Prosthetic Intervention in the Era of Microvascular Reconstruction of the Mandible—A Retrospective Analysis of Functional Outcome

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Purpose: The purpose of this retrospective study was to compare the functional outcomes of patients who had mandibular resection and reconstruction with and without prosthetic intervention, and to identify predictive factors that may have an impact on functional outcomes. **Materials and Methods:** Two hundred twenty head and neck cancer patients who had undergone mandibular resection and reconstruction with at least 6 months of postoperative convalescence formed the basis of this retrospective review. Patients who did not receive prosthetic intervention formed group I (n = 142); those who received prosthetic intervention formed group II (n = 78). Functional outcomes were measured using four individual assessments (nutritional status, swallowing, masticatory performance, and speech) and one that combined the information from these assessments, the global measure of functional outcome (GMFO). Statistical analyses were used to compare the baseline characteristics and functional outcome between groups I and II and to analyze independent predictors for GMFO. **Results:** Of the 220 patients reviewed, 78 (35%) had prosthetic intervention; group II patients had better individual functional outcome measures and GMFO. Use of a prosthesis remained associated with GMFO after controlling for other significant predictors; other independent predictors were xerostomia, number of remaining mandibular teeth, number of tooth-to-tooth contacts, type of reconstruction, flap interference, and tongue defect. Patients who had fewer mandibular teeth and received a smaller prosthesis had better overall outcome than patients who received a larger prosthesis. **Conclusion:** Patients who had prosthetic intervention after mandibular reconstruction had significantly better functional outcomes than patients who did not receive prosthetic intervention, even after adjusting for confounding variables. *Int J Prosthodont 2005;18:42–54.*

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The mandible differs from other bones of the body both anatomically and functionally. As it is closely related to many critical anatomic structures, surgical defects of the mandible often result in esthetic and functional impairments. Common causes of mandibular defects are tumor resections and, to a lesser degree, trauma and osteoradionecrosis. Prior to the era of microvascular reconstruction, prosthetic rehabilitation in these patients was reported to be less than optimal. Deviation of the residual mandibular segment toward the side of the defect results in an abnormal maxillomandibular relationship and limited masticatory function.[1] Removable dentures worn on the remaining mandibular segment have been reported as unstable and difficult and painful to wear.[2,3] Frictional movement of the denture on irradiated mucosa could lead to mucosal dehiscence and potentially predispose the patient to osteoradionecrosis.[4] Patients with mandibular defects are often referred to as the "forgotten patients" in maxillofacial prosthetics.[5]

The goals of mandibular reconstruction include restoration of the bony integrity of the mandible, soft tissue replacement, restoration of oral function with a dental prosthesis where possible, and establishment of vascular and sensory innervation. Dramatic improvement in microvascular surgical techniques has been reported, with success rates of more than 90%.[6,7] Initial studies on functional outcomes after mandibular reconstruction failed to document improved function.[8,9] Komisar[8] reports that reconstructed patients have poorer masticatory function and are less able to wear dentures compared to nonreconstructed patients. The methods of reconstruction used in that study were fraught with complications, which resulted in prolonged hospitalization, mandibular scarring, limited mandibular movement, and poorer functional and prosthetic outcomes. Other studies report improved function after mandibular reconstruction.[10–13] Patients with mandibular reconstruction have better masticatory performance compared to nonreconstructed patients.[14–16] However, when the residual dentition is intact, Patel et al[17] report no significant difference between groups.

The use of implant-supported prostheses in the reconstructed mandible has been reported to improve functional outcomes and quality of life for most patients.[18,19] However, in situations with massive soft tissue loss (ie, tongue resection and neural deficit), functional outcomes have been reported to be poor, even with the implant prosthesis.[20,21]

Although advances in microvascular surgery allow reconstruction of the mandible to presurgical anatomic norms with obvious esthetic enhancement, the restoration of function with a dental prosthesis remains unclear. The present retrospective study aimed to compare the functional outcomes of patients who had a mandibular resection and reconstruction with and without prosthetic intervention, and to identify predictive factors that may have an impact on the functional outcomes of these patients.

Materials and Methods

From April 1986 through December 2001, 260 consecutive patients underwent mandibular resection with immediate microvascular reconstruction, with and without prosthetic intervention, at Memorial Sloan-Kettering Cancer Center (MSKCC), New York. Study patients were identified from the operative logs and data extracted from the review of dental and medical records. Patients included in the study had to have at least 6 months of postoperative convalescence. Forty patients who had mandibular resections that involved the soft palate and maxilla were excluded from the study. Demographics, including age, sex, pathologic diagnosis, location of tumor, extent of bone and soft tissue defect, neural deficit, postsurgical dentition, and occlusion status, were recorded for each case. The remaining dentition in the maxilla and mandible was categorized as: 0 if it was edentulous; $\leqslant 8$ if there were 1 to 8 teeth per arch; and > 8 if there were 9 to 16 teeth remaining per arch. The number of tooth-to-tooth contacts was recorded after insertion of a prosthesis. For patients without prostheses, the number of tooth-to-tooth contacts was extrapolated from the remaining dentition using a panaromic radiograph. The paired tooth-to-tooth relationships were grouped as 0, $\leqslant 8$, and > 8 pairs of contacts.

