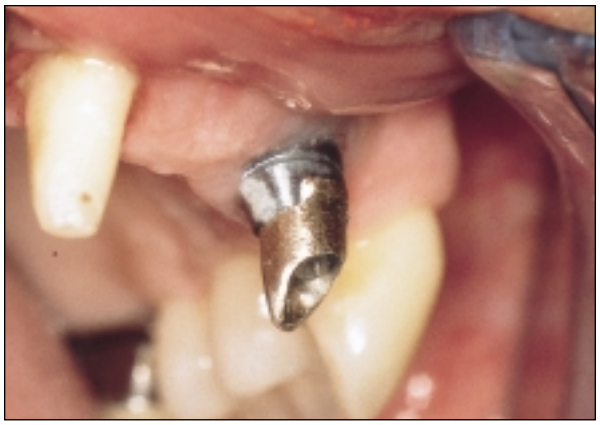

Fig 6 Clinical situation after placement of the individualized abutment.

periodontium. Only 1 distraction implant was used in patients with single tooth loss. For antibiotic prophylaxis, clindamycin (300 mg 3 × 1) was prescribed for 5 days.

The surgery was followed by a healing period of 7 (alveolar ridge defects) to 10 days (alveolar ridge atrophy). The distraction was then started by activation of the central distraction screw. The distraction was carried out at a rate of 0.25 (atrophy) to 0.5 mm (defects) per day. It was continued for 8 to 24 days to achieve an increase of 4 to 6 mm in alveolar ridge height. After the planned distraction height was achieved, the distraction insert was replaced by the definitive implant insert and the segment was stabilized.

Six patients with alveolar ridge atrophy and 9 patients with alveolar ridge defects were further treated with conventional dental implants 6 weeks after distraction. Before prosthetic treatment was started, these implants and all distraction implants healed for 4 (defects) to 6 months (atrophy). All distraction implants were loaded by prosthetic superstructures after the fabrication and placement of individual abutments (Fig 6). Conventional clinical follow-up was carried out for the first months until prosthetic treatment started. Prior to prosthetic treatment and 3, 6, and 9 months after implant loading, sulcus bleeding,[15] peri-implant probing depth, and implant mobility (Periotest, Siemens, Bensheim, Germany) were recorded. Sensory function of the mental nerve was examined by probing the skin in the mental and inferior labial regions. Anesthesia and hypoesthesia were noted. At each examination, the implants were viewed radiographically by panoramic or intraoral dental radiographs (Figs 7a and 7b). All patients were followed for 9 months after loading.

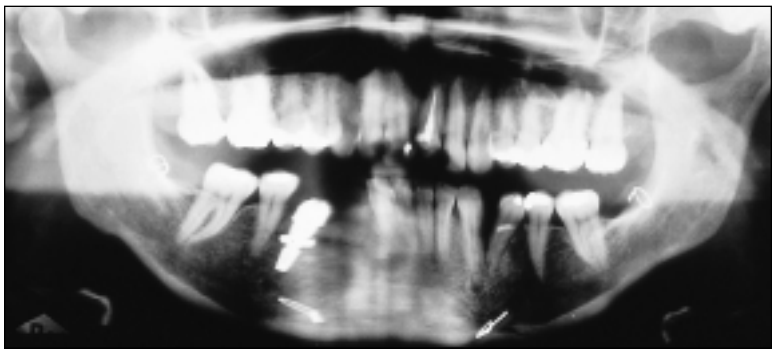

Fig 7a Panoramic radiograph 1 day after surgery.

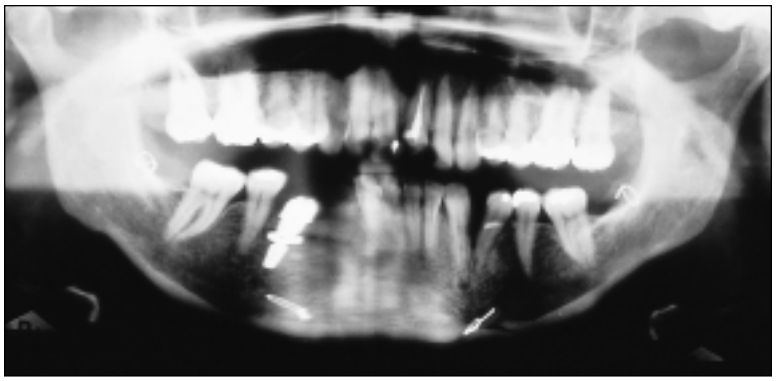

Fig 7b Panoramic radiograph 9 months after implant loading.

