Implant Prosthodontic Rehabilitation of Fibula Free-Flap Reconstructed Mandibles: A Memorial Sloan-Kettering Cancer Center Review of Prognostic Factors and Implant Outcomes

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Purpose: *This study aimed to estimate the cumulative survival rates (CSRs) of implants placed in reconstructed mandibles and to identify prognostic factors that may influence implant survival.* ***Materials and Methods:*** *The charts of 24 patients (10 male, 14 female) who had undergone mandibular resection and reconstruction with fibula free-flaps treated with implant-supported prostheses from April 1986 through December 2001 were reviewed. Information on demographics, surgical characteristics, treatment modalities, dentition, implant parameters, prostheses, and hyperbaric oxygen therapy (HBO) was gathered. Kaplan-Meier survival estimates were generated for the 100 implants that satisfied the inclusion criteria. Multivariate Cox proportional hazards regression models accounting for correlated implants within subjects were developed to identify prognostic factors for implant survival.* ***Results:*** *Nineteen implants had been placed in native mandible (3 in irradiated bone) and 81 in fibula bone flap. Six implants failed during the follow-up period (mean 51.7 months). The overall 5- and 10-year CSRs were 97.0% and 79.9%, respectively. In the univariate analysis, variables associated with implant survival were age, gender, chemotherapy, radiation therapy, HBO, irradiated bone, implant diameter, xerostomia, trismus, opposing dentition, and type of prosthesis. At 5 years, the CSR of implants in patients with HBO was 86.7%; HBO was statistically associated with an increased risk for implant failure (*P = .005, hazard ratio = 19.79, 95% CI: 2.42 to 161.71). ***Discussion:*** *The CSR was lower when implants were placed in a previously irradiated mandible. There is still a lack of reliable clinical evidence to support the effectiveness of HBO in these patients.* ***Conclusions:*** *A high survival rate was demonstrated for implants placed in fibula free-flap reconstructed mandibles. The finding that HBO was a risk factor can probably be attributed to the small sample size; further study is needed in this patient population.* Int J Oral Maxillofac Implants 2005;20:738–746

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Mandibular resection can lead to significant facial deformity, functional disabilities, and concomitant psychological problems. Loss of mandibular continuity and impaired sensory and motor control of the tongue may result in mandibular deviation as well as speech and swallowing difficulties. Prior to the era of microvascular reconstruction, prosthetic rehabilitation of mandibulectomy patients was less than optimal. Deficiencies such as scar contracture, redundant and insensate tissue, and the effects of radiation are often prohibitive to supporting dental prostheses. These patients were often referred to as the "forgotten patients," as little could be done to improve their oral function.[1] The advent of microvascular free-flaps has provided a means to predictably restore bony and soft tissue in many cases of large and complex defects. Various donor sites have been

used to obtain graft material for mandibular reconstruction. Immediate or subsequent placement of implants in the reconstructed mandible allows for the fabrication of dental prostheses that are more stable and retentive. Satisfactory functional results after implant rehabilitation of patients with reconstructed mandibles have been published in a number of case reports and clinical studies.[2–4] However, in situations where there is massive soft tissue loss (ie, tongue resection and neural deficit), functional outcome can be poor even with implant-supported prostheses.[5,6]

While studies have analyzed the overall success rates of grafts, free-flaps, and implants, few have reported on long-term results or on any associations between implant outcomes and host determinants in an objective and statistically valid manner. The aims of this retrospective study were to estimate the 5- and 10-year survival rates of implants placed in surgically reconstructed mandibles and to identify prognostic factors that may influence implant survival.