The extent of bony and soft issue defects was described based on a modification of Urken et al's classification.[6] When a lateral mandibular defect extended beyond the midline, it was categorized as a combined defect. Length of bony defect was measured from the panoramic radiograph and adjusted for magnification. The tongue was divided into eight anatomic sites, six in the oral tongue and two in the base of tongue. Tongue defect was recorded as total number of sites resected. The vestibules of the mandibular arch were divided anatomically into six sites, two buccal, two labial, and two lingual. The number of sites obliterated after reconstructive surgery was also recorded. Flap interference was assessed clinically through intraoral examination of the interarch space when the mandible was relaxed in its resting vertical dimension. If there was an encroachment on the space for potential prosthetic replacement, flap interference was recorded as positive. Where there was a horizontal interarch discrepancy between the maxilla and reconstructed mandible, a malocclusion was recorded.

Details of the surgical procedure, including the type of microvascular flap used, radiation and chemotherapy treatments and their sequelae, type of prosthetic intervention, and duration of follow-up, were documented. Follow-up period was calculated from the date of reconstruction to the date of most recent examination at MSKCC. Access and Excel software programs (Microsoft) were used for tabulation of data.

Prosthetic Intervention

About 2 to 3 months after mandibular reconstruction and completion of all cancer treatments, patients suitable for prosthetic intervention were restored with a removable acrylic resin interim prosthesis. This was followed about 6 months to 1 year later by a definitive

Fig 1a Hybrid prosthesis supported by four implants in fibula free flap–reconstructed mandible.

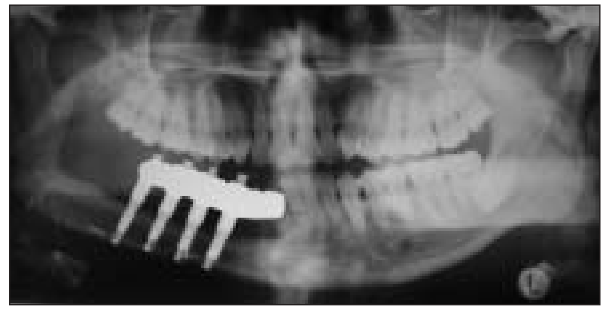

Fig 1b Panoramic radiograph with prosthesis in place.

Fig 2a *(right)* Postoperative view following tongue-mandible resection and reconstruction of mandible.

Fig 2b *(below)* Intraoral view of metal-based removable prosthesis retained by two posterior abutments.

Fig 2c *(below right)* “Small” prosthesis replaces several missing teeth.

prosthesis, which could be a metal-based removable or implant-supported prosthesis depending on the indications. Patients who had favorable tumor prognosis without coexisting systemic disease, good oral hygiene, sufficient bone quality and quantity, and residual tongue function and mouth opening were indicated for implant prostheses. Of the 78 patients who had prosthetic intervention, 25 had implant-supported prostheses (8 overdentures, 11 hybrid prostheses [Fig 1], and 6 metal-ceramic prostheses), and 53 had removable prostheses (Figs 2 and 3).

For the purpose of comparison, patients were divided into two groups based on the presence or absence of prosthetic intervention. Group I consisted of 142 patients who did not receive prosthetic intervention, whereas group II consisted of 78 patients who had been restored with a mandibular prosthesis.

Functional Assessment

The reported postoperative function of both patient groups was retrospectively retrieved from the clinicians’ subjective assessment and patients’ feedback to their clinicians. Functional outcome assessments, which included swallowing, speech, masticatory performance, and nutritional status, were available for 210 patients. As

Fig 3a *(left)* Intraoral view of reconstruction of right mandible.

Fig 3b *(below left)* Metal-based removable prosthesis in place.

