Free-Flap Mandibular Reconstruction: A 10-Year Follow-Up Study

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Free-flap reconstruction of oncologic mandibular defects has become the modern standard of care. However, no previous studies have established the long-term results of such reconstructions. The objective of this study was to review functional and aesthetic outcomes in patients a decade after free-flap mandibular reconstruction.

A single surgeon's experience with free-flap reconstruction of the mandible was retrospectively reviewed. Eighty-two consecutive patients who underwent reconstruction from January of 1987 to December of 1990 were identified. Of the 34 patients still alive, 20 agreed to participate (response rate, 59 percent). To assess complications and functional outcome, patients were interviewed using validated questions and questions developed specifically for the study. Aesthetic outcome was judged by two independent observers. Panorex radiographs were obtained to assess bone resorption. Bone height was measured at standardized locations on the body, ramus, and symphysis and compared with the immediate postoperative Panorex radiographs. Differences in Panorex magnification were adjusted for by comparison of miniplate measurements. Mean length of follow-up was 11 years. Mean patient age at the time of the study was 48 years. Nineteen of 20 patients had malignant disease, one of whom had a local recurrence during the follow-up period. Two patients received radiation therapy preoperatively and 13 postoperatively. Mean length of mandible resection was 13 cm. Defect types were as follows (Jewer's classification): 12 L, 4 H, 3 LC, and 1 LCL. All flaps survived.

At 10-year follow-up, aesthetic outcome was judged to be excellent in 55 percent of patients, good in 20 percent, fair in 15 percent, and poor in 10 percent. The aesthetic results were remarkably stable over time. Slight accentuation of subtle postoperative asymmetry became evident as facial aging progressed. Dental rehabilitation in the study group included five patients with osteointegrated implants and seven with conventional dentures. Seventy percent of patients reported a regular diet. The remainder required a soft diet. Food tolerance was good, as rated by the List Scale (mean score, 77 percent). Seventeen patients had easily intelligible speech, whereas three were intelligible with effort. At the midbody of the mandible, 92 percent of the postoperative bone height was preserved; at the midramus, 93 percent was maintained; and at the symphysis, 92 percent remained. In several patients, there was greater age-related bone loss from the residual native mandible compared with the reconstructed site. One patient developed an orocutaneous fistula following postoperative radiation therapy. Nine patients had miniplates removed, either because of plate problems or to allow implant placement. There were no cases of osteoradionecrosis, bone fracture, or miniplate fracture. There was no significant long-term disability related to the donor site.

Free-flap reconstruction of the mandible provides excellent functional and aesthetic results that remain stable over time. Bone resorption is surprisingly minimal, even in the face of postoperative radiation therapy. The majority of patients are able to tolerate a regular diet and to either wear dentures or acquire osteointegrated implants. Acceptable speech and appearance are restored and continue to be a source of patient satisfaction at least a decade after surgery. (*Plast. Reconstr. Surg.* 110: 438, 2002.)

Oncologic resection of the mandible has a major impact on the form and function of the lower face. Mastication, speech, and facial aesthetics are often severely compromised without reconstruction.[1] Early reconstructive efforts with nonvascularized bone grafts were plagued by a high incidence of postoperative complications and poor long-term outcomes.[2] This changed significantly with the advent of microvascular reconstruction. Early postoperative complications decreased even in the setting of postoperative radiation, and expectations for successful oral rehabilitation, including placement of osteointegrated implants, rose markedly.[3,4] In addition, restoration of near-normal facial appearance became a new standard of care.

Although experience with microvascular mandibular reconstruction has been very positive, no previous studies have documented

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that the functional and aesthetic benefits are maintained beyond 2 to 3 years of follow-up.[1,5–7] The objective of this study was to evaluate patients 10 years after mandibular reconstruction with respect to mastication, maintenance of bone volume, speech, and facial appearance.

PATIENTS AND METHODS

A retrospective review was performed of 84 consecutive patients who underwent microsurgical reconstruction of the mandible. This represented a single surgeon's experience from January of 1987 to December of 1990 and reflected a minimum of 10 years of follow-up. Forty-eight patients had either died from their disease or died of other causes. Six were overseas and could not be contacted. Of the remaining 30 patients, 20 agreed to participate in the study (response rate, 67 percent).

Hospital and clinic records were reviewed to identify early and late postoperative complications, including flap problems, fistula, miniplate exposure, infection, donor-site problems, and reoperation. Comorbid conditions and adjuvant therapy were also reviewed. To assess functional outcome, a survey was developed using a combination of validated questions and questions specifically designed for the study. The survey specifically assessed diet, dental rehabilitation, speech, aesthetics, and donor-site morbidity. Patients were interviewed either in person (14 patients) or by telephone (six patients) and were encouraged to make additional comments regarding their overall experience. A clinical examination (14 patients) was performed to evaluate oral excursion, dental occlusion, palpable plates, and tenderness. Aesthetic outcome was judged by two observers.