MATERIALS AND METHODS

From April 1986 to December 2001, 260 patients underwent mandibular resection and reconstruction at the Memorial Sloan-Kettering Cancer Center (MSKCC) in New York. Of these, 29 patients (11.2%) received implant rehabilitation. Five implant patients who had marginal resections without reconstruction were excluded from the study. Patients were selected as implant candidates based on the following criteria:

- Favorable tumor prognosis based on stage and grade
- Absence of a coexisting systemic disease that could compromise osseointegration
- Positive mental attitude and realistic expectations
- Good oral hygiene and high level of dental awareness
- Sufficient bone quality and quantity, good residual tongue function, lack of trismus
- Suitable maxillomandibular relationship and absence of untreatable soft tissue abnormalities

The clinical charts of 24 consecutive patients who had had fibula free-flap reconstruction and endosseous implant placement were reviewed. Information on demographics, surgical characteristics, treatment modalities, dentition, opposing dentition, implant parameters, prosthetic intervention, and hyperbaric oxygen therapy (HBO) was recorded.

The study consisted of 10 male and 14 female patients with a mean age of 42 years (median, 41.7 years; range, 6.7 to 80.5 years). Indications for mandibular ablative surgery were squamous cell carcinoma (6 cases), osteogenic sarcoma (9 cases), benign tumors (2 cases), osteoradionecrosis (2 cases), mucoepidermoid carcinoma (2 cases), and other sarcomas (3 cases) (Table 1). The tumors were located in the mandible (18 cases), floor of mouth (3 cases), tongue (2 cases), and gingiva (1 case). Of the 7 patients who had radiation therapy, 6 received radiotherapy before implant placement and 1 patient had radiotherapy after dental implants were placed. The radiation dose received ranged from 60 to 79 Gy and was given over a 6- to 8-week period. Two patients had HBO for the treatment of osteoradionecrosis prior to implant placement; 1 patient had HBO for "preventive osteoradionecrosis" purposes prior to implant placement. The HBO was administered according to Marx's protocol.[7]

Implant Placement

Endosseous implants were placed using a 2-stage procedure after adequate healing from the initial reconstructive surgery. The mean period between reconstruction and stage-1 implant surgery was 22 months (range, 5.6 to 48.6 months). Two commercially available titanium screw-type implant systems were used: Nobel Biocare (Yorba Linda, CA) and Osseotite (3i/Implant Innovations, Palm Beach Gardens, FL). Prior to stage-1 surgery, interosseous miniplate fixation screws were removed from the proposed implant sites to allow for proper placement of the implants.

Implants were placed by 2 oral and maxillofacial surgeons. The diameter of the implants placed varied from 3.25 mm to 5.0 mm; the length varied from 7.0 mm to 15.0 mm. A total of 102 implants were placed. All implants were allowed to integrate for at least 6 months before stage-2 surgery. Prosthodontic restoration was accomplished by 2 prosthodontists after stage-2 surgery and complete healing of the soft tissues.

Prosthetic Intervention

At the time of review, 20 patients had been restored with implant-supported prostheses. Of the remaining 4 patients, 2 died after stage-2 surgery, 1 had a pathologic fracture, and 1 was lost to follow-up. A total of 25 implant-supported prostheses were fabricated. These prostheses were retained by 83 functioning implants. Eleven overdentures (8 bar-retained, 3 O-ring–retained), 9 hybrid (fixed-detachable), and 5 metal ceramic prostheses were fabricated (Figs 1a to 1c). Of the 8 patients who received bar-retained overdentures, 5 had their initial prostheses replaced by O-ring overdentures (n = 3), a hybrid

Table 1 Summary of the Baseline Characteristics and Prosthetic and Implant Outcomes