Fig 3c *(below)* "Large" prosthesis replaces many missing teeth.

for the nutritional status, the patients were reported as having oral or tube feeding. Swallowing was categorized as either dysphagic or normal. Speech was determined and reported for each patient based on the ability to converse and be understood by the clinicians. A patient was classified as intelligible if the speech was easily understood, acceptable if there was slight difficulty, and unintelligible if the clinician had difficulty in understanding the conversation. The masticatory performance was recorded based on diets reported by the patients and clinicians in their records. The performance criteria were adapted from List's Performance Status Scale for Head and Neck Cancer Patients.[22]

The preliminary analysis showed that individual assessment of the components of functional outcome was difficult to interpret; hence, a global measure of functional outcome (GMFO) that integrated the four components of assessments was introduced. Speech, swallowing, nutritional status, and masticatory performance were grouped and ranked into three general grades ranging from good oral function to severe dysfunction:

- Grade I: Patient with unrestricted diet, normal swallowing, and intelligible speech
- Grade II: Patient eating soft, chewable foods or on liquid and pureed diet, with normal swallowing and acceptable or intelligible speech
- Grade III: Patient dependent on a percutaneous endoscopic gastrostomy (PEG) tube for feeding, dysphagic, with unintelligible, acceptable, or intelligible speech

Statistical Methods

Variables collected summarized demographic information, surgical characteristics, and information on reconstruction and dentition, as well as whether a patient received and wore a prosthesis and functional outcome. The baseline characteristics and functional outcomes were compared between group I and II patients (Tables 1 to 3). All variables were analyzed univariately with GMFO. Statistical significance was defined as a two-tailed P value $\leqslant$ .050, with no adjustment made for multiple evaluations. Any variable found to be significantly associated with overall function at the 5% significance level (or deemed clinically important) was placed in a multivariate logistic regression model. The multivariate model, derived using stepwise procedures, was used to assess whether a prosthesis and any of the other variables included in the model could be considered independent predictors of outcome. Variables significant at the 10% level were retained in the final model. All statistical analyses were performed using SAS 8.0 for Windows (SAS Institute).

Table 1 Demographics of Study Groups*

Baseline characteristic	Group I, no prosthesis (n = 142)	Group II, prosthesis (n = 78)	*P* value
Age†			
1–30 y	7 (4.9)	13 (16.7)	.010
31–60 y	88 (62.0)	40 (51.3)	
61–90 y	47 (33.1)	25 (32.0)	
Mean (y)‡	53.2	48.2	.050
Gender§			
Female	54 (38.0)	28 (35.9)	.760
Male	88 (62.0)	50 (64.1)	
Diagnosis§			
Malignant	128 (90.1)	65 (83.3)	.140
Benign	14 (9.1)	13 (16.7)	
Tumor site§			
Mandible	64 (45.1)	45 (57.7)	.080
Tongue/floor of mouth	47 (33.0)	25 (32.0)	
Retromolar triangle	20 (14.1)	7 (9.0)	
Other	11 (7.8)	1 (1.3)	
Radiation therapy§			
None	49 (34.5)	32 (41.0)	.290
Preoperative	23 (16.2)	7 (9.0)	
Postoperative	70 (49.3)	39 (50.0)	
Mean dose (cGy)	61,195.1	6,306.3	
Xerostomia§			
No	49 (34.5)	32 (41.0)	.340
Yes	93 (65.5)	46 (59.0)	
Type of chemotherapy§			
None	116 (81.7)	68 (87.2)	
Adjuvant	10 (7.1)	5 (6.4)	
Neoadjuvant	7 (6.3)	5 (6.4)	
Concomitant	9 (4.9)	0 (0.0)	

*No. (%).
†Cochran-Mantel-Haenszel mean score test.
‡Student's *t* test.
§Cochran-Mantel test for general association.

Results

Demographic, Oncologic, and Surgical Patient Characteristics

The median follow-up of the study population (N = 220) was 28 months (range 6 to 190 months). The mean age for group I patients was significantly higher compared to group II patients (53.2 vs 48.2 years, $P <$ .050; Table 1). The number of patients in group I was nearly twice that in group II. The ratio of male to female patients was 1.7:1.0.

Indications for mandibular resection were squamous cell carcinoma (144), osteoradionecrosis (10), ameloblastoma (7), sarcoma (30), other carcinoma (18), and benign tumor (11). Both groups had similar distribution of marginal and segmental resections. For the 192 patients who had segmental resection with immediate reconstruction, the types of microvascular free flaps used were: fibula (166), radius (8), scapula (3), iliac crest (2), rectus abdominis (12), and latissimus dorsi (1). Comparing groups I and II, there were more patients in group I with larger soft tissue defects who required soft tissue reconstruction (8.5% vs 1.0%).

Thirty-seven percent (81 of 220) of the study population did not have any type of radiation therapy. This high percentage of nonadjuvant therapy was due to patients diagnosed with benign tumors, ameloblastomas, and sarcomas, in which surgical intervention and chemotherapy were the standard treatment modalities.