New Panorex (Imaging Sciences International, Hatfield, Pa.) radiographs were obtained to assess bony resorption. Bone height was measured with calipers at standardized locations on the body, ramus, and symphysis. The bony height of normal adjacent mandible was also noted. These measurements were then compared with those obtained from the immediate postoperative Panorex radiographs. Differences in Panorex magnification between the early and late studies was adjusted for by comparison of miniplate measurements. The status of any osteointegrated implants was also documented.

Descriptive statistics were used to assess demographic and clinical data. Differential changes in bone height at the three locations on the mandible were examined using the Kruskal-Wallis test.

RESULTS

The mean length of follow-up was 11 years. The mean patient age at the time of the study was 48 years (range, 16 to 68 years) (Table I). There were 12 men and eight women.

Nineteen of 20 patients had malignant disease. Mean length of mandible resection was 13 cm (range, 8 to 20 cm). Defect types were as follows (Jewer's classification[5]): 12 L, 4 H, 3 LC, and 1 LCL (Fig. 1). Nineteen patients had immediate reconstruction; one was delayed. Nineteen patients underwent reconstruction with free fibula flaps. A single patient had a scapula flap. Eighteen arterial anastomoses were performed end to end, usually to the facial artery. Seventeen of the venous anastomoses were performed end to end, reflecting a preference for the external jugular vein as a recipient vessel. The mean number of osteotomies performed for each reconstruction (not including the ends of the graft) was 2.5 (range, one to five) and the mean number of plates used was six (range, three to 11). Seven patients undergoing hemimandible reconstruction had the native condyles removed with the specimen, resected from it, and then fixed to the microvascular graft as a nonvascularized graft. The condyle was replaced into the glenoid fossa without specific repair of the joint capsule when the graft was inset. These patients were maintained in intermaxillary fixation for 1 week. One patient, with an LCL defect, required an external skin paddle over the central chin and 13 patients required intraoral skin paddles. Mean duration of anesthesia was 15 hours (range, 10 to 21 hours), and mean duration of hospitalization was 19 days (range, 13 to 30 days). Perioperative complications occurred in 20 percent of patients. Two patients developed donor-site infections that required intravenous antibiotics, and two patients developed microvascular thromboses that required reexploration. All flaps survived.

Two patients received radiation therapy preoperatively and 12 postoperatively. The typical dose was 6000 to 6500 cGy. Two patients received postoperative chemotherapy. One patient had a local recurrence during the follow-up period that was controlled with radiotherapy. She subsequently remained free of disease.

TABLE I
Patient Summary and Defect Classification

Patient	Age (yr)	Follow-Up (yr)	Pathology	Defect Length (cm)	Classification (Modified Jewer)
1	36	11	SCC	20	H-m
2	34	13	Osteofibroma	13	H
3	68	13	SCC	12	LC-m
4	52	13	Osteogenic sarcoma	10	L
5	64	14	Osteogenic sarcoma	12	L
6	61	11	SCC	20	L-m
7	41	12	SCC	13	L
8	60	12	SCC	13	LC-m
9	53	10	SCC	9	L-mt
10	16	11	Lymphoma	12	LC-m
11	55	11	SCC	18	L-m
12	43	11	SCC	12	L-mt
13	51	11	Mucoepidermoid carcinoma	10	L
14	33	11	Adenoid cystic carcinoma	12	L-m
15	59	11	SCC	14	LCL-sm
16	40	10	SCC	8	L-m
17	36	10	Mucoepidermoid carcinoma	14	L
18*	54	10	SCC	12	L-m
19	13	10	Osteofibroma	13	H
20	39	10	SCC	14	H-m

SCC, squamous cell carcinoma.
* Scapula flap reconstruction. All other reconstructions with fibula flap.

At 10-year follow-up, aesthetic outcome was judged to be excellent in 55 percent of patients, good in 20 percent, fair in 15 percent, and poor in 10 percent (Table II). The aesthetic results remained remarkably stable over time, with little to no change in contour or projection of the mandible (Figs. 2 through 8). Normal, age-related soft-tissue atrophy and ptosis appeared to affect the reconstructed side of the lower face slightly more than the side that did not undergo operation, accentuating any early postoperative asymmetry. This was most notable among patients who had received postoperative radiotherapy.

