Vertical Distraction Osteogenesis of Edentulous Ridges for Improvement of Oral Implant Positioning: A Clinical Report of Preliminary Results

Matteo Chiapasco, MD[1]/Eugenio Romeo, MD[2]/Giorgio Vogel, MD[3]

This study examined the opportunities offered by intraoral distraction osteogenesis to vertically elongate insufficient alveolar ridges and thereby improve local anatomy for ideal implant placement. Eight patients presenting with vertically deficient edentulous ridges were treated by means of the distraction osteogenesis principle with an intraoral alveolar distractor. Two to 3 months after consolidation of the distracted segments, 26 implants were placed in the distracted areas. Four to 6 months later, abutments were connected and prosthetic loading of the implants was started. The mean follow-up after initial prosthetic loading was 14 months. In all patients, the desired bone gain was reached at the end of distraction (mean vertical bone gain of 8.5 mm). Probing depth, Bleeding Index, and Plaque Index around implants were evaluated, and Periotest values were also calculated. The cumulative success rate of implants was 100%. Radiographic examinations 12 months after functional loading of implants showed a significant increase in the density of the newly generated bone in the distracted areas. This technique seems to be reliable, and the regenerated bone has withstood the functional demands of implant loading. Success rates of implants, periodontal indices of peri-implant soft tissues, and Periotest values were consistent with those reported in the literature regarding implants placed in native bone. (Int J Oral Maxillofac Implants 2001;16:43–51)

Key words: *dental implants, distraction osteogenesis, implant-supported prosthesis, preprosthetic oral surgical procedures*

Vertically deficient edentulous alveolar ridges still represent a challenge for appropriate implant placement and predictable long-term results. Vertical guided bone regeneration (GBR) with semipermeable barriers may present some limitations (eg, unpredictable bone gain; risk of membrane exposure; technique-related success[1–3]), and autogenous bone grafts increase morbidity and are prone to unpredictable resorption.[4,5] Distraction osteogenesis was originally created for orthopedic purposes[6–9] and was later applied to the maxillofacial region for the correction of severe malformations such as obstructive sleep apnea syndrome, hemifacial microsomia, Franceschetti syndrome, and craniosynostosis.[10–12] More recently, the procedure has been used in the treatment of vertical resorption of edentulous arches to improve bone volume for dental implant placement.[13,14] Preliminary results have demonstrated good quality of the newly generated bone, with adequate characteristics for implant osseointegration.[15–18]

In this preliminary study, the authors present their experience in treating vertical defects of edentulous ridges by means of intraoral vertical distraction osteogenesis, followed by placement of endosseous implants in the distracted areas. Early results are reported concerning distraction and success rates of implants.

MATERIALS AND METHODS

Patients

In a 2-year period (1998–1999), 8 patients (3 males and 5 females, aged from 22 to 52 years with a mean

[1]Assistant Professor, Unit of Oral Surgery, Department of Dentistry and Stomatology, San Paolo Hospital, University of Milan, Italy.
[2]Assistant Professor, Unit of Prosthodontics, Department of Dentistry and Stomatology, San Paolo Hospital, University of Milan, Italy.
[3]Full Professor and Chairman, Department of Dentistry and Stomatology, Department of Medicine, Surgery, and Dentistry, San Paolo Hospital, University of Milan, Italy.

Reprint requests: Dr Matteo Chiapasco, Clinica Odontostomatologica, Via Beldiletto 1/3, 20142 Milano, Italy. Fax: +390-2-8130200. E-mail: matteo.chiapasco@unimi.it