No.	Patient	Sex	Age	Diagnosis	Tumor site	Chemotherapy	Radiation	Dose	HBO	Bony defect	Flaps	Total	Native mandible	Neo-mandible	Implant "put to sleep"	Implants failed	Interval* (mo)	Type of prosthesis
1	A	M	14.3	Spindle cell sar	L mandible					SBR	Fibula	5	0	5			35.0	
2	B	F	43.4	Angiosarcoma	R mandible					CRBSh	Fibula	3	0	3			12.5	FBAB
3	C	M	44.0	ORN	Ant mandible		Pre-Stage 1	7000	Yes	BSB	Fibula	4	0	4			5.6	ODB, ODOR
4	D	F	6.7	Ewing's sar	R mandible	Adjuvant				RBSh	Fibula	4		2 , 2†			10.5	ODB, FMC
5	E	M	40.0	Osteogenic sar	L mandible	Adjuvant				BSBR	Fibula	2		2			6.2	
6	F	F	62.1	ORN	Ant mandible		Pre-Stage 1	7900	Yes	BSB	Fibula	6		3 , 3†		3	14.2	ODB, FBAB
7	G	M	65.6	Osteogenic sar	L mandible					ShBRC	Fibula	7	4	3			22.1	ODB
8	H	F	26.9	Osteogenic sar	L mandible					ShB	Fibula	4		4			13.6	FBAB
9	I	F	62.2	Ameloblastoma	R mandible					CRB	Fibula	4	2	2			21.4	FBAB
10	J	M	15.4	Ossifying fibroma	Ant mandible					BSB	Fibula	4		4			40.6	ODB
11	K	F	32.0	Osteogenic sar	R mandible					RBS	Fibula	6		6			17.0	FMC
12	L	F	62.5	SCC	R FOM					RBSh	Fibula	2	1	1			17.7	ODB
13	M	F	65.2	SCC	L mand ging					ShB	Fibula	4	1	3		1	48.6	FBAB
14	N	F	49.7	SCC	L lat tongue		Post-Stage 1	7020		BSB	Fibula	5		5			14.8	
15	O	M	38.7	Osteogenic sar	Ant mandible	Neo-adjuvant	Pre-Stage 1	7050		BSB	Fibula	4		4	1		41.0	ODB, ODOR
16	P	M	18.4	Mucoepidermoid	L mandible					ShBRC	Fibula	3		3			5.6	FBAB
17	Q	M	18.0	Osteogenic sar	R mandible	Adjuvant				RBSB	Fibula	6		6			13.7	FBAB
18	R	F	54.3	Osteogenic sar	L mandible	Neo-adjuvant				ShRB	Fibula	5	3	2	1		25.9	ODB, ODOR
19	S	M	39.1	Mucoepidermoid	L mandible					SBR	Fibula	6	3	3			37.0	FMC
20	T	M	57.5	Rec SCC	R oral tongue		Pre-Stage 1	6000		RBS	Fibula	2	2				12.4	FBAB
21	U	F	80.5	Rec SCC	R FOM		Pre-Stage 1	6300	Yes	BSh	Fibula	5	3 (irrad)	2		2	28.5	
22	V	F	54.7	Osteogenic sar	R mandible	Neo-adjuvant				BS	Fibula	4		4			34.3	FBAB
23	W	F	32.6	Rec SCC	R FOM		Pre-Stage 1	6300		BSh	Fibula	4	1	3			12.2	FMC
24	X	F	23.4	Osteogenic sar	L mandible					BR	Fibula	3		3			35.9	FMC

*Interval between reconstruction and stage 1 in months.

†Implants were placed in separate stages.

ORN = osteoradionecrosis; Sar = sarcoma; Ant = anterior; ODB = overdenture bar-retained; Rec = recurrent; L = left; Mand = mandibular; ODOR = overdenture O-ring–retained; SCC = squamous cell carcinoma; R = right; Ging = gingiva; FMC = full metal ceramic; FOM = floor of mouth; Lat = lateral; FBAB = hybrid prosthesis. For the bony defects, S = symphyseal; B = body; Sh = parasymphyseal; r = ramus; and c = condylar.

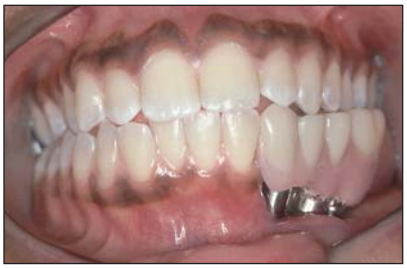

Fig 1a Hybrid prosthesis retained by 3 implants in a fibula free-flap.