Mean oral excursion, as measured at the central incisors, was 36 mm (range, 22 to 50 mm). Patients with condyle graft replacement had a similar degree of function compared with those in whom the joint was not disturbed. Seventy percent of patients reported a regular diet. The remainder required a soft diet. Food tolerance by the List Scale[8] was 79 (range, 50 to 100). This validated scale assesses food tolerance along a list of food types that require increasing amounts of mastication and bite force. A score between 75 and 80 corresponds to an ability to eat a full diet with the exception of nuts and steak.

Five patients received osteointegrated dental implants during the follow-up period. One patient developed infection, which necessitated

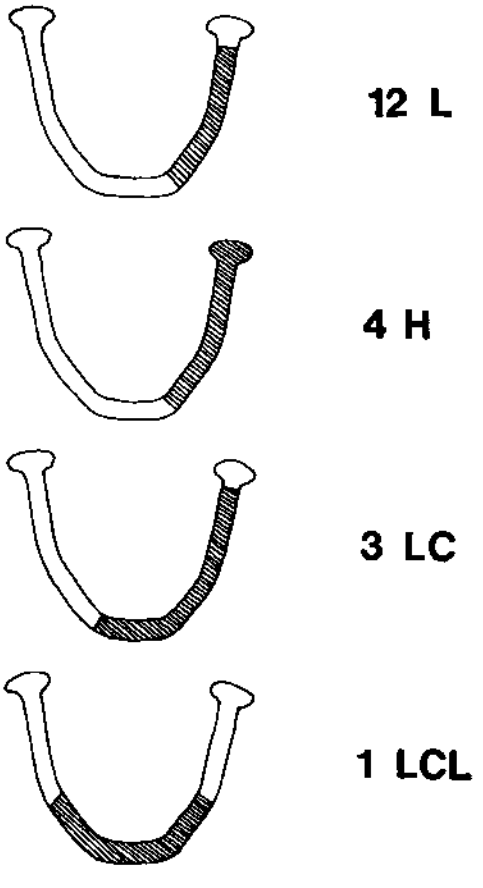

FIG. 1. Study patients grouped by bone defect type (Jewer classification system). *H*, hemimandible segment that includes the condyle; *L*, lateral segment without the condyle; *C*, central segment including the canine teeth.

TABLE II
Surgical Outcomes

Patient	Aesthetics	Speech	Diet	Oral Excursion	Dental Rehabilitation
1	Good	Easily intelligible	Soft	22	No
2	Excellent	Easily intelligible	Regular	48	No
3	Good	Intelligible w/effort	Soft	40	Dentures
4	Excellent	Easily intelligible	Regular	39	Osteointegrated implants (5)
5	Excellent	Easily intelligible	Regular	50	Osteointegrated implants (3)
6	Good	Easily intelligible	Regular	30	Dentures
7	Excellent	Easily intelligible	Regular	37	Dentures
8	Fair	Easily intelligible	Soft	37	Osteointegrated implants (3)
9	Excellent	Intelligible w/effort	Soft	*	No
10	Excellent	Easily intelligible	Regular	25	Dentures
11	Poor	Easily intelligible	Regular	28	No
12	Excellent	Easily intelligible	Soft	30	Dentures
13	Excellent	Easily intelligible	Regular	38	No
14	Fair	Easily intelligible	Regular	30	No
15	Poor	Intelligible w/effort	Soft	47	No
16	Good	Easily intelligible	Regular	35	No
17	Excellent	Easily intelligible	Regular	50	Osteointegrated implants (6)
18	Excellent	Easily intelligible	Regular	38	Dentures
19	Excellent	Easily intelligible	Regular	40	Osteointegrated implants (4)
20	Fair	Easily intelligible	Regular	34	No

* Unable to obtain measurement. Patient had recently suffered cerebral vascular accident.

removal of three of five implants; there were no other implant-related complications. Of the 15 patients who required dentures, seven were able to wear their prostheses without difficulty. For the remaining eight patients who experienced difficulty with their dentures, intraoral numbness and difficulty with food manipulation because of partial glossectomy were the main difficulties that limited the usefulness of the prostheses.

Seventeen patients had easily intelligible speech, whereas three were intelligible with effort (Table II). The latter three patients had partial or hemiglossectomies as part of their original oncologic resection.

There was minimal loss of bone volume as measured by graft height over time. At the midbody of the mandible, 92 percent (range, 71 to 100 percent) of the postoperative bone height was maintained. At the midramus, 93 percent (range, 80 to 100 percent) remained, and at the symphysis, 92 percent (range, 77 to 100 percent) was preserved. In the three edentulous patients, age-related bone loss from the residual native mandible was equal to or greater than on the side that was reconstructed. Importantly, there was no statistically significant difference in long-term volume loss between irradiated and nonirradiated free-flap bone grafts, although the sample size was small.

