Internal Distraction Osteogenesis in Mandibular Reconstruction: Clinical Experience in 10 Cases

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Background: Distraction osteogenesis has been used for reconstruction of bone and soft-tissue defects. The authors present their clinical experience in the reconstruction of mandibular segmental defects by means of internal distraction osteogenesis.
Methods: Ten patients with mandibular defects ranging from 30 to 80 mm in length were treated in the authors' department. Internal distraction devices with transcutaneous activators were placed immediately after complete resection of the affected bone. Distraction was initiated 10 days after surgery at a rate of 0.5 mm/day. The consolidation period ranged from 12 to 22 weeks. Finally, the distractor device was removed. In two patients, an additional iliac crest bone graft was needed to complete bone union.
Results: Follow-up ranged from 4 to 47 months after surgery. Partial cutaneous and intraoral exposure was observed in two patients. At the end of the follow-up period, successful distraction osteogenesis was achieved in eight patients. Six patients were alive and free of disease, whereas two patients showed local relapse and required new resective surgery. Complete intraoral exposure with failure of the distraction process was observed in one patient, whereas another patient did not complete distraction because of metastatic disease diagnosed 4 months after surgery.
Conclusions: Good clinical results for reconstruction of mandibular and soft-tissue postablative defects are reported with the use of this technique. The use of semiburied devices provides better aesthetics and acceptable quality of life to the patients. Larger series are required to popularize the use of this procedure. (*Plast. Reconstr. Surg.* 121: 563, 2008.)

Distraction osteogenesis was first introduced by Ilizarov in 1957.[1–3] Since then, it has been used in the gradual lengthening of endochondral bones of the extremities. Regarding the craniofacial skeleton, the first clinical case of mandibular lengthening was reported by McCarthy et al. in 1992.[4] Constantino et al.[5] demonstrated the effectiveness of bifocal distraction osteogenesis in the reconstruction of mandibular defects in dogs.

Excellent results have been obtained by means of microvascularized free flaps for reconstruction of large segmental mandibular defects.[6–8] However, its morbidity and costs advocate for an alternative in selected patients with increased surgical risks. Moreover, because of the composite nature of most mandibular segmental defects, the reconstruction of both bone and soft tissues becomes a desirable objective. In relation to it, distraction osteogenesis has been referred to as a successful surgical treatment in mandibular segmental defects.[9–11] By means of bifocal distraction osteogenesis, new bone is formed after osteotomy and gradual separation of the bony fragments.

Initial experimental studies used external devices in the restoration of mandibular defects.[5,12–14] However, cutaneous scarring and compliance of the patient may be important considerations.

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Received for publication February 25, 2005; accepted April 4, 2005.

DOI: 10.1097/01.prs.0000297640.65255.70

Disclosure: *The authors have no financial interests in the products, devices, or drugs mentioned in this article.*

Table 1. Internal Mandibular Bone Transport: Patient Data

	Case 1	Case 2	Case 3	Case 4
Sex/age, years	M/67	F/78	M/48	F/50
Main diagnosis	SCC floor of the mouth	SCC tongue, floor of the mouth	SCC oropharynx (tonsils)	Leiomyosarcoma left hemimandibular body
Stage, pTNM	IV	IV	IV	IV
Defect length, mm/site	46/hemimandibular body and symphysis	59/hemimandibular body	37/hemimandibular body	80/hemimandibular body
Disk length, mm	26	22	27	25
Amount of lengthening, mm	19 (uncompleted)	15 (uncompleted)	37	80
Latent period, days	10	10	10	10
Rhythm distraction, mm/day	0.5	0.5	0.5	0.5
Consolidation period, weeks	0	22	12	12 in each period
Approach for placement	Extraoral, but activator intraoral	Extraoral	Extraoral	Extraoral
Device (location)	Gonial angle	Parasymphysial	Body	Gonial angle
No. of devices	1	1	1	2
Quality of bone (macroscopically)	Bad	Good, but distraction was not completed	Excellent	Excellent
Quality of bone (microscopically)	Not tested	Not tested	Not tested	Mature bone, lower density
Local treatment	Bone and surrounding soft-tissue resection	Bone and surrounding soft-tissue resection	Bone and surrounding soft-tissue resection	Bone and surrounding soft-tissue resection
Cervical treatment	Yes	Yes	Yes	No
Previous radiotherapy/dose	Yes/64 Gy	No	Yes/60 Gy (in another center)	No
Radiotherapy post/dose	No	Yes/60 Gy during distraction	No	No
Complications	Failure, complete intraoral exposure and loosening of all screws	Distant metastases, bad general status; uncompleted distraction	Maximum oral opening decreased	Pain at the end of the distraction period; slight asymmetry
Follow-up since the resective surgery, months	15	4	29	43
Evolution	Death	Death	Alive, free of disease	Local relapse; new resective surgery
Bone graft/donor site	No	No	No; a greenstick fracture was performed at the proximal stump	Yes/iliac crest

SCC, squamous cell carcinoma; M, male; F, female; pTNM, pathologic tumor-node-metastasis.