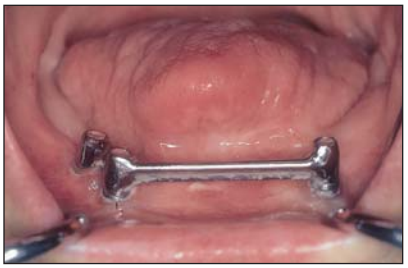

Fig 1b Bar framework supported by 3 implants in a fibula free-flap.

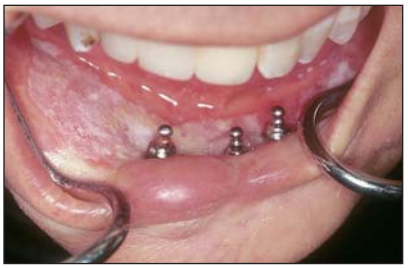

Fig 1c O-ring–retained overdenture in a reconstructed mandible that lacked both the lingual floor of the mouth and labial vestibules. Intraoral view of the abutments.

(fixed-detachable) prosthesis (n = 1), or a metal-ceramic fixed prosthesis (n = 1). These 5 replacement prostheses were necessary because of soft tissue complications.

Implant Outcome and Statistics

The primary outcome variable of interest was implant failure, which was defined as implant removal. The duration of implant survival was computed by calculating the time between stage-1 implant surgery and the date of the last follow-up or implant removal. The duration of implant survival was reported in months. Overall implant survival was estimated using the Kaplan-Meier method for 100 implants. Two implants that were "put to sleep" were excluded in the survival analysis, as their inclusion would have no merit in assessing whether different variables had an impact on implant survival. Because each patient could contribute multiple implants to the dataset, Cox proportional hazard regression models accounted for correlated implants within subjects were used to identify covariates associated with implant failure. Statistical analyses were performed using the software SAS v.9.1 (SAS Institute, Cary, NC). Statistical significance was set at $P < .05$.

RESULTS

The overall 1-, 5-, and 10-year implant survival rates for patients in this study were 97.0%, 97.0%, and 79.9% respectively (Fig 2). The mean follow-up time was 51.7 months (median, 42 months) with a range of 1.3 to 138 months. Of the 100 implants analyzed, 42 implants were in male patients and 58 were in female patients. Twelve implants were lost in patients who succumbed to disease, and 8 were lost to follow-up.

With regard to implant distribution, 59 implants were placed in the anterior mandible, and 41 were placed in the posterior mandible. Nineteen implants were placed in native mandible. Three of these were placed in a mandible that had previously been irradiated. Eighty-one implants were placed in a fibula bone flap. The most commonly used implant dimensions were 10 × 3.75 mm, 13 × 3.75 mm, and 10 × 3.25 mm. Implants with a diameter of of 5.0 mm were infrequently used; only 6 were placed (Fig 3). The limited width of fibula grafts precluded the placement of wide-diameter implants. Implants were placed in 7 edentulous and 17 partially dentate mandibular arches.

In the present study, the overall implant failure rate was 6.0% (6/100). These failures occurred in 3 female patients (F, M, and U). Failures occurred with implant lengths of 8.5 mm, 10 mm, and 13 mm and diameters of 3.25 mm and 3.75 mm (Table 2). Five failed implants were in the anterior mandible and 1 was in the posterior mandible. Of the 6 implants that failed, 2 exfoliated (patient U), 1 was lost before stage-2 surgical uncovering (patient M), and another 3 failed after being loaded for 8 years (patient F). Of the 2 implants that exfoliated, 1 was in a fibula free-flap while the other was in an irradiated mandible. Patient U had complications of infection and fistulae that developed at the submental region before implant placement. She received 20 sessions of HBO therapy at 2.4 atm before implant placement and another 10 sessions afterward. Early failures were the result of lack of osseointegration. She subsequently developed pathologic fracture at the junction between the graft and native mandible.