One patient developed an orocutaneous fistula following postoperative radiation therapy that required operative debridement and closure. Nine patients had between one and five miniplates removed (mean, three plates): one because of miniplate exposure, four for impending extrusion through skin, and four to prepare for osteointegrated implant placement. There were no cases of osteoradionecrosis or fracture of the mandible. There was no miniplate breakage that required operative intervention. One patient with a condyle graft reconstruction complained of moderate temporomandibular joint discomfort but had not sought medical therapy for this. One patient complained of dysesthesia in the mental nerve distribution that necessitated reexploration and plate removal without improvement. Seventy-five percent of patients experienced some degree of oral incontinence, which was usually mild and intermittent. This was primarily related to decreased sensation in the mental nerve distribution. In one patient with a central mandibular defect and an external skin paddle, this problem was severe.

There was no significant disability related to the donor site. Although three of 20 patients described mild, intermittent leg weakness or pain, only one had symptoms severe enough to curtail physical activities such as jogging. One patient reported running a marathon without any difficulty.

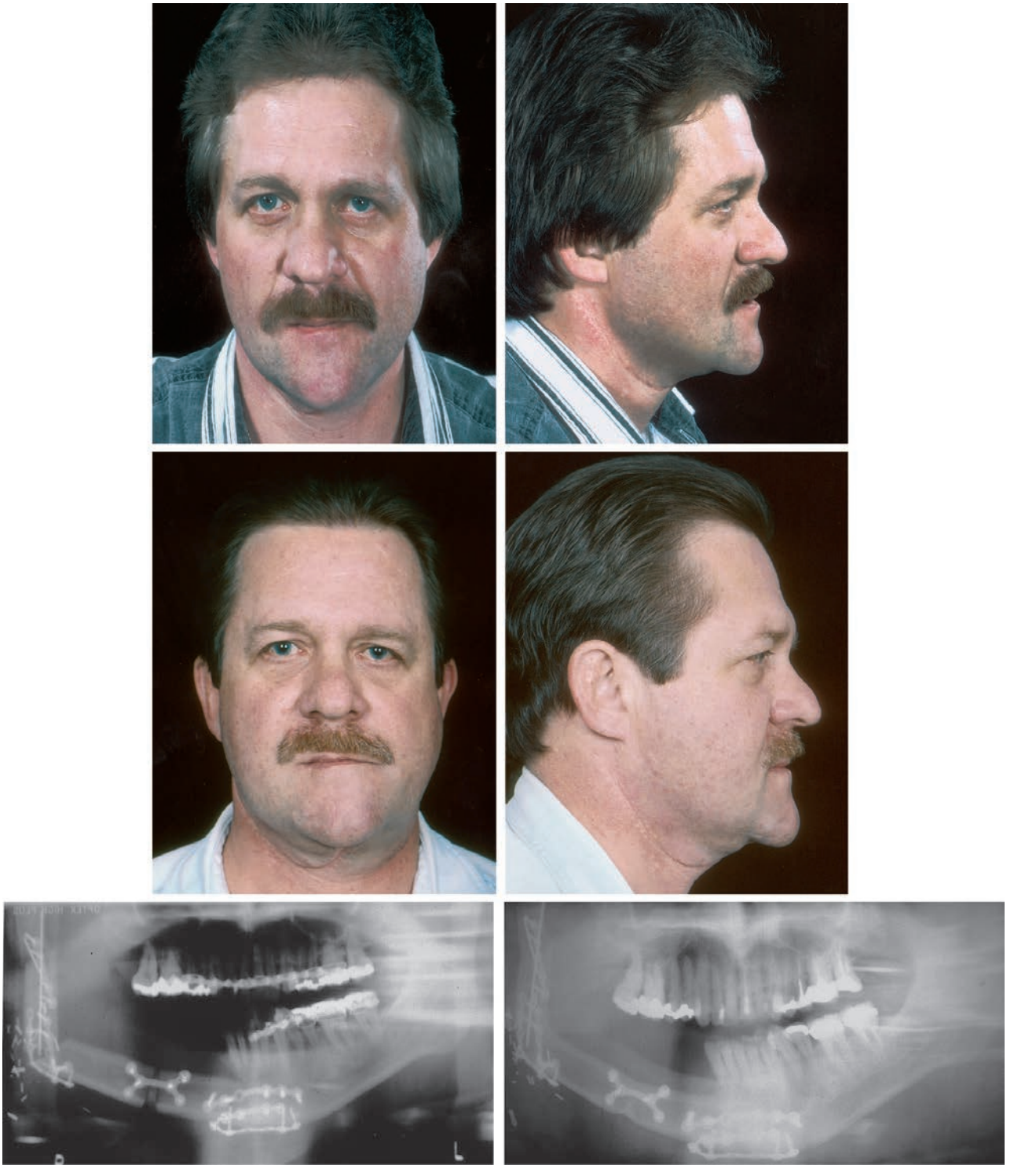

FIG. 2. Patient 2 in Tables I and II. (*Above*) Postoperative views at 2 years 4 months. (*Center*) Postoperative views at 13 years 4 months. (*Below, left*) Early postoperative Panorex radiograph. (*Below, right*) Panorex radiograph at long-term follow-up shows healed osteotomies and maintenance of bone height.