When compared with the extraoral technique, internal distraction has improved stability, aesthetics, and patient motivation. In this article, we report our clinical experience with 10 patients in whom reconstruction of mandibular segmental defects by means of bifocal distraction osteogenesis with semiburied devices was performed. The present study represents the continuation of a previous preliminary report.[15]

PATIENTS AND METHODS

Patients who fulfilled the following inclusion criteria were included in our study: (1) a segmental bony defect flanked by adequate bone in quantity and quality, (2) limited soft-tissue defects, and (3) adequate patient compliance. The presence of both bone and substantial soft-tissue defects would preclude the use of this technique in favor of vascularized free flaps. After analyzing all the cases, bone transport was considered the reconstructive method of choice for general or local reasons, to avoid a more aggressive treatment.

Thirteen submerged mandibular distraction devices with transcutaneous activators were placed in 10 patients with segmental mandibular defects resulting from ablative surgery (Table 1 and Fig. 1). Bone transport was used to reconstruct defects in all of the patients. Clinical and management data such as sex, age, diagnosis, pathologic tumor-

Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
M/66	M/80	M/69	F/47	F/53	F/
Mandibular osteoradionecrosis after radiotherapy, SCC oropharynx (tonsils)	Mandibular osteoradionecrosis, SCC tongue	Mucoepidermoid carcinoma, retromolar trigone	SCC floor of the mouth	Ameloblastoma, mandibular body	Mandibular osteoradionecrosis after third molar extraction; SCC hypo-oropharynx
—	IV	V	IV	—	IV
35/hemimandibular body and symphysis	80/right premolar region, left mandibular angle	40/hemimandibular body	34/hemimandibular body	25 right, 26 left/bilateral mandibular body	30/hemimandibular body
29	29 right, 7 left	12	9	15 right, 16 left	29
35	30 right, 40 left	40	37	25 right, 23 left	35
10	10	10	10	10	10
0.5	0.5	0.5	0.5	0.5	0.5
20	12	12	12	12	20
Extraoral	Extraoral bilateral	Extraoral	Extraoral	Extraoral bilateral	Extraoral
Parasymphysial	Right body, left gonial angle	Parasymphysial	Gonial angle	Gonial angle	Gonial angle
1	2	1	1	2	1
Excellent	Good	Excellent	Good	Good	Good
Not tested	Not tested	Not tested	Not tested	Not tested	Not tested
Bone resection including cutaneous fistulae	Bone and surrounding soft-tissue resection	Bone and surrounding soft-tissue resection; forearm free flap	Marginal mandibulectomy and surrounding soft-tissue resection; temporalis myofascial flap	Bone and surrounding soft-tissue resection	Bone resection
No	Yes	Yes	Yes	No	No
Yes/60 Gy	Yes/62 Gy	No	Yes/60 Gy	No	Yes/70 Gy
No	No	No	No	No	No
Partial intraoral exposure	None	None	Submental abscess and fistulae, swelling, oral bleeding	Pain at the end of the distraction period; slight asymmetry	Partial cutaneous exposure right hemimandibular body
37	41	47	45	Resection in another center 20 yr ago	15
Alive, free of disease	Alive, free of disease	Alive, free of disease	Alive, SCC recurrence	Alive, free of disease	Alive, free of disease
No; a greenstick fracture was performed at the proximal stump	No	Yes/iliac crest	No	No	No

node-metastasis staging, location and size of the defect, amount of lengthening, number and location of the devices, complications, and follow-up are listed in Table 1. Because of the limited number of patients in the series, no statistical analysis was performed.

At the time of diagnosis, seven patients presented with squamous cell carcinoma of the oral cavity/oropharynx; the remaining three patients presented a mucoepidermoid carcinoma, a mandibular ameloblastoma, and a mandibular leiomyosarcoma, respectively. Three of the patients with squamous cell carcinoma presented with mandibular osteonecrosis after treatment with adjuvant radiotherapy. In these patients, the major defect generated was attributable to the excision of the necrosed tissue. All of the cases of squamous cell carcinoma of the oral mucosa were moderate to poorly differentiated at the initial biopsy. Eight patients underwent primary reconstruction by means of bone transport at the same surgical procedure, whereas two patients were treated primarily by means of a hybrid forearm free flap and a temporalis myofascial flap, and were submitted to distraction osteogenesis several months after surgery.

In all patients, computed tomographic scanning was performed before surgery to determine the limits of the lesion, the effect on the surrounding tissues such as the bone, and the existence of