As for the 3 implants that failed after 8 years, patient F had scarring and tethering of the lower lip with obliterated labial and lingual vestibules, which made oral hygiene access very difficult. In addition, the patient had systemic osteoarthritis medicated with weekly doses of methotrexate and quinine sulfate. The soft tissues were persistent with chronic hyperemia and calculus accumulation requiring surgical removal every 6 months over a 3-year period. This, together with pressure necrosis from the con-

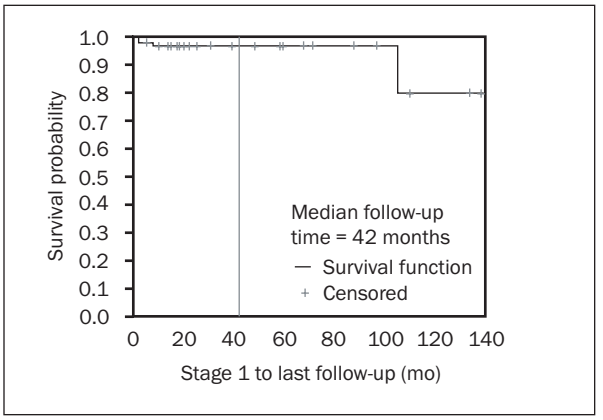

Fig 2 Cumulative survival rate of implants in reconstructed mandibles (n = 100).

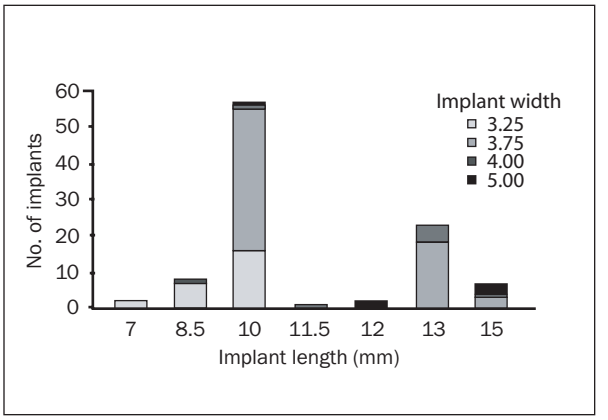

Fig 3 Implant distribution by length and diameter (n = 100).

Table 2 Failed Implants

Mandibular site	Implant bed	Time before failure (mo)	Time between placement and restoration (mo)*	Time of prosthetic service (mo)	Implant length (mm)	Implant diameter (mm)	HBO
Left canine	Fibula	105.8	9.1	96.8	13.0	3.75	Yes
Left central incisor	Fibula	105.8	9.1	96.8	13.0	3.75	Yes
Right lateral incisor	Fibula	105.8	9.1	96.8	13.0	3.75	Yes
Left first molar	Fibula	7.8	NR	0	13.0	3.25	No
Right canine	Fibula	1.3	NR	0	8.5	3.25	Yes
Left canine	Irradiated native mandible	1.3	NR	0	10.0	3.25	Yes

*Implants that were not restored were lost at or before surgical uncovering (stage 2).
NR = not restored.

tracted lip, caused dehiscence of the buccal bone and exposure of the implant threads. Upon surgical removal of the implants, it was found that each implant had 180-degree bone loss; however, the implants were immobile. Subsequently, 3 new implants and a Hader bar were placed to support a new prosthesis.

In the univariate analysis (Table 3), unadjusted hazard ratios (HRs) were derived from Cox proportional hazard models that accounted for correlated implants within subjects. Where there was no implant failure within the subgroup, the HR equaled 0. Variables that were statistically significant were age, gender, chemotherapy, radiation therapy, hyperbaric oxygen, irradiated bone, implant diameter, xerostomia, trismus, opposing dentition, and type of prosthesis. By including variables that have implant failures within all subgroups in the multivariate models and using stepwise selection method, HBO therapy remained statistically associated with implant failure after adjusting for other covariates. The adjusted HR and associated 95% confidence interval (CI) for HBO was 19.8 (2.42 to 161.71, $P = .0053$).

DISCUSSION

The cumulative implant survival rates were 97% after 5 years, and 79.9% after 10 years. These high survival rates could be attributed to the stringent criteria used in the selection of patients for implant rehabilitation. These results are comparable to previously reported studies on implant survival in free-flaps.[8,9] However, the reported studies did not include correlations between implant outcomes and host determinants.