DISCUSSION

There are few published long-term follow-up studies on free-flap mandible reconstruction.[1,2,9] As a result, there are many unresolved questions regarding the long-term function, appearance, and fate of the microvascular

FIG. 3. Patient 17 in Tables I and II. (*Above*) Postoperative views at 4 months. (*Below*) Postoperative views at 10 years 3 months.

grafts. The most important issues addressed by this study are as follows:

1. Stability of bone graft volume.
2. Osteotomy site integrity.
3. Fate of retained miniplate fixation devices.
4. Fate of condyles transplanted as nonvascularized grafts.
5. Stability of osseointegrated implants.
6. Effect of postoperative radiation therapy on graft viability.
7. Opening ability and mastication (diet).
8. Speech.
9. Stability of associated graft soft-tissue volume.
10. Effects of mandible reconstruction on facial aging.

This study provides insight into all of these issues on the basis of its review of patients who have been followed at least 10 years since reconstruction. Two issues that this study does not address are the long-term effects on man-

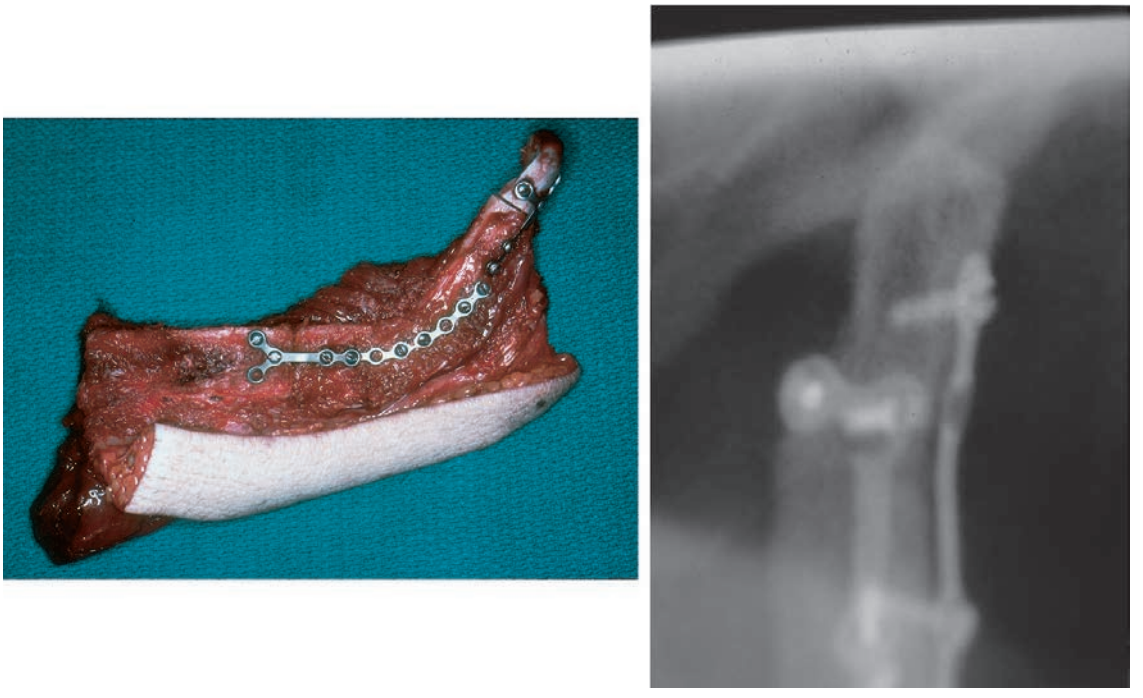

FIG. 4. (*Left*) This patient's completed fibula free-flap graft is shown before insetting with the transplanted condyle in place. (*Right*) Close-up Panorex view at long-term follow-up shows condyle graft condition. Comparison of miniplate and screw landmarks on radiography with adjacent flap view verifies complete survival of the condyle graft.

dibular growth in the pediatric population and the fate of osseointegrated implants placed in irradiated mandibular grafts.

Bone graft volume has proven uniformly stable, with only small losses occurring over a decade. There were no cases of significant graft dissolution with impending fracture. Moreover, the degree of volume loss was comparable and not greater than that of the remaining native mandible. In one particular case involving an edentulous mandible, the reconstructed portion aged significantly better than the remaining native portion. This may reflect in part the differences in embryologic origin between the microvascular graft (endochondral bone) and the native mandible (membranous bone).