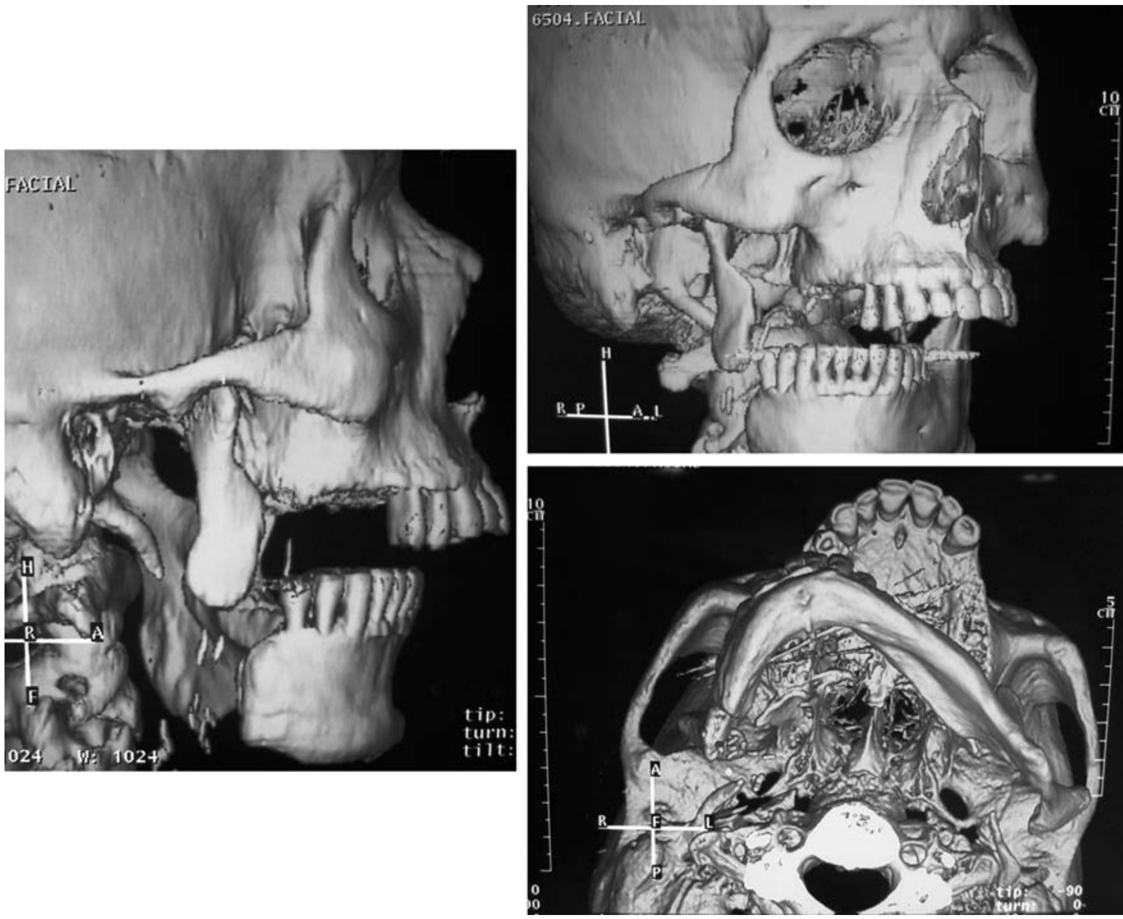

Fig. 1. Three-dimensional computed tomographic scans of the patient in case 7. (*Left*) Lateral view. (*Above, right*) Three-quarter view. (*Below, right*) Inferior view.

neck lymph node metastasis. Panoramic radiographs were taken monthly during the distraction and consolidation periods to determine the progress of distraction osteogenesis and to evaluate the direction of the transport disk during the active distraction period.

No patient showed distant metastasis in the initial diagnostic evaluation. All of the patients underwent radical surgery with macroscopically free margins. Six patients underwent cervical lymph node dissection at the same time by means of an ipsilateral modified type III radical neck dissection.

Because of the necessity of local wide excision of the primary lesion in all cases, a submandibular approach was used in each patient to provide good access, with ablation of both hard and soft tissues around the lesion. This approach was also used to design the transport disk and to place the reconstruction plate and semiburied distraction device. A reconstruction plate was used in seven patients. It was placed before creation of the bone transport segment to obtain an appropriate mandibular stability. During surgery, special attention was paid to preserve the periosteum over the bone transport disk, to ensure its vascularity. At this point, an osteotomy was performed proximal to the defect to create the transport disk. The unidirectional distraction device (AO Synthes, Oberdorf, Switzerland) used in this study allowed a maximal lengthening of 40 mm. This is the reason why the patient in case 4 required the use of two consecutive distraction devices to restore the normal length of the mandibular body. Moreover, the patients in cases 6 and 9 required the use of two simultaneous distraction devices placed bilaterally to reconstruct 70- and 48-mm mandibular defects, respectively. The transport bone fragment was fixed to the moveable part of the distraction device by means of two bicortical 10- to 14-mm-length screws, whereas two other bicortical screws fixed the device to the rest of the mandible. After verifying the mobility of the distractor, the device was

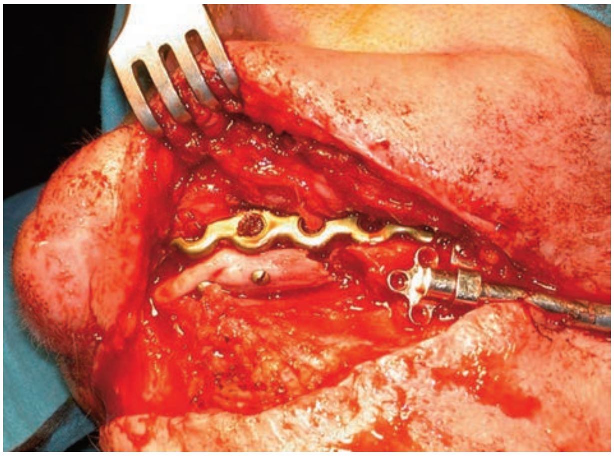

Fig. 2. Intraoperative view after the distraction process. Note the continuity of the mandible and removal of the distraction device. Osteosynthesis is completed with miniplates. The reconstruction plate is left in place.