It is important to acknowledge certain inherent deficiencies in this study. As this is a retrospective study, it was limited by the availability and content of the medical records. The reliability and validity of the data collected and the potential for biases and

Table 3 Prognostic Factors Assessed for Implant Survival in Reconstructed Mandibles (n = 100)

Variable	No. of implants (%)		5-year implant survival rate (%)	*P*	HR (95% CI)
	Survived	Failed			
Age					
≤ 30	35 (37.2)	0	100	< .001	0†
31 to 60	44 (46.8)	3 (50.0)	100	.60	0.49 (0.03–7.25)
≥ 61*	15 (16.0)	3 (50.0)	82		
Gender					
Male	42 (44.7)	0	100	< .001	0†
Female*	52 (55.3)	6 (100.0)	95		
Chemotherapy					
Adjuvant	11 (11.7)	0	100	< .001	0†
Neoadjuvant	12 (12.8)	0	100	< .001	0†
No*	71 (75.5)	6 (100.0)	96		
Radiation therapy					
Pre-stage 1	19 (20.2)	5 (83.3)	92	.02	12.45 (1.51–102.41)
Post-stage 1	5 (5.3)	0	100	< .001	0†
No*	70 (74.5)	1 (16.7)	99		
HBO therapy					
Yes	10 (10.6)	5 (83.3)	87	.005	19.79 (2.42–161.71)
No*	84 (89.4)	1 (16.7)	99		
Type of implant bed					
Fibula free-flap	76 (80.9)	5 (83.3)	98	.49	2.20 (0.23–21.23)
Native mandible*	18 (19.1)	1 (16.7)	95		
Implant in irradiated bone					
Yes	2 (2.1)	1 (16.7)	67	.005	32.33 (4.53–230.76)
No*	92 (97.9)	5 (83.3)	98		
Implant type					
Machined	63 (67.0)	4 (66.7)	99	.27	0.23 (0.02–3.14)
Acid-etched*	31 (33.0)	2 (33.3)	94		
Implant length					
≤ 10 mm	65 (69.1)	6 (100.0)	97	.35	0.41 (0.06–2.65)
> 10 mm*	29 (30.9)	4 (66.7)	97		
Implant diameter					
≤ 3.75 mm*	79 (84.0)	6 (100.0)	96		
> 3.75 mm	15 (16.0)	0	100	< .001	0†
Implant location in the arch					
Anterior	54 (57.4)	5 (83.3)	97	.39	2.77 (0.27–28.70)
Posterior*	40 (42.6)	1 (16.7)	98		
Xerostomia					
Yes	24 (25.5)	5 (83.3)	93	.03	11.06 (1.31–93.41)
No*	70 (74.5)	1 (16.7)	99		
Trismus					
Yes	4 (4.3)	0	100	< .001	0†
No*	90 (95.7)	6 (100.0)	97		
Opposing dentition					
Natural / Fixed*	84 (89.4)	6 (100.0)	97		
Removable	10 (10.6)	0	100	< .001	0†
Type of prosthesis (n = 83)					
Hybrid prosthesis*	32 (40.5)	4 (100.0)	97		
Metal ceramic	23 (29.1)	0	100	< .001	0†
Overdenture	24 (30.4)	0	100	< .001	0†

*Reference group.
†HR (95% CI) equals 0 because of the absence of implant failure.

confounding factors are some of the shortcomings in this study. Despite the limitations, the study is a single institutional report wherein a standardized protocol for implant indications, treatment philosophy, surgical placement, and prosthodontic rehabilitation were practiced. In that regard, variables associated with management policy were somewhat minimized.

In the present study, older patients (≥ 61 years) had a significantly higher risk of implant failure. Although the integration process itself is not compromised by increased age, older patients may have potentially longer healing times, more systemic health factors, and decreased ability to maintain hygiene.