Most reconstructions had between two and three osteotomies within the graft in addition to requiring fixation at each end. Therefore, each patient had at least four sites requiring stabilization. There were no osteotomy site fractures or nonunions in any patient. It can therefore be concluded that multiply osteotomized microvascular bone grafts have adequate blood supply and heal like normal bone. It has also been demonstrated that the multiple screws and plates necessary at each site of fixation do not compromise graft blood supply in a manner that would encourage long-term loss of bone volume.

Miniplate fixation was originally attractive because it enabled accurate fabrication of the graft by sequential osteotomy and fixation, a process aided in accuracy by mandibular templates and measurements taken from the surgical specimen.[10,11] This method is inherently more precise than the alternative of using a single reconstruction plate and avoids adding unwanted bulk to the external surface of the graft. The use of miniplates for osteotomy site fixation has proven durable and trouble-free in this study. The need to remove plates or screws because of impending external extrusion through the skin occurs occasionally. When it happened, it was usually because of inadequate soft-tissue coverage and was not a problem attributable directly to the hardware. Removal of plates because of intraoral soft-tissue breakdown was also unusual. When it occurred, only the exposed plates in the immediate vicinity of the wound breakdown were removed, and only after the bone had healed. This rare need to remove miniplates, now proven by long-term follow-up, is remarkable given the contami-

FIG. 5. Patient 10 in Tables I and II. (*Above*) Postoperative views at 10 months. (*Center*) Postoperative views 10 years 7 months later. There is atrophy of the submental soft-tissue volume (flexor hallucis longus muscle) and ptosis of the chin pad. (*Below, left*) Early postoperative Panorex radiograph. (*Below, right*) Panorex radiograph at long-term follow-up shows good symmetry and healed osteotomy sites.