RESULTS

In 29 patients, distraction was carried out without complications. The planned augmentative height was achieved following the distraction. Patients had no pain but sensed a "tension of the gingiva" during distraction and until 20 minutes afterward. Five patients with atrophy of the edentulous mandible had hypoesthesia of the lip or chin region after surgery. In 4 patients the hypoesthesia disappeared within the first 2 months, and sensory function of the mental nerve became normal. One patient had hypoesthesia of the lower lip for 6 months on one side and persistent hypoesthesia on the other side. One patient with atrophy of the mandible experienced loosening of 1 distraction implant after using it for masticatory function. Distraction was discontinued after distraction height of 4 mm had been achieved, and the loose distraction implant was removed and replaced with a conventional implant. One patient with traumatic single tooth loss required removal of the distraction implant, since the segment to be distracted lost stability and the distractor moved out of the segment. Guided bone regeneration was used for bone augmentation in this patient. A conventional implant was placed and later loaded by a single crown restoration.

Two patients with severe alveolar ridge defects experienced premature reunion of the fragments. Therefore, distraction was stopped 1 mm before the planned distraction height could be realized. Since only a small persisting deficiency of the newly formed ridge remained, the distraction implant was used for prosthetic superstructures. The dental crown was 1 mm longer than the crowns of the adjacent teeth, but no further surgical augmentation techniques were applied. In 2 other patients, the distraction was terminated by the surgeon 1 mm before the planned distraction height was reached, because the clinical situation seemed to be acceptable and further distraction would have resulted in inadequate crown restorations. In 1 patient, such an over-correction occurred, resulting in a short crown. In 1 patient with mandibular alveolar ridge atrophy, a vestibuloplasty and transplantation of mucosa was performed 8 months after implant loading. The patient had peri-implant problems because of minimal attached gingiva. The peri-implant probing revealed sulcus bleeding around 4 distraction implants before prosthetic treatment and around 1 implant during all examinations after implant loading (Fig 8). Probing depths were deeper than 3 mm in 3 implants before prosthetic treatment and for 1 implant during all examinations. Before prosthetic treatment, Periotest values ranged from +1

to –2. The value decreased during the first 9 months after implant loading. After the end of distraction, no distraction implants had to be removed. All results can be seen in Tables 2 to 4.

DISCUSSION

Augmentation techniques for the correction of alveolar ridge deficiency often have a high rate of complication. Although interpositional grafts have realized good results within the first years,[12,14,16] they are often associated with disturbances in neurosensory function.[17] Furthermore, these techniques require bone transplantation and may cause donor site problems.[18–20] Alveolar ridge distraction may also require alveolar ridge splitting, but it eliminates bone transplants and donor site problems. After the alveolar ridge is split, only slow segment movements occur, and expansion of the soft tissue is possible. This may be the reason for the minimal neural disturbances in the mental nerve region. When inlay bone grafts are used, much more tension is created by the immediate heightening of the alveolar process. With alveolar ridge distraction, the alveolar neurovascular bundle can be stretched gently, so that very little persisting neurosensory dysfunction results. In orthognathic surgery this advantage has been well known for some time.[21] Thus, the most gentle single-step technique should be preferred, because every subsequent surgery can cause new complications and scarification.[10,22]

It is important that distraction of the bone and the expansion of the soft tissue that is enabled with distraction implants be carried out in a clinically controlled manner. Furthermore, good peri-implant conditions should result, which can be achieved by use of the distraction implants. This is a significant factor in long-term implant success, because peri-implant infections are often the reason for late implant loss.[23,24] Desirable tooth esthetics can be achieved only if the dental crown is correctly positioned and angulated.[25] Therefore, abutments with individually created angulation and design are used for prosthetic superstructures of distraction implants. Correction of misangulations is possible in all 3 dimensions. That means that the distraction system makes possible individual and clinically controlled corrections of alveolar ridge deficiency and customized prosthetic treatment.