In terms of postsurgical dentition, 36 patients were completely edentulous. The proportion of patients with $>$ 8 teeth in the mandible was higher in group I than in group II (33.8% vs 20.5%). However, the proportion of patients with $\leqslant$ 8 teeth in the mandible was higher ($P =$ .010) in group II (59.0% vs 38.7%). The proportion of patients with $>$ 8 pairs of contacts in group II was twice that in group I (65.4% vs 31.7%). Comparing the surgical outcomes of both groups, patients in group I had more flap interferences (37.3% vs 16.7%), obliterated vestibules (52.8% vs 30.8%), and trismus (40.1% vs 25.6%).

Table 2 Surgical Characteristics, Reconstruction, and Dentition of Study Groups*

Baseline characteristic	Group I, no prosthesis (n = 142)	Group II, prosthesis (n = 78)	*P* value
Mandibular reconstruction†			
Marginal	16 (11.3)	12 (15.4)	.380
Segmental	126 (88.7)	66 (84.6)	
No. of maxillary teeth remaining‡			
0	28 (19.7)	13 (16.7)	.830
≤ 8	8 (5.6)	4 (5.0)	
> 8	106 (74.6)	61 (78.2)	
No. of mandibular teeth remaining‡			
0	39 (27.5)	16 (20.5)	.010
≤ 8	55 (38.7)	46 (59.0)	
> 8	48 (33.8)	16 (20.5)	
No. of tooth-to-tooth contacts‡			
0	41 (28.9)	1 (1.3)	< .001
≤ 8 pairs	56 (39.4)	26 (33.3)	
> 8 pairs	45 (31.7)	51 (65.4)	
Mandibular defect†			
Anterior jaw	31 (21.8)	15 (19.2)	.280
Lateral jaw	50 (35.2)	22 (28.2)	
Combined	23 (16.2)	9 (11.5)	
Hemimandibular	22 (15.5)	20 (25.6)	
Marginal	16 (11.3)	12 (15.4)	
Length of bony defect†			
< 8 cm	48 (44.9)	26 (40.6)	.590
≥ 8 cm	59 (55.1)	38 (59.4)	
Mean (cm)	8.7	9.1	
Reconstruction type†			
Bony	114 (80.3)	65 (83.3)	.080
Soft tissue	12 (8.5)	1 (1.3)	
None (marginal)	16 (11.2)	12 (15.4)	
Malocclusion†			
No	127 (89.4)	64 (82.0)	.120
Yes	15 (10.6)	14 (18.0)	
Flap interference†			
No	89 (62.7)	65 (83.3)	.001
Yes	53 (37.3)	13 (16.7)	
Tongue defect‡			
No sites removed	91 (64.1)	54 (69.2)	.530
1–4 sites removed	46 (32.3)	23 (29.5)	
5–8 sites removed	5 (3.5)	1 (1.3)	
Obliterated vestibule‡			
No sites obliterated	23 (16.2)	32 (41.0)	< .001
1–2 sites obliterated	44 (31.0)	22 (28.2)	
3–6 sites obliterated	75 (52.8)	24 (30.8)	
Neural deficit†			
Sensory	83 (58.5)	43 (55.1)	.170
Motor	7 (4.9)	4 (5.1)	
Both	18 (12.7)	4 (5.1)	
None	34 (23.9)	27 (34.6)	
Lip competence†			
No	28 (19.7)	14 (17.9)	.750
Yes	114 (80.3)	64 (82.1)	
Trismus†			
No	85 (59.9)	58 (74.4)	.030
Yes	57 (40.1)	20 (25.6)	
Tongue immobility†			
No	109 (76.8)	68 (87.2)	.060
Yes	33 (23.2)	10 (12.8)	

*No. (%).
†Cochran-Mantel test for general association.
‡Cochran-Mantel-Haenszel mean score test.

Table 3 Comparison of Outcomes Between Groups I and II (N = 210)*

Outcome assessment	Group I, no prosthesis (n = 132)	Group II, prosthesis (n = 78)	*P* value
Nutritional status†			
Per oral	110 (83.3)	75 (96.2)	.006
Tube fed	22 (16.7)	3 (3.8)	
Swallowing†			
Dysphagic	23 (17.4)	3 (3.8)	.004
Normal	109 (82.6)	75 (96.2)	
Masticatory performance‡			
Unrestricted diet	48 (36.4)	53 (68.0)	< .001
Soft, chewable foods	30 (22.7)	14 (17.9)	
Pureed/liquid diet	32 (24.2)	8 (10.3)	
Tube dependent	22 (16.7)	3 (3.8)	
Speech‡			
Intelligible	103 (78.0)	74 (94.9)	.004
Acceptable	22 (16.7)	4 (5.1)	
Unintelligible	7 (5.3)	0 (0.0)	
Overall function (GMFO)†			
Grade I	48 (36.4)	53 (67.9)	< .001
Grade II	63 (47.7)	23 (29.5)	
Grade III	21 (15.9)	2 (2.6)	

*No. (%).
†Cochran-Mantel test for general association.
‡Cochran-Mantel-Haenszel mean score test.
GMFO = global measure of functional outcome.