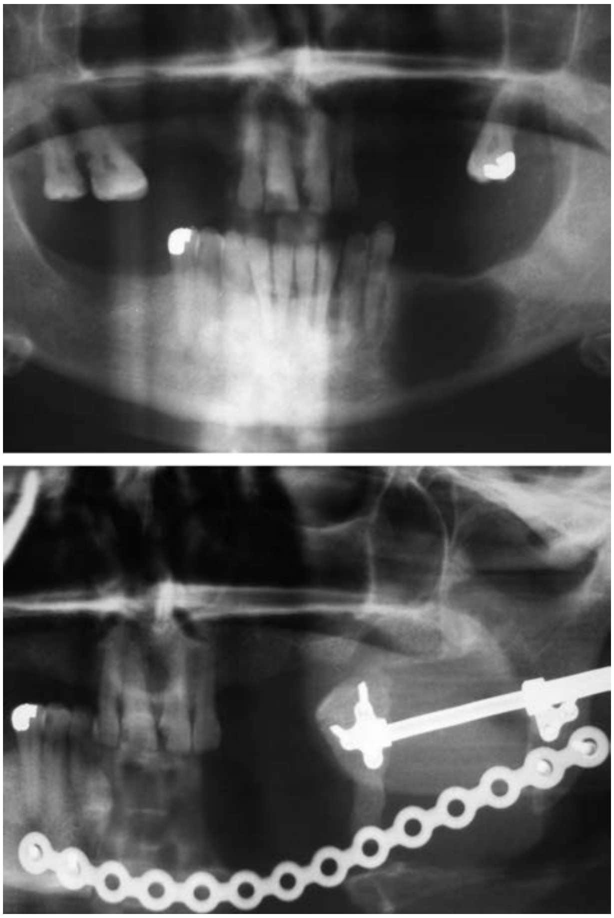

Fig. 3. Panoramic radiographs of the patient in case 4. (*Above*) View of the leiomyosarcoma in the left hemimandibular body. (*Below*) Radiograph obtained during the distraction process.

returned to its original position, with the distraction activator placed percutaneously.

During the first 10 days (latency period), no device activation was carried out. At this time, distraction was initiated at a rate of 0.5 mm/day. The distraction process continued until the bone transport segment reached the distal stump and, at this point, the consolidation phase took place, with a variable duration ranging from 12 to 22 weeks. Two patients required additional bone grafting obtained from the anterior iliac crest to complete bone union when the device was removed (Figs. 2 through 4). The rest of the cases underwent a corticotomy in the distal stump of the transported bone and a corticotomy in the residual bone. Both poles were fixed by means of reconstruction plates or miniplates. Bone union was achieved without complications by means of this technique. Two of 10 cases involved the symphyseal region together with a hemimandibular defect. Despite its more difficult reconstruction,

Fig. 4. Panoramic radiograph obtained at the end of the distraction process. Osteosynthesis is completed with miniplates. Note the interposition of a bone graft between the transport disk and the distal stump.

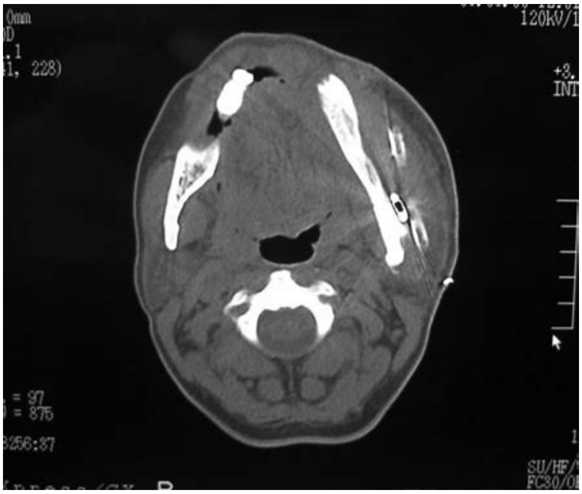

Fig. 5. Axial computed tomographic scan of the patient in case 4. Note the newly generated bone before removal of the distraction device.

good results were obtained by means of a greenstick fracture performed at the proximal stump, to replicate the mandibular curvature. The majority of patients received reconstruction plates at the time of device removal. However, one patient underwent repair by means of miniplates. In this case, the new generated bone was thin and the gap between bone fragments was small, so a reconstruction plate seemed to be too large.

RESULTS

Eight patients completed the distraction procedure. One of them (case 2) died as a result of distant metastasis 4 months after surgery; in this case, distraction was not completed. The other patient (case 1) failed to form adequate bone; complete intraoral exposure of the device was encountered, and surgical removal of the distractor had to be performed. The patient in case 4 was diagnosed as having a low-grade leiomyosarcoma of the mandible, a rare tumor. After hemimandibulectomy, a great mandibular defect was produced (80 mm) (Table 1). It was the reason why two consecutive distraction procedures were applied. Although distraction osteogenesis was successfully achieved, this patient showed local relapse several months after the first procedure, and new resective surgery and reconstruction with a microvascularized fibular flap were required (Figs. 3 through 5).