The only disadvantage is that the system must be handled very carefully throughout the distraction procedure, because osseointegration of the distractor is necessary for later prosthetic treatment. Slow distraction speed is therefore necessary, and this system requires a longer distraction period than other distractors.[4,5] This slow distraction speed can cause premature reunion of the distracted segment and can lead to early termination of the distraction. Because of the necessity of retaining osseointegration, no large force can be used for activating the distraction implant.[26] With other systems, greater forces can be applied, because the distractors must withstand the distraction period only and are not used for prosthetic loading.[4,5] Also, a distraction of 1.0 mm a day is usually performed,[4,5] which leads to a higher speed of distraction. Nevertheless, if distraction is too fast, the callus can be injured and disturbances in wound healing can be seen.[27] With distraction implants, a distraction rate of 0.5 mm a day seemed to be ideal for histologic success and implant osseointegration.[26]

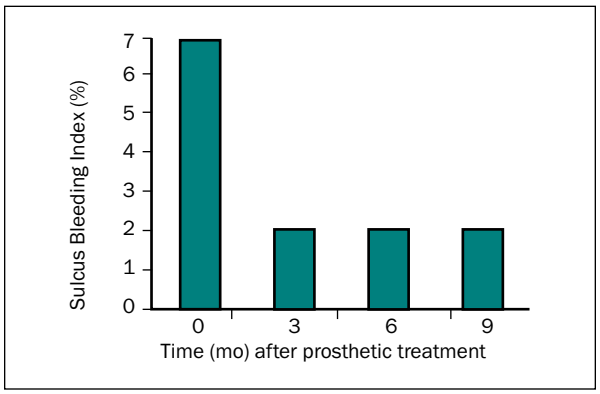

Fig 8 Mean peri-implant sulcus bleeding (Sulcus Bleeding Index) (n = 34 patients/60 implants).

The clinical follow-up of patients in this series also confirms implant osseointegration 4 to 6 months after distraction. All Periotest values were physiologic[28,29] and decreased during the first months of implant loading. The apparent reason for this phenomenon is an increase in bone-to-implant contact caused by bone remodeling.[30,31] Furthermore, the bone-to-implant surface can be extended by early implant loading.[32–34] This increase in stability may be expected to continue, since increased bone remodeling activity has been seen for about 1 year after distraction.[35]

CONCLUSIONS

The follow-up (9 months after prosthetic treatment, 13 to 15 months after distraction) of 62 distraction implants revealed successful alveolar ridge distraction, with a low rate of implant loss. The main advantage of the distraction implant system is its small dimension, which includes the potential for osseointegration and prosthetic restoration. The patient experiences surgery only once, and minimal scarification with a good esthetic and functional outcome can