Functional Outcome

Sixty-eight percent (53 of 78) of the prosthetically restored patients were able to return to per-oral full diets without restriction, and 28% of patients were limited to per-oral soft and liquid diets. Three patients were dependent on PEG tube feeding. Overall, patients with prosthetic intervention (group II) had better swallowing, speech, nutritional status, masticatory performance, and GMFO scores compared to group I patients (Table 3).

Statistical Results

In the univariate analysis, age, tumor site, radiation therapy, xerostomia, number of maxillary and mandibular teeth remaining, number of tooth-to-tooth contacts, type of mandibular defect, type of reconstruction, malocclusion, amount of tongue defect, obliterated vestibule, neural deficit, tongue immobility, trismus, and xerostomia were associated with GMFO (Table 4).

In the multivariate analysis, the odds ratio for the number of tooth-to-tooth contacts (postprosthesis) suggested that having 0 or ≤ 8 teeth in contact increased a patient's odds of having a good overall outcome. This seemingly counterintuitive observation was most likely due to the confounding effects of a prosthesis and the number of mandibular teeth remaining.

Further analysis using cross-tabulation (Table 5) showed that, among patients who received a prosthesis, those who started out with ≤ 8 mandibular teeth and ended up with ≤ 8 pairs of teeth in contact (a small prosthesis; mean overall score of 2.04) did better in terms of overall outcome compared to patients who started out with ≤ 8 mandibular teeth but ended up with > 8 pairs of teeth in contact (a larger prosthesis; mean overall score of 2.61). Thus, patients with fewer mandibular teeth remaining after surgery and a larger prosthesis (long occlusal table; Fig 3c) had a poorer outcome than those with a smaller prosthesis (short occlusal table; Fig 2c). However, patients who started out with ≤ 8 mandibular teeth and ended up with > 8 pairs of teeth in contact (a larger prosthesis; mean overall score of 2.60) still compared favorably with those patients who started out with ≤ 8 mandibular teeth and did not receive any prosthesis (mean overall score of 3.01). Other variables considered independent predictors of overall function were xerostomia, number of mandibular teeth remaining, type of reconstruction, flap interference, and tongue defect (Table 6).

Discussion

It is important to acknowledge certain inherent deficiencies of this study. As this is a retrospective study, it is limited by the availability and contents of the medical records. The reported assessments of functional outcomes were subjectively determined through patients' feedback and clinicians' assessments. Patients' responses to questions asked by the clinicians may be weighted more in favor of the clinicians' expectations.

Table 4 Results of Univariate Analyses with Global Measure of Functional Outcome (GMFO; N = 210)*