For the patients with whom distraction osteogenesis was successfully achieved, the follow-up period ranged from 15 to 47 months. Neither pseudoarthrosis nor premature consolidation was observed. No special discomfort or disruption of normal activities was reported by the patients with the use of the semiburied distraction device. Although no histologic examination was performed in any case (except the patient in case 4), the quality of the new bone was tested macroscopically, by comparison with the adjacent bone during the second surgical procedure. The new created bone was considered to be good or excellent by the surgeons.

To obtain the required distraction vector, special attention was paid during placement of the distraction device. Eight patients showed progressive calcification of the entire gap after 12 weeks. The two unsuccessful cases did not show calcification and the gap remained radiolucent. Three-dimensional computed tomographic scans were performed in some patients to achieve better control of the new formed bone, but it was not

Fig. 6. Three-dimensional computed tomographic scan after the bone transport process in the patient in case 5. Note the newly generated bone.

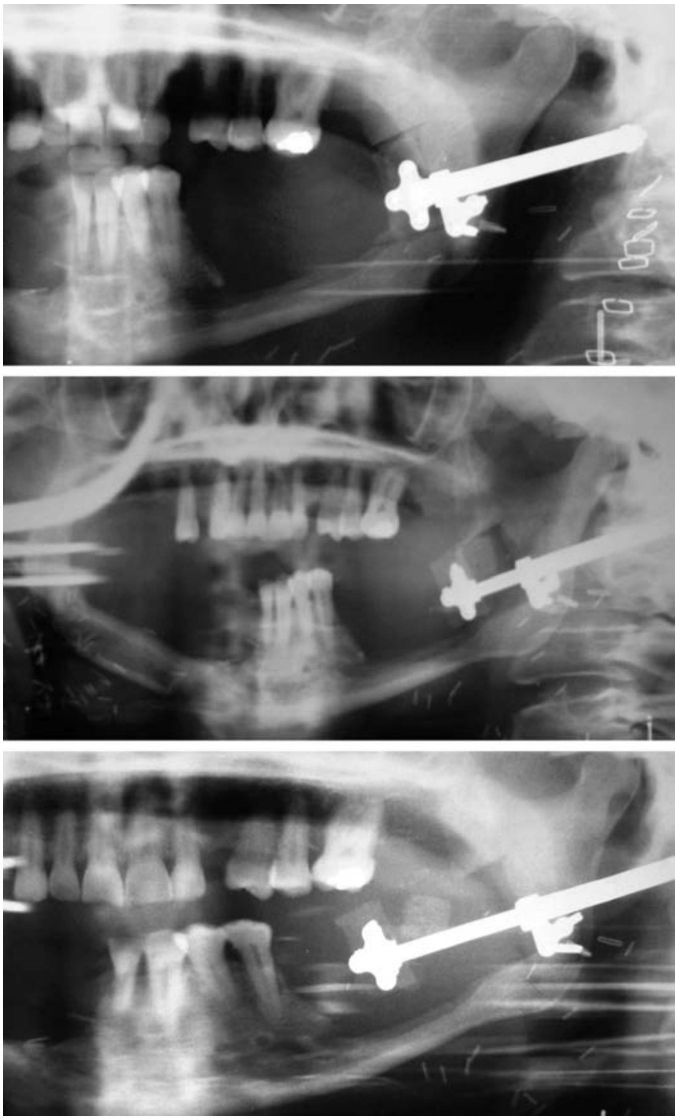

Fig. 7. Panoramic radiographs of the distraction process in the patient in case 8 (*above*) immediately after the bone transport disk osteotomy, (*center*) at the beginning of the distraction process, and (*below*) at the midpoint of the distraction process.

a routine procedure (Fig. 6). Some complications appeared in relation to distraction osteogenesis, such as pain at the end of the distraction period (two patients), partial intraoral exposure (one patient), submental abscess (one patient), complete intraoral exposure (one patient), and partial cutaneous exposure (one patient) (Table 1).

DISCUSSION

Many surgical techniques are currently available with which to reconstruct mandibular defects. Microvascular procedures have been widely used, although donor-site morbidity, difficulty of the technique, and contraindication in unhealthy patients may advocate for the use of distraction osteogenesis. By means of distraction, new bone is formed in the mandibular gap. Two foci of bone formation are present in bifocal distraction osteogenesis, and a transport disk is moved along the mandibular defect to generate new bone (Fig. 7). As previously observed by Constantino et al.,[5] the diameter of the new formed bone is similar to the mandible and transport disk. Moreover, the inferior alveolar nerve and artery are recannulated in most cases,[16,17] with clear benefits for the patients. All these conditions may improve the subsequent placement of osseointegrated implants.

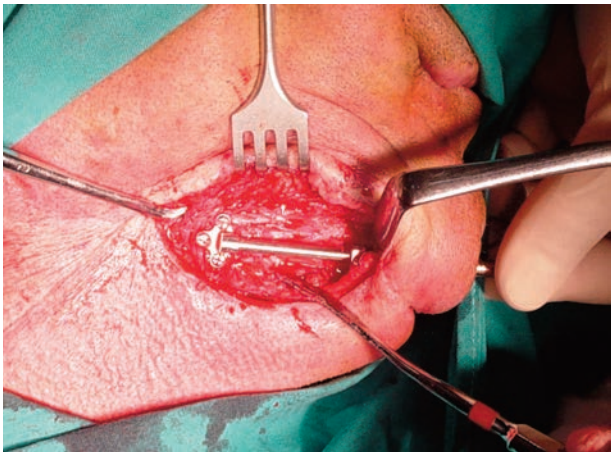

Fig. 8. Intraoperative view of the patient in case 7 demonstrating placement of the distraction device by means of a submandibular approach.