Table 3 Results of Peri-implant Probing

Patient	Implant no.	Probing depth (mm)			
		Before prosthetic treatment	3 months after implant loading	6 months after implant loading	9 months after implant loading
Alveolar ridge atrophy (mandible)					
1	1	3	3	3	3
	2	4	3	2	2
2	3	—	—	—	—
	4	2	3	3	2
3	5	2	2	2	2
	6	2	2	2	2
4	7	3	3	3	3
	8	3	3	2	2
5	9	2	3	3	3
	10	3	4	4	4
6	11	3	3	2	2
	12	3	2	2	2
7	13	2	2	2	2
	14	3	3	3	2
Single tooth loss					
1	15	—	—	—	—
2	16	2	3	2	2
3	17	2	3	3	2
4	18	1	1	1	1
5	19	2	2	2	1
6	20	3	3	2	2
7	21	2	2	2	2
8	22	1	1	1	1
9	23	2	3	2	3
Alveolar ridge defect					
1	24	2	2	2	2
2	25	3	3	3	2
	26	2	3	2	2
	27	2	2	2	2
	28	2	2	2	2
3	29	3	2	2	2
	30	2	2	2	2
4	31	3	2	2	1
	32	2	1	1	1
5	33	2	2	2	2
	34	2	2	1	2
6	35	3	2	2	2
	36	2	1	1	1
7	37	3	1	1	1
	38	2	1	1	1
8	39	3	3	3	2
9	40	2	2	2	2
	41	3	2	2	2
10	42	2	0	0	0
	43	2	1	1	1
11	44	1	0	1	1
	45	0	0	0	0
12	46	3	3	3	3
	47	3	3	3	2
13	48	2	1	1	1
	49	1	0	1	1
14	50	3	2	2	2
	51	2	2	2	2
15	52	1	1	1	1
	53	2	2	2	2
16	54	3	2	2	2
	55	1	1	1	1
	56	2	1	2	2
Alveolar ridge atrophy (maxilla)					
1	57	3	3	3	3
	58	2	1	1	1
2	59	4	2	2	2
	60	3	3	3	2
3	61	3	2	2	2
	62	4	2	2	2

— = Implant lost.

Table 4 Periotest Values

Patient	Implant no.	Periotest values: Before prosthetic treatment	3 months after implant loading	6 months after implant loading	9 months after implant loading
Alveolar ridge atrophy (mandible)					
1	1	+1	–2	–3	–4
	2	+1	–2	–2	–2
2	3	—	—	—	—
	4	+1	0	–2	–2
3	5	0	–3	–4	–4
	6	0	–3	–4	–5
4	7	+1	–2	–3	–3
	8	+1	–1	–2	–2
5	9	+1	0	–1	–2
	10	+1	–1	–2	–2
6	11	0	–2	–4	–3
	12	0	–1	–3	–4
7	13	–1	–3	–5	–5
	14	–1	–2	–2	–3
Single tooth loss					
1	15	—	—	—	—
2	16	+1	–2	–2	–4
3	17	+1	–1	–2	–2
4	18	0	0	–1	–1
5	19	+1	+1	–1	–2
6	20	–2	–3	–5	–5
7	21	–3	–3	–3	–3
8	22	–1	–1	–2	–4
9	23	–2	–3	–4	–5
Alveolar ridge defect					
1	24	0	–1	–2	–2
2	25	–1	–3	–5	–5
	26	0	–3	–4	–3
	27	–1	–4	–4	–5
	28	–2	–4	–3	–4
3	29	0	0	–1	–1
	30	0	0	–2	–1
4	31	–1	–1	–2	–2
	32	0	–2	–2	–4
5	33	–2	–3	–5	–6
	34	–1	–2	–2	–4
6	35	–1	–4	–4	–5
	36	0	–4	–5	–5
7	37	+1	0	–2	–3
	38	+1	0	–1	–2
8	39	+1	0	–2	–1
9	40	–1	–3	–4	–4
	41	–1	–2	–2	–2
10	42	0	–2	–4	–4
	43	+1	–1	–2	–2
11	44	+1	0	–3	–3
	45	+1	0	–1	–2
12	46	0	+1	–1	–1
	47	0	+1	–2	–2
13	48	+1	–1	–2	–2
	49	+1	–1	–3	–2
14	50	+1	–1	–2	–4
	51	+1	–1	–3	–5
15	52	–1	–3	–4	–4
	53	0	–1	–2	–4
16	54	–2	–1	–2	–2
	55	–2	–2	–4	–5
	56	–2	–2	–3	–6
Alveolar ridge augmentation (maxilla)					
1	57	0	0	–1	–2
	58	–1	–1	–2	–3
2	59	0	–1	–2	–2
	60	–1	–1	–2	–2
3	61	–1	–1	–1	–2
	62	0	–1	–2	–3

— = Implant lost.

be the result. The rate of complication is low. The main disadvantage is possible premature ankylosis caused by the slow distraction speed; however, the slow distraction speed is necessary for later osseointegration. While a gentle distraction technique makes good esthetic and functional success possible, the distraction device must be treated with care.

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