Table 1 Clinical Data of Patients and Implants

Patient	Sex	Age (y)	Defect etiology	Site of defect and missing teeth	Bone gain (mm)	No. and type of implants placed
1	M	30	Tumor resection	Mandible, right canine–second molar	15	4 (Brånemark)
2	F	24	Ectodermal dysplasia	Mandible, complete edentulism	7	5 (Brånemark)
3	F	28	Atrophy	Mandible, right second premolar and first molar	8	2 (Brånemark)
4	M	22	Trauma	Mandible, right lateral incisor–left second premolar	6	4 (ITI)
5	M	40	Resection for keratocyst	Mandible, left first premolar–second molar	10	3 (ITI)
6	F	52	Atrophy	Mandible, right central incisor–canine	9	2 (ITI)
7	F	41	Trauma	Maxilla, right central incisor–first premolar	7	4 (Brånemark)
8	F	48	Atrophy	Mandible, left second premolar and first molar	8	2 (ITI)

of 36.7 years) who presented with vertically deficient edentulous ridges consequent to atrophy, trauma, congenital malformations, and sequelae of oncologic surgery were treated by means of the distraction osteogenesis principle with an intraoral alveolar distractor (Gebruder Martin GmbH, Tuttlingen, Germany) in the Unit of Oral Surgery, Department of Medicine, Surgery, and Dentistry at San Paolo Hospital, University of Milan, Italy. Patient data, including location of the deficit and etiology of the defects, are reported in Table 1.

Inclusion criteria for alveolar vertical distraction osteogenesis and implant placement were: good general health at the time of the surgical procedure and the presence of vertical defects of partially or completely edentulous ridges, but with sufficient width of the edentulous segment to permit implant placement in a second-stage surgical procedure (because vertical distraction can correct only the vertical dimension, not the width of the defect). An average bone width of at least 5 mm was arbitrarily chosen as the minimum dimension necessary for implant placement in a second stage. Exclusion criteria were: alcohol and tobacco abuse; severe renal or liver disease; history of radiotherapy in the head and neck region; antiblastic chemotherapy at time of the surgical procedure; uncontrolled diabetes; periodontal disease involving the residual dentition; mucosal disease, such as lichen planus, in the areas to be treated; poor oral hygiene; or non-compliance.

Routine documentation of the treated patients was as follows:

1. Intraoral photographs were taken preoperatively, intraoperatively, at the time of removal of the intraoral distractor and implant placement, at the time of implant uncovering and abutment connection, and at the end of prosthetic rehabilitation.
2. Panoramic radiographs were taken before treatment, at the time of application of the distractor, at the time of distractor removal, at the time of implant placement, at the time of prosthetic rehabilitation, and annually thereafter.
3. Intraoral radiographs were taken at the time of prosthetic rehabilitation and annually thereafter.

Four patients were also evaluated with computed tomographic scans to thoroughly evaluate bone dimensions at the edentulous site level.

Surgical Procedure

The distraction procedure was performed under local anesthesia with intravenous sedation (diazepam 0.2 mg/kg) in 3 patients, and under general anesthesia with nasotracheal intubation in the 5 remaining patients. The type of anesthesia was chosen according to extent and site of the defect, accessibility, predetermined duration of the procedure, and patient compliance.

The procedure was started with an intraoral incision in the buccal vestibule, without lateral releasing incisions. Careful subperiosteal dissection was performed to obtain adequate visibility of the underlying bone, but to preserve as much as possible the lingual or palatal pedicle after the osteotomy was

performed. Preplating and adjustment of the intraoral distractor was performed before starting the osteotomy. With an oscillating saw or a fissure bur, under irrigation with sterile saline, the bone segment to be vertically distracted was completely separated from the basal bone. The vertical osteotomies were enlarged to allow movement of the segment with no interference. Once the osteotomy was completed, the intraoral distractor was fixed to both the basal bone and the ostetomized segment with 1.5-mm titanium miniscrews (Gebruder Martin GmbH). The osteotomized segment to be distracted was immediately moved by activating the distractor to check the direction of distraction and freedom of movement. Finally, the osteotomized segment was repositioned at its initial position and the surgical access was sutured with 4/0 silk sutures. Healing by secondary intention is unavoidable, because a portion of the distractor must pass through the incision to activate the distractor.

All patients received antibiotics and nonsteroidal analgesics postoperatively. A soft diet for 2 weeks postoperatively and appropriate oral hygiene with 0.2% chlorhexidine mouthwash were prescribed. After a 7-day waiting period for closure of the surgical wound, sutures were removed and the activation was started. A distraction of 1 mm per day (subdivided into 2 activations of 0.5 mm every 12 hours) was performed with a specific device until the desired amount of distraction was obtained. The distractor was then maintained in position for 2 to 3 months to obtain maturation of the neocallus formed between the basal bone and the distracted segment. Once consolidation of the distracted segments was obtained, the distractor was removed and endosseous implants were placed following the indications of surgical templates.