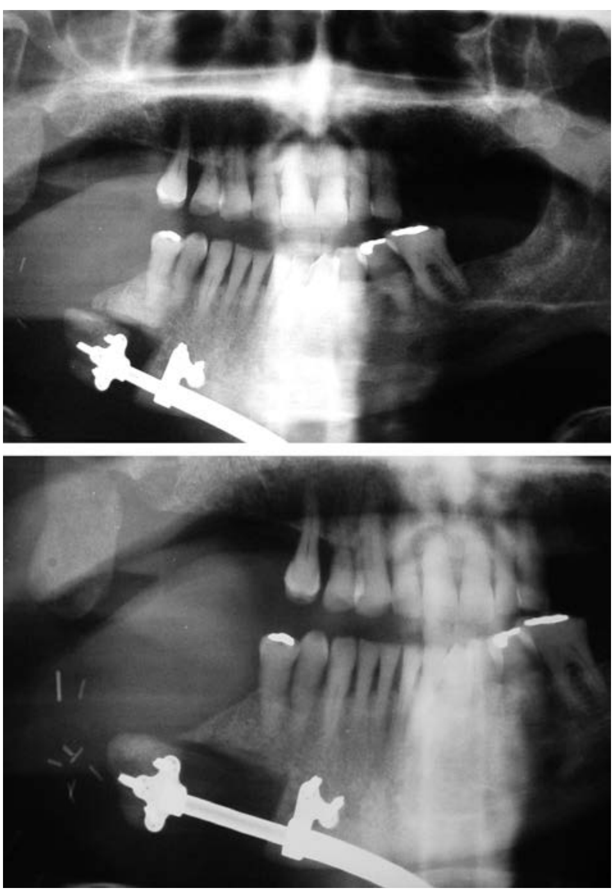

Fig. 9. Panoramic radiographs of the patient in case 7 demonstrating the first step of the distraction procedure, (*above*) at the beginning and (*below*) at the end of the distraction process.

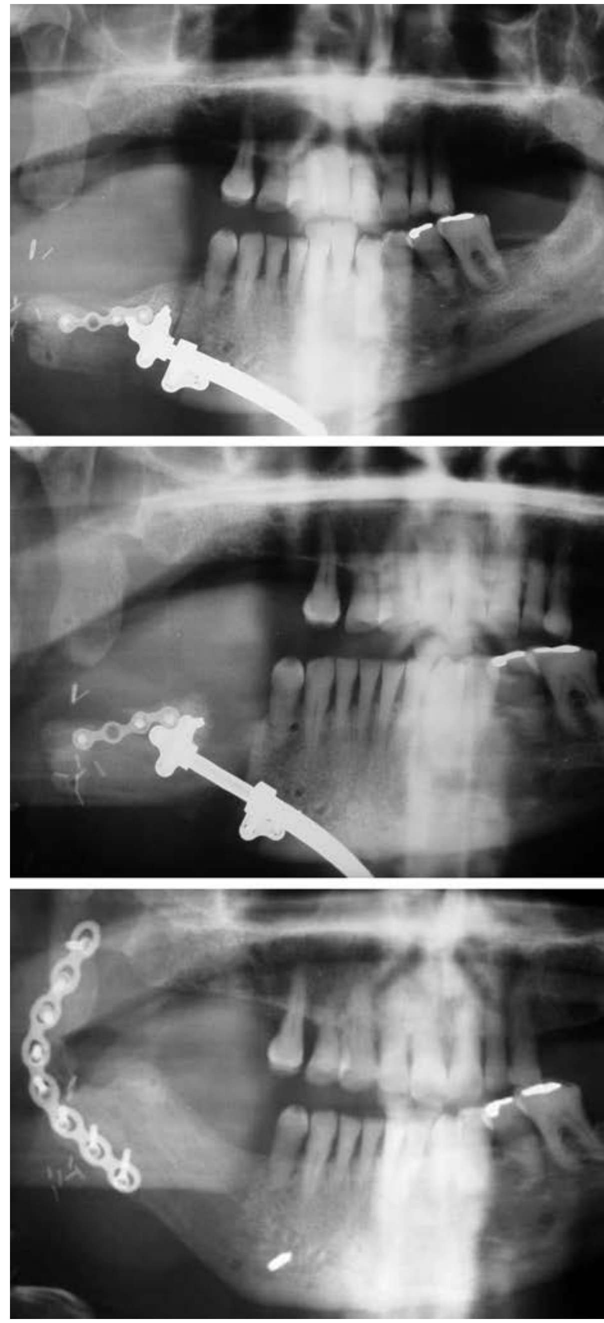

Fig. 10. Panoramic radiographs of the patient in case 7 demonstrating the second step of the distraction procedure, (*above*) at the beginning, (*center*) at the midpoint, and (*below*) at the end of the distraction process.