Outcome assessment	GMFO Grade I (n = 101)	GMFO Grade II (n = 86)	GMFO Grade III (n = 23)	*P* value
Age†				
1–30 y	17 (16.8)	2 (2.3)	1 (4.3)	.010
31–60 y	55 (54.5)	56 (65.1)	12 (52.2)	
61–90 y	29 (28.7)	28 (32.6)	10 (43.5)	
Tumor site‡				
Mandible	67 (66.3)	30 (34.9)	7 (30.4)	< .001
Tongue/floor of mouth	18 (17.8)	39 (45.3)	12 (52.2)	
Retromolar triangle	11 (10.9)	12 (14.0)	2 (8.7)	
Other	5 (5.0)	5 (5.8)	2 (8.7)	
Radiation therapy‡				
None	54 (53.5)	18 (20.9)	3 (13.0)	< .001
Preoperative	12 (11.9)	11 (12.8)	6 (26.2)	
Postoperative	35 (34.6)	57 (66.3)	14 (60.9)	
Xerostomia‡				
No	54 (53.5)	18 (20.9)	3 (13.0)	< .001
Yes	47 (46.5)	68 (79.1)	20 (87.0)	
No. of maxillary teeth remaining§				
0	2 (2.0)	28 (32.6)	9 (39.1)	< .001
≤ 8	6 (5.9)	3 (3.5)	1 (4.3)	
> 8	93 (92.1)	55 (64.0)	13 (56.5)	
No. of mandibular teeth remaining§				
0	6 (5.9)	38 (44.2)	8 (34.8)	< .001
≤ 8	51 (50.5)	35 (40.7)	11 (47.8)	
> 8	44 (43.6)	13 (15.1)	4 (17.4)	
No. of tooth-to-tooth contacts§				
0	0 (0.0)	30 (34.9)	9 (39.1)	< .001
≤ 8 pairs	45 (44.6)	25 (29.1)	8 (34.8)	
> 8 pairs	56 (55.4)	31 (36.0)	6 (26.1)	
Mandibular defect‡				
Anterior jaw	10 (9.9)	26 (30.2)	7 (30.4)	.004
Lateral jaw	41 (40.6)	24 (27.9)	4 (17.4)	
Combined	11 (10.9)	16 (18.6)	4 (17.4)	
Hemimandibular	24 (23.8)	9 (10.5)	6 (26.1)	
Marginal	15 (14.9)	11 (12.8)	2 (8.7)	
Reconstruction type‡				
Bony	84 (97.7)	70 (93.3)	16 (76.2)	.004
Soft tissue	2 (2.3)	5 (6.7)	5 (13.8)	
Malocclusion‡				
No	83 (82.2)	75 (87.2)	23 (100.0)	.030
Yes	18 (17.8)	11 (12.8)	0 (0.0)	
Flap interference‡				
No	65 (64.4)	62 (72.1)	20 (87.0)	.030
Yes	36 (35.6)	24 (27.9)	3 (13.0)	
Tongue defect‡				
No sites removed	85 (84.2)	47 (54.7)	7 (30.4)	< .001
1–4 sites removed	16 (15.8)	38 (44.2)	11 (47.8)	
5–8 sites removed	0 (0.0)	1 (1.1)	5 (21.7)	
Obliterated vestibule‡				
No sites obliterated	34 (33.7)	17 (19.8)	2 (8.7)	< .001
1–2 sites obliterated	38 (37.6)	17 (19.8)	7 (30.4)	
3–6 sites obliterated	29 (28.7)	52 (60.4)	14 (60.9)	
Neural deficit‡				
Sensory	58 (57.4)	51 (59.3)	11 (47.8)	.001
Motor	3 (3.0)	4 (4.7)	3 (13.0)	
Both	5 (5.0)	10 (11.6)	6 (26.1)	
None	35 (34.6)	21 (24.4)	3 (13.9)	
Trismus‡				
No	73 (72.3)	53 (61.6)	9 (39.1)	.003
Yes	28 (27.7)	33 (38.4)	14 (60.9)	
Tongue immobility‡				
No	94 (93.1)	61 (70.9)	14 (60.9)	< .001
Yes	7 (6.9)	25 (29.1)	9 (39.1)	

*No. (%).
†Pearson's test for correlation.
‡Cochran-Mantel test for general association.
§Cochran-Mantel-Haenszel mean score test.

Table 5 Summary of Pairwise Comparisons of Overall Outcome Scores*

No. of tooth-to-tooth contacts (postprosthesis)	No. of mandibular teeth remaining ≤ 8	No. of mandibular teeth remaining > 8
≤ 8 pairs		
Prosthesis	2.04 (26)	2.00 (1)
No prosthesis	3.01 (87)	2.00 (2)
> 8 pairs		
Prosthesis	2.61 (36)	2.27 (15)
No prosthesis	–	2.49 (43)

*Mean (no.).

Table 6 Results of Multivariate Analyses with Global Measure of Functional Outcome

Variables in model	Wald χ^2	*P* value	Odds ratio (95% confidence interval)
Prosthesis	23.8	< .001	
No vs yes			0.06 (0.02–0.19)
Xerostomia	11.8	.001	
No vs yes			3.62 (1.74–7.55)
No. of mandibular teeth remaining	20.4	< .001	
0 vs > 8			0.05 (0.01–0.24)
≤ 8 vs > 8			0.05 (0.01–0.19)
No. of tooth-to-tooth contacts	13.7	.001	
0 vs > 8 pairs			1.93 (0.42–8.90)
≤ 8 vs > 8 pairs			9.05 (2.68–30.55)
Reconstruction type	5.9	.050	
Bony vs marginal			0.77 (0.30–1.99)
Soft tissue vs marginal			0.17 (0.04–0.78)
Flap interference	6.0	.010	
No vs yes			0.41 (0.20–0.84)
Tongue defect	17.7	< .001	
0 vs > 0 sites			4.73 (2.29–9.76)

The reliability and validity of the data collected, biases and confounding factors, and lack of controls contribute to the shortcomings in this study.

Despite these limitations, this study has a reasonable sample size compared to other functional outcome studies[23,24] on oral cancer patients. Small sample size may compromise the ability of a study to detect real changes that occur over time or between subgroups of interest. Our study is a single institutional report where there is a uniform management policy in terms of surgical resection, reconstruction, and prosthetic rehabilitation. In that respect, variables pertaining to management policy are minimized. The median follow-up of 28 months was a reasonable duration for functional outcome assessments following prosthetic rehabilitation.

Group I and II patients were comparable in most characteristics, except for age, number of mandibular teeth remaining, number of tooth-to-tooth contacts, flap interference, obliterated vestibules, and trismus. The differences in these variables more than likely precluded patients in group I from receiving a prosthesis and accounted for the better functional outcomes observed in group II patients.