A total of 26 titanium screw-shaped endosseous implants were placed in the distracted segments; 4 patients received 15 Brånemark System implants (Nobel Biocare, Göteborg, Sweden), and 4 patients received 11 screw-type ITI implants (Straumann, Waldenburg, Switzerland). Distribution of the number and type of implants placed is reported in Table 1. Four to 6 months later, abutments were connected to the implants, and prosthetic treatment was started. Implants were followed with clinical examinations and panoramic radiographs every 6 months. The following parameters were evaluated: *(1)* vertical bone gain obtained after distraction; *(2)* radiographic assessment of peri-implant bone resorption mesial and distal to each implant; *(3)* peri-implant soft tissue parameters (Modified Plaque Index [MPI], Modified Bleeding Index [MBI], and probing depth [PD]); and *(4)* implant stability, both manually and with the Periotest instrument (Siemens AG, Bensheim, Germany). Probing depth and MBI measurements were performed with a calibrated plastic probe (TPS Probe, Vivadent, Schaan, Liechtenstein).

Vertical bone gain was evaluated clinically by adding up the number of rotations performed with the specific device (every complete rotation equaled 0.5 mm) and by then measuring on panoramic radiographs, with a transparent millimeter ruler, the distance between the upper and lower miniplates of the distractor. Measurements were made at the beginning and end of distraction. Dimensional distortion between the different panoramic radiographs was corrected by knowledge of the actual dimensions of the distractor. Peri-implant bone resorption was determined by comparing panoramic radiographs taken immediately after implant placement, at the time of prosthetic loading, and annually thereafter. Measurements were made mesial and distal to each implant by means of a transparent millimeter ruler, measuring the distance between the apex of the implant and the most coronal level of direct bone-to-implant contact. Measurements were made to the nearest 0.5 mm. The dimensional distortion related to panoramic radiographs and among them was corrected by knowing the actual dimensions of implants.

Modified Plaque Index and MBI scores were recorded at 4 sites for each implant (mesial, distal, buccal, and lingual) according to the modifications described for implants by Mombelli and coworkers.[19] Probing depth measurements were made at 4 sites for each implant (mesial, distal, buccal, and lingual) to the nearest millimeter using a calibrated plastic probe (TPS Probe). Measurements were recorded 6 and 12 months after initial prosthetic loading. Implant stability was tested clinically with the handles of 2 dental mirrors and with the Periotest instrument. Periotest measurements were made for each implant at the time of abutment connection and 12 months after the initial prosthetic loading.

Implant success was evaluated according to Albrektsson and coworkers' criteria.[20] The only modifications to these criteria concerned the lack of results 5 years after prosthetic loading and neural disturbances. This latter parameter could not be evaluated in 2 patients because the alveolar nerve had been severed before distraction and implant placement during mandibular resection in the segments; this was related to tumor diagnosis in one patient and relapsing keratocyst in a second. A representative case is presented in Figs 1a to 1e.

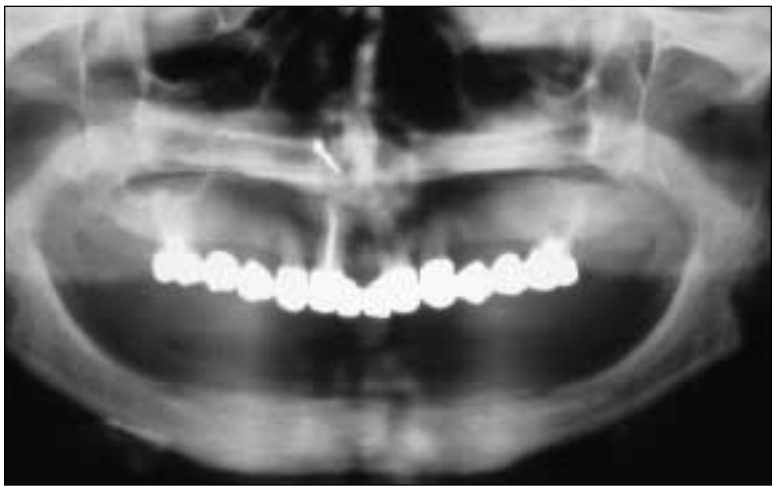

Fig 1a Preoperative panoramic radiograph of patient #2, showing complete edentulism in the mandible and relevant vertical atrophy.