Preservation of a well-vascularized transport disk is essential to ensure its viability. In relation to it, special care must be taken when performing the osteotomies, and the periosteal envelope and muscular attachments must be preserved as much as possible. However, in oncologic patients, a wider dissection of the mandible is often mandatory. Because of this condition, all our patients underwent subperiosteal placement of the internal devices. This fact was not apparently a negative influence for adequate osteogenesis. During sur-

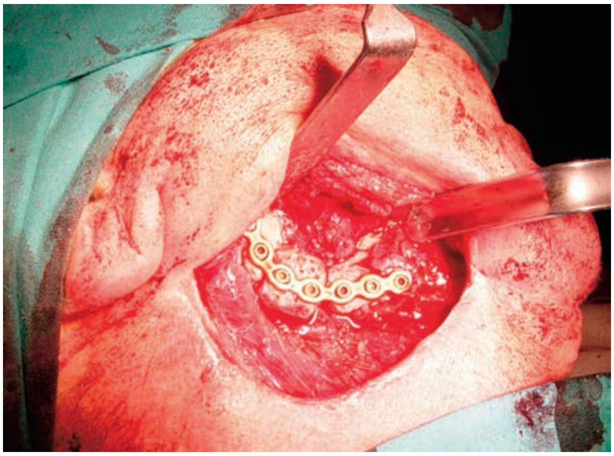

Fig. 11. Intraoperative view of placement of the bridging plate and the iliac crest bone graft in the patient in case 7.

Fig. 12. Clinical view of the patient in case 7 after the distraction process. Note the newly generated bone and soft tissues. A radial forearm free flap was used to cover the retromolar trigone.

gery, special attention must be taken to avoid soft-tissue prolapse in the bony gap. The appearance of granulation tissue may obstruct the advancing bony edges during the distraction period. This condition has been referred to as a limiting factor for bone regeneration in large mandibular defects. The insertion of a resorbable shield to protect the bony defect as an additional measure to prevent soft-tissue relapse has been recently

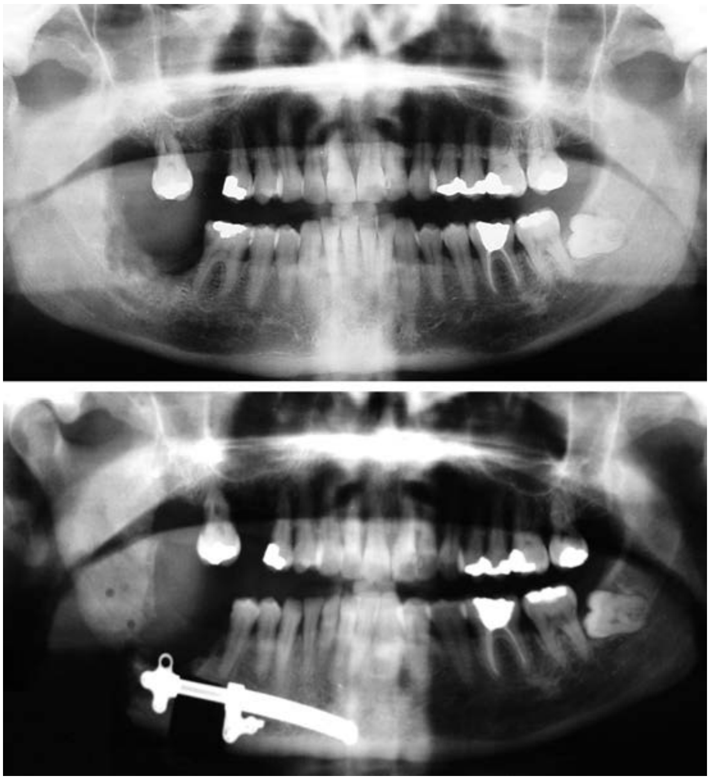

Fig. 13. Images of the patient in case 10. (*Above*) Panoramic radiograph after the third molar extraction showing an area of osteoradionecrosis. (*Below*) Panoramic radiograph taken at the beginning of the distraction process.

Fig. 14. Images of the patient in case 10. (*Above*) Partial cutaneous exposure at the end of the distraction process. (*Center*) Removal of the distraction device; note that neither an exposure of the newly formed bone nor orocutaneous fistulas were observed. (*Below*) Intraoperative view: removal of the distraction device and placement of a reconstruction plate. Reconstruction of the cutaneous exposure by means of a radial forearm free flap.

proposed.[18] We cannot obviate this condition, because two of our patients needed additional bone graft to fill the gap.