All implants were placed secondarily after bony reconstruction and after adjunctive therapy, with a delay of at least 4 to 6 months after cancer therapy. This period was to allow healing of the osteotomy sites and evaluation of the patient and disease status and to avoid placing an implant in a compromised position. The advantages of secondary placement of implants have been well-described.[8,9]

On the other hand, authors[10,11] advocating immediate placement of implants claimed that this would obviate the need for additional surgical procedures, adjunctive HBO, and problems associated with the placement of dental implants in irradiated tissue. They suggested that allowing a period of 4 to 6 weeks between surgery and initiation of radiation therapy would be sufficient. However, further studies need to be undertaken to provide histologic evidence to support this suggestion. Limited follow-up periods and the number of implants put to sleep after stage 1 were not reported in these studies.[10,11] At MSKCC, immediate implant placement is not recommended, as it can lengthen the operative procedure and result in a potentially compromised implant position, leading to non-use of the implant.

The effect of chemotherapy on the osseointegration and survival of endosteal implants is not well established. In the present study, all 23 implants that were placed in patients who received chemotherapy survived. Similar findings were reported by Kovacs.[12] In that study, chemotherapy did not have a detrimental effect on the survival and success of 106 implants placed in the mandibles of 30 patients.

Patients who had radiation prior to implant surgery had a lower implant survival rate compared to those who did not receive radiation (92% versus 99%; $P = .02$). However, for the patient (N) who had radiation after implant surgery, the implant survival rate was 100%. This observation was probably related to the fact that the 6 failed implants occurred in only 2 patients (F and U) who had radiation before implant surgery and 1 patient (M) who did not have radiation. An animal study[13] has demonstrated that radiated vascularized bone healed better and had fewer complications than radiated nonvascularized bone. However, clinical data to support such findings in humans are still lacking. For patients who had xerostomia, the lower implant survival rate (93% versus 99%) could be attributed to the confounding effects of radiation therapy, changes in flora of the mouth, and poor oral hygiene. Although trismus might potentially impede oral hygiene access, implant failures were seen in patients without trismus in this study. These failures may have been the result of other confounding factors.

The implant survival rate (67%) was worse when the implants were placed in a previously irradiated mandible (67% versus 98%; $P = .005$). These results are in concordance with other studies.[14,15] The reduction in implant survival was likely related to the effects of radiation on bone. Radiation causes alteration in the blood vessel walls, provoking ischemia and decreasing extravascular cell vitality. Alterations in osteoblast and osteoclast activities inhibit the ability of bone to undergo reparative and remodeling processes.[16] Jacobsson and associates[17] demonstrated that there was a significant decrease in new bone formation around implants placed in irradiated bone.

The role of HBO therapy in irradiated patients receiving endosseous implants is still controversial. Eckert and colleagues[18] reported a 99% survival rate for 89 implants placed in the mandibles of 18 patients over a period of 12 years. These patients were irradiated with an average dose of 60 Gy without HBO. However, their report did not differentiate irradiated bone from irradiated tissue and or indicate whether the implants were placed in irradiated or nonirradiated bone. Franzen and coworkers[19] reported an implant success rate of 95% for 20 implants placed in 5 irradiated mandibles without HBO. These authors suggested that HBO was not required for every patient and should be used in a prudent manner.

Taylor and Worthington[20] reported an implant success rate of 100% for 21 implants placed in previously irradiated mandibles (5,950 to 6,500 cGy) of 4 patients after a 3- to 7-year follow-up. Three of the 4 patients were treated with HBO. Arcuri and associates[21] reported an implant success rate of 94% for 18 implants placed in mandibles irradiated with 5,580 to 6,480 cGy. All the patients were treated with HBO and followed for 1 to 5 years. In contrast to previous studies,[18,19] these studies supported the use of HBO when considering the placement of implants in an irradiated mandible.