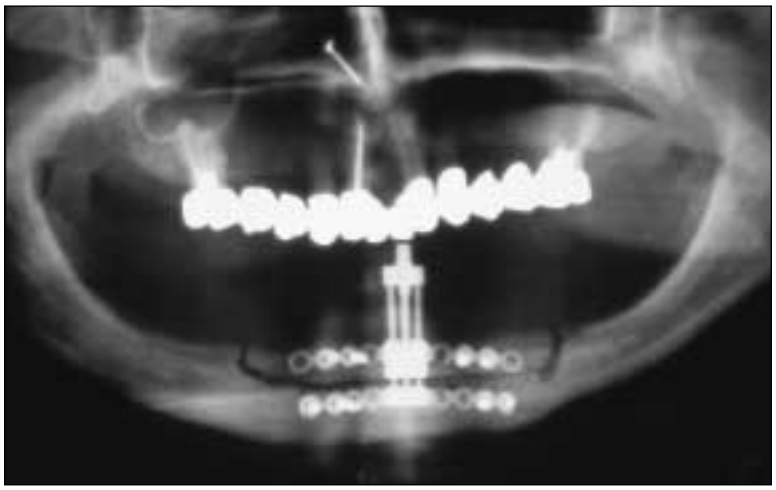

Fig 1b Postoperative panoramic radiograph taken immediately after application of the intraoral distractor.

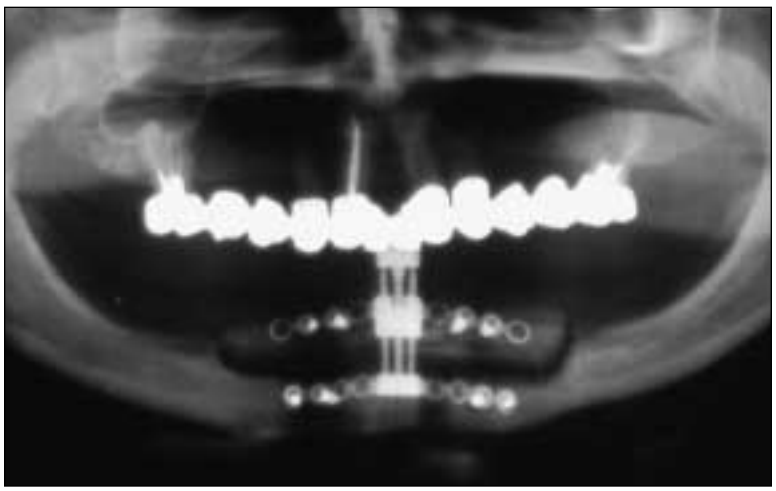

Fig 1c Panoramic radiograph taken after the completion of distraction.

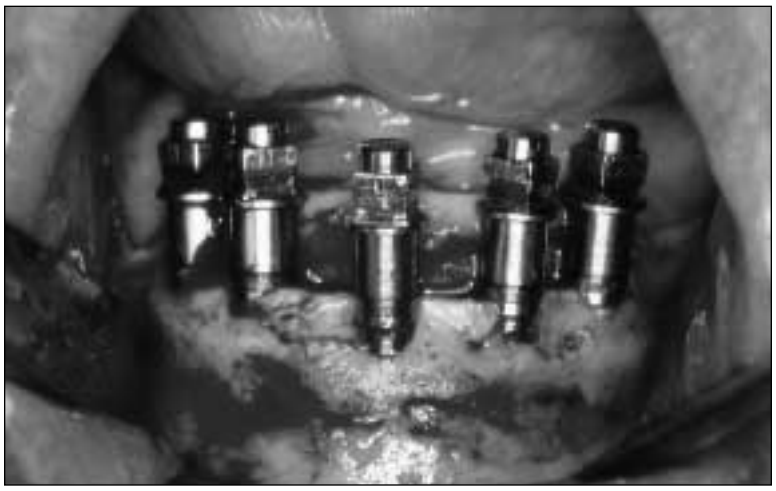

Fig 1d Implant placement at time of distractor removal, 2 months after completion of distraction. Bone formation in the distracted area is clearly visible.