The number of patients aged 1 to 30 years in group II was twice that in group I. Thirteen patients in group II had diagnoses of bone tumors (ameloblastoma, osteogenic sarcoma, and Ewing's sarcoma) that are more prevalent in the younger age group (1 to 30 years). These patients had minimal soft tissue defects and thus a better prosthetic prognosis. Seven of these 13 patients who had fibula free-flap reconstructions were subsequently restored with osseointegrated implant prostheses with good functional outcomes.

The difference between groups in number of mandibular teeth remaining could be explained by the location of the mandibular resection. Group I patients had more distal resections that included the ramus and condyle, whereas group II patients had more resections that involved the tooth-supporting segments. The proportion of patients in group II with > 8 pairs of tooth-to-tooth contacts was twice that in group I (65.4% vs 31.7%). Such a discrepancy can be accounted for by tooth contacts contributed by the prosthesis.

Our prosthetic intervention rate of 35% is relatively high compared to most studies.[9,11,25] Boyd et al[25] report that only 8 of 38 patients (21.1%) reconstructed with AO plate and radial forearm free flaps were able to receive a prosthesis. They had a reconstruction failure rate of 35% for the anterior mandible and 5% for the lateral mandible. Infection, extrusion, and plate fractures made prosthetic rehabilitation difficult and sometimes impossible. The introduction of fibula osteocutaneous free flaps has revolutionized mandibular reconstruction at MSKCC and has been considered a gold standard. In the present study, fibula free flaps were used in 86.5% of the mandibular reconstructions. High flap success rate[7] and predictable implant osseointegration in the reconstructed mandible allowed restoration of more patients with prostheses.[26–28]

Prosthetic intervention remained associated with overall function (GMFO) after controlling for other significant predictors in a multivariate setting. With an odds ratio of 0.06 (95% confidence interval [CI] 0.02 to 0.19), a patient without a prosthesis was less likely to experience a better overall outcome than a patient who had received a prosthesis (Table 6). A similar result was reported in a pilot study on the masticatory performance of five hemimandibulectomy patients.[16] Patients who received a prosthesis had improved masticatory performance scores. However, it is difficult to make inferences from that study because of its small sample size.

The number of teeth remaining in the mandible remained an independent variable for overall outcome. Patients with fewer teeth remaining had a poorer overall outcome compared to those with more teeth remaining. In situations with sufficient functional remaining dentition for mastication on the nondefect side, prosthetic intervention was not necessary. Seventy-five percent (48 of 64) of patients with > 8 teeth remaining in the mandible did not require any prosthetic intervention. Studies on normal geriatric populations have shown that a shortened dental arch comprising the anterior and premolar regions could satisfy most of the functional demands of these patients.[29–31] In addition, patients with mandibular reconstruction favor chewing on the nonreconstructed site, even with a prosthesis present.[32] Proprioceptive influence of the remaining dentition greatly facilitates occlusal intercuspation and enhances mastication.[33]

The results of the cross-tabulation showed that for patients with few mandibular teeth remaining after surgery, a smaller prosthesis may be better than a larger prosthesis, and for patients who did not receive prostheses, the number of remaining teeth and contacts had a direct impact on the overall outcome. The former observation was confined mainly to patients who received tooth-retained removable prostheses; those with implant-supported prostheses had good overall outcomes. Of the 25 patients who had implant-supported prostheses, 23 had a Grade I GMFO score, and 2 had a Grade II GMFO score.

The extent of tongue resection is well-known to be a major contributor to postoperative functional impairment.[34–36] This was confirmed in our study. With an odds ratio of 4.73 (95% CI 2.29 to 9.76), patients with tongue resection were 4.7 times worse off in terms of overall outcome. Several groups report that tongue resection is the most important predictor of functional outcome after oral and orapharyngeal resection.[34–36] However, none of those studies included significant numbers of patients with mandibular reconstruction or critically examined functional outcome with respect to potentially predictive baseline and surgical patient variables. A prospective study of 21 patients who underwent free tissue transfer of oromandibular defects found that tongue resection is a primary determinant of functional outcome.[37] That study, however, did not assess the impact of dental rehabilitation on functional outcomes.

Loss of tongue function and volume affects the patient's ability to discriminate food particle location and size. This creates inefficiencies in the manipulation and consolidation of the food bolus, resulting in impairment of the oral and pharyngeal phases of swallowing. In such a situation, even a stable prosthesis will not benefit the patient.[20,21]

Patients with xerostomia often had associated dysphagia and poorer nutritional status and dietary intake. The effects of xerostomia on perception and performance of swallowing function were studied by Logemann et al.[38] In their study of 36 patients who underwent chemoradiation without surgical intervention, the severity of xerostomia was measured in terms of saliva weight. Their results showed no significant relationships between the saliva weight of patients with and without complaints of swallowing problems. Logemann et al[38] attribute this to the small sample size. In contrast, other studies[39,40] demonstrate significant functional impairments in patients in the posttreatment group. In our study, only nine patients had chemoradiation. Although all of them were reported to have xerostomia, six were able to feed orally, and three were tube fed because of dysphagia.