With an HR of 19.79 (95% CI: 2.42–161.71), patients in the present investigation who received

HBO therapy had a significantly higher implant failure rate compared to those without therapy (33.3% versus 1.18%; $P = .005$). The observed results were most likely the result of the small sample size (15 implants) and selection bias; the patients selected for HBO were believed to be at a higher risk for osteoradionecrosis or implant loss. Of the 3 patients who received HBO therapy, 2 (C and F) had diagnoses of osteoradionecrosis and were treated with HBO without any improvement. Each patient subsequently underwent segmental mandible resection followed by immediate reconstruction. The only patient (U) who received HBO therapy for implant placement had 2 implant failures; both implants were lost within 1 month of placement. In view of the small number of patients in this group, it was not possible to suggest any relationship between HBO therapy and its benefit on implant osseointegration in an irradiated mandible. A systematic review of the literature on HBO has failed to find reliable clinical evidence to support the effectiveness of HBO therapy in irradiated patients requiring dental implants.[22] Hence, there is a need for randomized controlled clinical trials to determine the effectiveness of HBO in cases where implants are placed in irradiated mandibles.

There was a lower survival rate (96%) for implants with diameters ≤ 3.75 mm. All 6 of the implants that failed were ≤ 3.75 mm wide. Similar findings were reported by Winkler and Morris.[23] They found that implants ≥ 3 mm in diameter had a lower mean stability compared with implants ≥ 4 mm in diameter. Implants opposing natural dentition or restored fixed prosthesis had higher risk of implant failure compared to implants opposing removable prostheses. This could be related to the reduced occlusal loading found with removable prostheses.

No association was found between different types of implant beds or lengths and implant survival rate (Table 3). These responses are similar to observations made in other reports.[24,25] The lack of statistical significance may be related to the few patients with risk factors in the study, or it may be the result of a true lack of difference among the factors. There was no significant difference between the different implant surfaces (machined versus acid etched) or between different locations in the arch with respect to implant survival.

Regarding prosthesis type, implants supporting hybrid prostheses ($P = 0.024$) had a lower survival rate than overdentures or metal-ceramic prostheses (97.0% for overdentures versus 100% for other types; $P < .001$). The hybrid prosthesis was the recommended design in the early days of the modern era of implant dentistry (the 1980s). The late implant failures occurred in one patient (F) with a hybrid prosthesis. A study on implant mobility[26] using the Periotest method (Siemens, Bensheim, Germany) showed higher values for hybrid prostheses (3.69 ± 4.12) compared to O-ring–retained (0.53 ± 2.95) or bar-retained prostheses (1.62 ± 3.71). However, whether increased Periotest values will definitely lead to host site deterioriation is unclear, as there is the possibility of elastic adaptation of the bone.

Cadaveric studies[27,28] comparing thickness of various bone flaps have concluded that the fibula remains an excellent donor site for mandibular reconstruction. In the present study, all mandibular reconstructions were done using a fibula free-flap, resulting in an excellent flap survival rate.[29] The fibula is preferred because of its reliable anatomy, low morbidity, ability to maintain bone mass over time, and ability to mobilize the flap at the same time as the ablative procedure.

"Peri-implant" soft tissue proliferation is a common phenomenon for implants placed in a fibula free-flap. Implant abutments must traverse thick movable soft tissue beds before entering the oral cavity and are frequently plagued with soft tissue maintenance problems. Tissue movement, plaque accumulation, and ineffective oral hygiene efforts may affect peri-implant health and possibly long-term retention of the implant. In the present study, of the 13 patients who had soft tissue hyperplasia that needed debulking or skin grafting, only 1 patient (F) had implant failures. This could be the result of the "adaptive rebuilding" phenomenon proposed by Kovacs.[30] The author observed that the incidence of peri-implant inflammation and pocket depths reduced over time because of the "adaptive rebuilding" that took place in transplanted soft tissues.

CONCLUSIONS

The results of the present study demonstrate a high survival rate for implants placed in reconstructed mandibles. With proper case selection, osseointegrated implants can facilitate a successful prosthetic rehabilitation for these patients. HBO was found to be a risk factor for implant failure; however, the observed result was most probably the result of small sample size. There is a need for randomized control clinical trials to determine the effectiveness of HBO in this patient population.

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