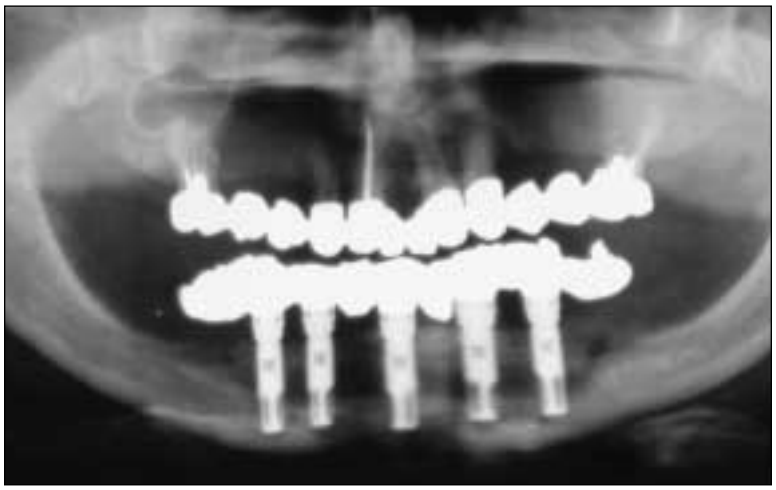

Fig 1e Radiograph taken after final prosthetic rehabilitation.

RESULTS

Recovery after the distraction procedure was uneventful in all patients treated, and all patients regularly followed the recall program. In all patients, the desired bone gain was reached at the end of distraction, with a mean vertical bone gain of 8.5 mm (range: 6 to 15 mm) (Table 1). In all patients it was possible to place the previously planned number of implants with primary stability and with complete embedding of the implants in both native and newly generated bone at the level of the distracted area. The mean follow-up after initial prosthetic loading was 14 months (range: 12 to 18 months). None of the implants placed were lost during the follow-up period. The cumulative success rate of implants according to Albrektsson and coworkers' criteria was 100% (Table 2). The mean peri-implant bone resorption at the time of prosthetic loading and 12 months after prosthetic loading is reported in Table 3. Radiographic examinations 12 months after the initial functional loading of implants also showed a significant increase in bone density of the newly generated bone in the distracted areas.

The mean MPI, MBI, and PD values recorded 6 and 12 months after the initial prosthetic loading for the Brånemark System and ITI implants are reported in Tables 4 to 6. The mean Periotest values recorded at the beginning of prosthetic loading and 12 months later for both types of implants placed are reported in Table 7.

Table 2 Life Table Analysis Showing Cumulative Success Rates of Implants Placed in Distracted Segments

Interval	Implants at risk during interval	Withdrawn	Failed	CSR (%)
Placement to loading	26	0	0	100
Loading to 1 year	26	0	0	100
1 to 2 years	7	0	0	100

CSR = cumulative success rate.

Table 3 Mean Bone Resorption (in mm, ± SD) at Time of Prosthetic Loading and 12 Months After Prosthetic Loading

	Brånemark implants			ITI implants		
Site	n	Loading	12 months after loading	n	Loading	12 months after loading
Mesial	15	0.6 ± 0.4	1.2 ± 0.3	11	0.5 ± 0.4	1.3 ± 0.3
Distal	15	0.5 ± 0.4	1.3 ± 0.4	11	0.4 ± 0.2	1.0 ± 0.2
Mean bone resorption	15	0.5 ± 0.4	1.3 ± 0.3	11	0.5 ± 0.3	1.3 ± 0.3