It is essential to predict an adequate vector during surgery, to form new bone in the desired direction (Fig. 8). Furthermore, the distraction device must apply compression forces at the docking sites, to achieve fusion with the residual distal skeleton stump. This ideal condition was not obtained in all the cases, and anterior iliac crest bone grafts were placed between the transport disk and the proximal stump (Figs. 9 through 11). Final results in these patients were also good at the end of the follow-up (Fig. 12). The requirement for bone grafts to complete bone union is not an argument against distraction osteogenesis. The graft is always much smaller than that required if distraction osteogenesis is not performed. Moreover, soft tissue is expanded according to the bone transport.[19]

There have been few studies concerning distraction osteogenesis and radiotherapy.[10,20] Gantous et al.,[21] in an experimental study with dogs, failed to show a relationship between previous radiotherapy and distraction osteogenesis. Holmes et al.[20] described two patients treated with radiotherapy who failed to achieve osteogenesis by means of distraction. Sawaki et al.[10] reported a successful distraction osteogenesis in a previously irradiated patient. In a recent clinical report by Herford,[19] two patients received postoperative irradiation as part of their treatment and achieved adequate bone formation. Seven patients of our series received radiotherapy ranging from 60 to 70 Gy. Six of them underwent preoperative radiotherapy, whereas the other one underwent postoperative radiotherapy. Only one of these patients (case 1) showed exposition of the distraction device. These observations could support the idea that previous radiotherapy does not have negative effects in the normal development of distraction osteogenesis. However, because of the limited number of patients of the series, no conclusion can be drawn about the influence or not of the irradiation in the distraction procedure. In summary, the role of irradiation over distracted bone is still unclear, and further studies are necessary to assess whether the need for postoperative radiotherapy may limit the use of distraction osteogenesis.

Two of our patients also received transposed soft-tissue flaps, such as the forearm free flap and temporalis myofascial flap. Uneventful bone distraction was performed under the flap, with no relapse of soft tissue in the defect. These results suggest that it is feasible to reconstruct mandibular defects covered with transposed soft-tissue flaps by means of distraction, although care must be taken to avoid distraction

Fig. 15. Panoramic radiograph taken at the end of the reconstructive procedures.

Fig. 16. Clinical view of the patient after reconstruction by means of a radial forearm free flap.

obstruction by interposed flaps (Figs. 13 through 16).

As previously reported by our group,[22] and because of its reliability, we used internal semiburied distraction devices in all of our patients. In fact, this is the only method currently used in our department. It offers some advantages in comparison with external distraction devices, such as (1) better stability, (2) a lower incidence of infection and dehiscence, (3) a lower incidence of unaesthetic scars and trauma, and (4) greater comfort and subsequent tolerance. Although external devices have been widely used for reconstructing mandibular segmental defects, there are no clinical series regarding mandibular reconstruction by means of submerged distraction devices. The use of this type of distraction has been previously applied for mandibular regeneration in a canine model with good results.[23] Moreover, in comparison with other internal devices such as the intraoral or the transmucosal activator, the external activator allows easier access for activation. With this type of activator, extraoral access is needed and complications derived from intraoral exposure are avoided. This is the reason why risks of infection and dehiscence decreased. In fact, the only patient of our series who underwent an intraoral approach failed to achieve osteogenesis. All our patients underwent a cervical submandibular approach for placement of the internal device, with minimal morbidity.

The technical limitation of the distractor used in this study is derived from the total length achieved after distraction. A total segment of 40 mm of formed bone is the maximum lengthening obtained by means of the use of one device. This shortcoming was overcome with the use of two consecutive distraction devices in a patient whose defect was much greater than 40 mm. This implies a new surgical approach, with possible complications derived from a new operation. Another limitation may be the one derived from the direction followed by the transport disk after the osteotomy. It tends to move parallel to the proximal segment

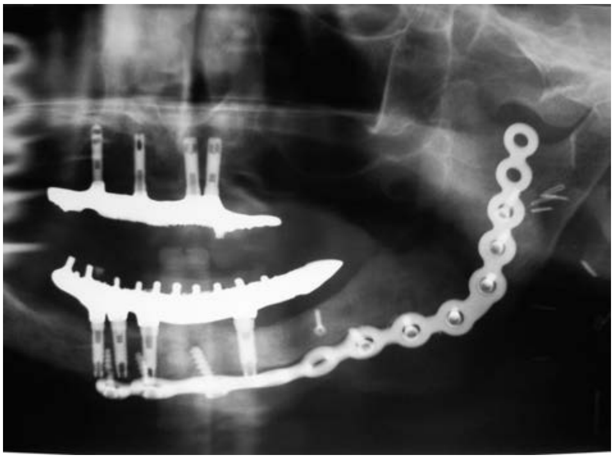

Fig. 17. Implants placed within the newly generated bone after the distraction process.

of the mandible, so sometimes it can be necessary to perform a greenstick fracture osteotomy after distractor removal to reproduce the mandibular curvature in the symphysial region. The use of a plate-guided distraction device, as reported by Herford,[19] could obviate this condition, although distraction technology has still to be refined to develop newer and more adapted devices.

All the patients in this study experienced a latency period of 10 days after the placement of the distraction device. No premature consolidation was observed in this period. After this, a distraction rate of 0.5 mm/day two times per day was achieved. Although it is slower than that reported for distraction osteogenesis of hypoplastic mandibles, we consider it more convenient to avoid excessive stretching of the periosteum. It is well known that it suffers extensive detachment after large mandibular resections. No patients showed unaesthetic scars. Dental rehabilitation by means of implants has been performed in two patients, with good functional rehabilitation (Fig. 17).

CONCLUSIONS

In our experience, distraction osteogenesis of mandibular segmental defects is a reliable method for reconstruction in those patients who are not candidates for more aggressive surgical procedures. Our results advocate for the use of bone transport by means of internal distraction devices with the use of transcutaneous activators as an optimum alternative in this type of patient.

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