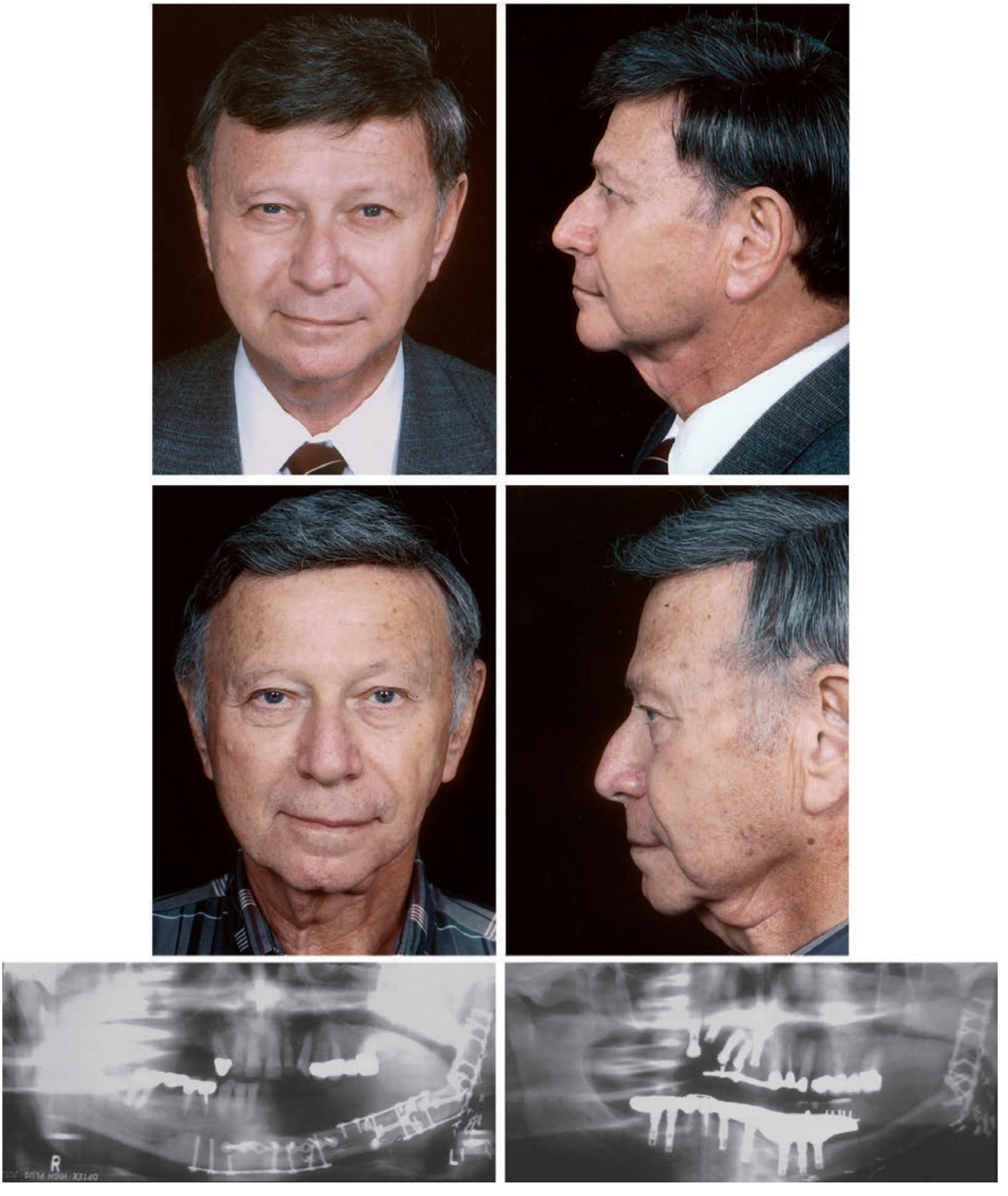

FIG. 6. Patient 5 in Tables I and II. (*Above*) Postoperative views at 1 year 6 months. (*Center*) Postoperative views at 12 years 7 months. Facial asymmetry has become more obvious with aging (*Below, left*) Early postoperative Panorex radiograph. (*Below, right*) Panorex radiograph at long-term follow-up shows extensive dental reconstruction with osseointegrated implants.

nated oral wound environment that is often open for more than 12 hours during surgery.

A previous study has shown that the condyle can be resected from the surgical specimen when deemed to be oncologically safe, fixed to the end of the free-flap bone graft, and inset into its native position within the glenoid fossa during reconstruction.[12] This restores tandem

FIG. 7. Patient 1 in Tables I and II. (*Above* and *below*, *left*) Preoperative views. (*Above* and *below*, *center*) Postoperative views after two-stage reconstruction with fibula free flap for bone and scapula free flap for additional soft-tissue augmentation. (*Above* and *below*, *right*) Postoperative views at 11 years 11 months.

temporomandibular joint function across the midline, a unique property of the mandible. Follow-up Panorex studies have confirmed that these grafts can survive intact for over a decade (Figs. 3 and 4). There were two patients in whom the nonvascularized condyle graft failed to survive completely. Function was not compromised by pain, trismus, or ankylosis even in these patients. There were no instances where use of the condyle had negative oncologic consequences. This safety record is largely a reflection of conservative judgment in selecting candidates for condyle transplantation. The results of this study support the use of the condyle as a nonvascularized graft when specimen transection is planned at the midramus level or higher. It seems to be a superior alternative to not reconstructing the condyle at all, shaping the end of the graft to resemble a condyle, or using a prosthetic condyle.

Osseointegrated implant placement as a secondary procedure after free-flap mandible reconstruction has proven to be a worthwhile procedure.[3,13,14] However, not all mandible reconstruction patients are candidates for dental reconstruction with this method. Excluding factors include extent of disease, amount of remaining dentition, postoperative radiation therapy, patient preference, and expense.[7,14] There were 21 implants placed in five patients in this study. A few implants were ultimately not loaded because of alignment problems. Only one patient required implant removal because of infection and nonintegration. Implants were subsequently replaced successfully in this case. A decade of follow-up has proven this method of dental reconstruction to be safe, effective, and durable.

Twelve of 20 patients (60 percent) in this study received full radiation therapy following mandible resection and primary reconstruction. This study has shown that radiation ther-