Table 4 Modified Plaque Index (± SD) at 6 and 12 Months after Prosthetic Loading

	Brånemark implants		ITI implants	
Site	6 months	12 months	6 months	12 months
Mesial	0.7 ± 0.6	0.5 ± 0.5	0.5 ± 0.5	0.4 ± 0.5
Buccal	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5
Distal	0.5 ± 0.5	0.4 ± 0.5	0.6 ± 0.7	0.5 ± 0.7
Oral	0.4 ± 0.5	0.3 ± 0.5	0.4 ± 0.5	0.4 ± 0.7
Mean	0.5 ± 0.5	0.4 ± 0.5	0.5 ± 0.5	0.4 ± 0.6

Table 5 Modified Bleeding Index (± SD) at 6 and 12 Months After Prosthetic Loading

	Brånemark implants		ITI implants	
Site	6 months	12 months	6 months	12 months
Mesial	0.3 ± 0.5	0.2 ± 0.4	0.4 ± 0.5	0.5 ± 0.5
Buccal	0.4 ± 0.5	0.3 ± 0.5	0.3 ± 0.5	0.3 ± 0.5
Distal	0.3 ± 0.5	0.3 ± 0.6	0.3 ± 0.5	0.4 ± 0.7
Oral	0.4 ± 0.5	0.4 ± 0.6	0.3 ± 0.5	0.3 ± 0.5
Mean	0.3 ± 0.5	0.3 ± 0.5	0.3 ± 0.5	0.4 ± 0.5

Table 6 Probing Depth (± SD) at 6 and 12 Months After Prosthetic Loading

	Brånemark implants		ITI implants	
Site	6 months	12 months	6 months	12 months
Mesial	2.2 ± 0.7	2.1 ± 0.6	2.1 ± 0.7	2.5 ± 0.5
Buccal	1.7 ± 0.5	1.9 ± 0.4	2.1 ± 0.5	2.0 ± 0.6
Distal	1.9 ± 0.8	2.1 ± 0.7	2.3 ± 0.7	2.3 ± 0.8
Oral	2.2 ± 0.4	2.4 ± 0.5	2.4 ± 0.5	2.3 ± 0.6
Mean	2.0 ± 0.7	2.1 ± 0.6	2.2 ± 0.6	2.3 ± 0.6

Table 7 Periotest Values (± SD) at Time of Prosthetic Loading and 12 Months After Prosthetic Loading

	Mean Periotest values	
Implant type	Loading	12 months after loading
Brånemark	–2.9 ± 0.7	–3.9 ± 0.7
ITI	–3.2 ± 0.9	–4.4 ± 0.8

DISCUSSION

In recent years, dental rehabilitation of edentulous patients by means of implant-supported prostheses has presented a significant treatment alternative to conventional restorations, with meaningful improvement in masticatory function and well-being of partially or completely edentulous patients. In particular, high percentages of success after implant placement may be expected when favorable local conditions of the residual bone exist. Ideal conditions include: *(1)* residual bone height greater than or equal to 10 mm, *(2)* residual bone width greater than or equal to 6 mm, *(3)* normal maxillomandibular

relationship, and *(4)* healthy peri-implant soft tissues.[20–22] Yet the clinician is frequently confronted with unfavorable situations, which may compromise the long-term survival of implants. In particular, a deficit in edentulous ridge height may cause insufficient bone support for implants and an increased maxillomandibular distance with unfavorable crown-to-implant ratios. The most frequent etiologic factor is represented by ridge atrophy following tooth loss, but unfavorable conditions may also derive from congenital malformations (eg, congenital dental agenesis), resection for tumors involving the mandible or maxilla, or sequelae of trauma with loss of teeth and the supporting alveolar process. In recent years, 2 main solutions to these problems have been proposed: onlay grafts using autogenous bone, and GBR with semipermeable barriers.

Bone grafts taken from intraoral or extraoral sites had been criticized before the advent of osseointegrated implants, because of extensive resorption after reconstruction, particularly in situations involving loading with removable prostheses.[23,24] In contrast, the use of autogenous bone grafts in association with osseointegrated implants seems to significantly reduce bone resorption, as dem onstrated by long-term results in a number of studies.[25–31] Nevertheless, some unpredictability in bone resorption, especially during the months before implant placement and with onlay grafts in the mandible, may be expected.[4,5] Moreover, increased morbidity should be expected because of the necessity of harvesting bone from intraoral or extraoral sites.