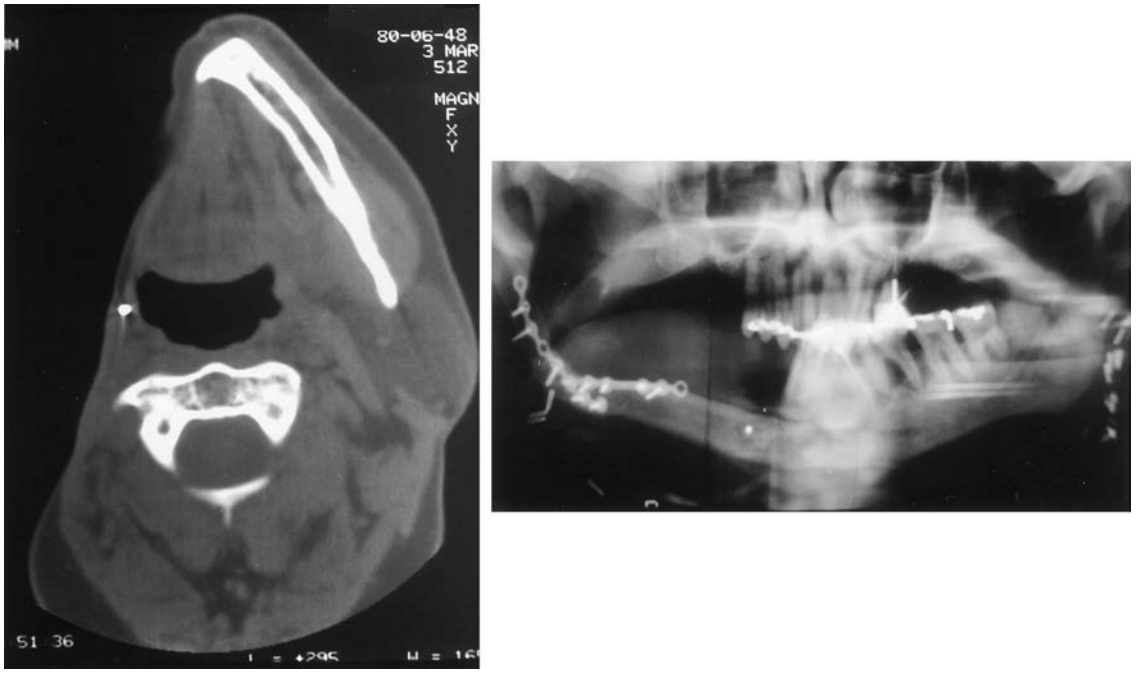

FIG. 8. (*Left*) Preoperative computed tomographic scan of patient from Figure 7 shows extent of original tissue defect. (*Right*) Panorex radiograph at long-term follow-up. Note the symmetric contour of the inferior border of the mandible, the primary determinant of lower facial symmetry restoration.

apy does not delay the healing of osteotomy sites or compromise bone graft viability. In addition, there was no statistically significant difference in long-term volume loss demonstrated between irradiated and nonirradiated free-flap bone grafts, although the sample size was small. There were no patients in whom osseointegrated implants were placed into irradiated grafts as a secondary procedure. As a result, no conclusions were possible regarding the safety or efficacy of this practice, which still has few advocates.

Previous studies[15] have suggested that microvascular reconstruction can successfully restore preoperative occlusion and satisfactory mastication, at least in short-term follow-up. This has been confirmed in this study, in which the majority of patients maintained adequate oral excursion and were able to tolerate a normal to near-normal diet for at least 10 years (Table II). This is a highly important outcome from a quality-of-life standpoint. Placement of osteointegrated implants is an important contributing factor to this success even though masticatory function was generally good among patients who did not receive implants.

It is well documented that ablative surgery of the oral cavity can significantly alter speech.[16] However, 85 percent of patients had easily intelligible speech in this series (Table II). Microvascular reconstruction of the mandible enhances the potential for excellent postoperative speech quality by restoring a stable platform for tongue mobility. Significant speech disability should be expected only among those patients who require significant tongue resections.

There was little change in facial symmetry a decade after reconstruction; nor were there significant changes in aging attributable to it. Soft-tissue asymmetry was more progressive over time among patients who had received postoperative radiotherapy. One patient exhibited ptosis of the chin pad (Fig. 5). Minor facial asymmetry became slightly more pronounced in older individuals (Fig. 6), but changes in neck laxity were largely consistent with a normal aging process.

It became apparent during this study that functional and aesthetic results correlate more with the extent of the soft-tissue defect than with the extent of the bone defect. Although the latter can be accurately reconstructed, the quality of the soft-tissue reconstruction can suffer from inadequate volume replacement, a skin patch effect externally, or substitution of nonfunctional bulk for specialized tissue such as tongue or facial mimetic muscles. Classification of mandible defects should therefore include a soft-tissue designation to be most useful

in describing the likely aesthetic and functional impact of a particular defect. The Jewer classification system can be effectively used for this purpose when one or more letters are included to categorize the associated soft-tissue defect. This is a simple method that has as much predictive value as more complex classification systems.[15] According to the modified Jewer description, "o" indicates a bone-*o*nly defect, "m" an associated *m*ucosal defect, and "s" an external *s*kin defect.[17] A combination of letters is possible. Using the letter "t" to indicate a significant tongue defect would make this system even more useful. Reconstruction of an LCL bone-only defect, for example, would be expected to have a significantly better functional and aesthetic result than an LCL-sm or LCL-mt defect. The patients in this study are described using this new classification system in Table I, where "o" has been deleted in the case of bone-only defects.

In conclusion, this study has shown that reconstruction of the mandible with a microvascular free flap is functionally and aesthetically durable a decade later. This confirms the promise reported in previous short-term studies.[1,7,18,19]

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