Guided bone regeneration has been presented as a reliable solution for the correction of atrophic ridges, with acceptable long-term results. Yet most of the literature concerns the correction of narrow ridges,[32–40] whereas literature regarding vertical GBR is very limited.[1–3] In particular, a significant risk of membrane exposure and/or infection is present, and the potential for vertical regeneration is frequently limited. Furthermore, there is a lack of long-term results reported after the prosthetic loading of implants placed in vertically regenerated areas.[2,3] The necessity for evaluating the behavior of regenerated tissue by means of semipermeable barriers after initial prosthetic loading of implants is particularly important because extensive resorption after membrane removal has been demonstrated.[41]

Distraction osteogenesis for the correction of vertical deficits of edentulous ridges seems to be a reliable method for overcoming the problems connected with bone grafting and GBR. The following advantages can be anticipated with intraoral distraction osteogenesis.

1. It provides the opportunity to obtain a natural formation of bone between the distracted segment and basal bone in a relatively short time span.
2. It eliminates the need to harvest bone, with consequent shortening of operating times and reduction in morbidity.
3. Soft tissues can follow elongation of the underlying bone.
4. Frequently, the procedure can be performed under local anesthesia on an outpatient basis, and postoperative recovery is favorable.
5. The regenerated bone seems to resist resorption.
6. The newly generated bone seems to be able to withstand the functional demands of implant-supported prostheses.[13–18]

These advantages have been confirmed by the present study. In particular, a progressive increase in bone density was consistently found in this patient series, as shown by the comparison between panoramic radiographs taken at the time of implant placement and 1 year after the start of prosthetic loading. In this study, vertical peri-implant bone resorption mesial and distal to each implant was consistent with values reported in the literature as regards implants placed in native bone.[42–46]

The results obtained in this preliminary study concerning periodontal indices (MPI, MBI, and PD) and Periotest values demonstrated outcomes that are consistent with those reported in the literature for implants placed in native bone.[46–51] However, use of the Periotest for clinically stable implants is of little additional value in assessing the stability of implants, as compared to manual mobility assessments.[52]

Although the present technique was applied to very different clinical situations (trauma sequelae, tumor resection sequelae, congenital malformations, atrophy) with different local conditions, the treatment thus far has been completed successfully, and no problems were found after a 1-year follow-up.

A particular application of vertical distraction osteogenesis is represented by vertical lengthening of revascularized fibular flaps used for reconstruction of the mandible after tumor resection.[53] The fibular flap presents many advantages (ie, sufficient length of the bony segment, good vascularization, good bone quality, long vascular pedicle, adequate volume to receive dental implants), but because of its limited height (rarely more than 15 mm), it presents some disadvantages with regards to definitive prosthetic rehabilitation, especially in cases of partial mandibular resection with residual dentition on the contralateral side.[54–57] This situation may create

a clinically significant difference in the level of the alveolar crest between the residual mandible and the reconstructed segment, thus causing functional and esthetic problems. When duplication of the fibular flap is not feasible,[58] vertical elongation of free revascularized fibular flaps by intraoral distraction osteogenesis, followed by implant placement in the distracted area, avoids further grafting and optimizes the final prosthetic result.

SUMMARY

Despite the limited number of patients and implants reported in the present study, this technique seems to be very reliable, with reduction of postoperative morbidity and shortening of rehabilitation times. The only limitation may be represented by a vertical deficit associated with a reduction in the width of the edentulous site to be treated. In this situation 2 different possible outcomes exist. Where significant reduction in ridge width is evident, this technique is contraindicated. In case of width reduction in only the more crestal part of the edentulous ridge, the problem can be overcome by an overcorrection of the vertical deficit. At the time of implant placement, the atrophic margin of the distracted segment can be removed with a bur until adequate bone width is found in the inferior part of the distracted segment.

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