Encroachment on interarch space by a bulky flap from reconstruction may preclude the possibility of fabricating a prosthesis. Although the possibility of functioning with a prosthesis was increased in patients without flap interference, other confounding factors might have dampened the effects of the prosthesis for better overall outcome.

Normal vestibular anatomy is necessary for extension of the prosthetic flanges (labial, buccal, and lingual) for support, stability, and retention. Our study did not measure the extension of flanges in primary support areas, as this was difficult to quantify. Most of the flanges were short and molded to the anatomic shape of the surgically modified vestibules. Loss of vestibules following surgical resection and reconstruction will dramatically affect the prognosis of a tissue-supported removable prosthesis.[41] Without vestibules, patients are not able to retain the prosthesis, especially in a situation with neural deficit and soft tissue defects. Osseointegrated implants can contribute to prosthetic rehabilitation in situations where vestibules are obliterated and conventional or modified removable prostheses cannot be used.

Patients with marginal and segmental resections were included in this study. Although these are significantly different defects that may affect the functional outcomes, our results suggested otherwise (Table 6). There was no difference in overall outcome between patients with bony reconstruction and marginal resection. In addition, the percentage of marginal resection patients was evenly represented in groups I and II (11.3% vs 15.4%).

With an odds ratio of 0.17 (95% CI 0.04 to 0.78), patients with soft tissue reconstruction were less likely to experience a better overall outcome than patients with marginal resection. Our results are in accordance with others.[42,43] McConnel et al[42] studied the impact of flap reconstruction on functional results of speech and swallowing in a multi-institutional setting. Patients with primary closure had a significantly higher swallowing efficiency compared to those with soft tissue free-flap reconstruction. That study included patients from different institutions; thus, the potential for differences in ablative surgical and reconstruction techniques exists. Schliephake and Jamil[43] report similar results in their prospective study on the impact of intraoral soft tissue reconstruction on quality of life in 53 patients. In patients with large-volume soft tissue defects reconstructed with vascularized flaps, quality of life was not restored to the presurgical stage, and physical, functional, and social domains remained significantly lower. The shortcoming of that study is that it only evaluated quality of life in patients with soft tissue reconstruction.

The impact of prosthetic intervention on functional outcomes in this group of patients is difficult to isolate. Although prosthetic rehabilitation appears as an independent predictor on multivariate analysis, this does not eliminate the effect of bias. There was definitely a selection bias in which patients with better anatomic outcome following ablative surgery and reconstruction were selected for prosthetic intervention. The selection bias was also demonstrated by the significant differences between the groups in terms of age, number of mandibular teeth remaining, number of tooth-to-tooth contacts, trismus, flap interference, and obliterated vestibules. Other contributing factors for patients not receiving prosthetic intervention included geographic location of patients after discharge, recurrence and/or metastatic disease or other comorbidities, and patient disinterest.

To better determine if prosthetic intervention makes a difference, the two groups should be specifically matched for defects and reconstructions, with the only variable being with or without prosthesis. In addition, all patients' functional outcomes should be assessed before and after dental intervention to isolate the influence of prosthetic intervention on outcome. This can only be accomplished in a prospective manner using validated objective measurements. The valuable information obtained from this retrospective study should be used as a baseline for a future prospective study on functional outcomes of mandibular reconstructed patients.

At MSKCC, the Dental Service participates in a multidisciplinary fashion with the surgeons from both the Head and Neck Service and Plastic and Reconstructive Service. All patients are referred prior to surgery for consultation, dental impressions, and radiograph evaluation. If the patient is dentate in the unresected portion of the mandible and has maxillary opposing teeth, the Dental Service attendings intervene in the operating room after the mandible segment is removed to align the maxillomandibular occlusion in temporary elastic fixation via Eric arch bars and/or IV loops. This is done prior to connecting the microvascular portion of the donor site (neomandible) to the recipient site. We believe this alignment prevents malocclusion and helps the plastic surgical team in determining the position of the osteotomies for placement of miniplates, and in establishing optimal cosmetic and symmetric facial line angles.

Regardless of the dental specialist intervening (ie, maxillofacial prosthodontist or oral and maxillofacial surgeon), establishment of the dentist's role in the overall treatment—management and rehabilitation of the head and neck patient—is an important aspect for allowing the patient to determine if he or she is a candidate for maximum prosthetic rehabilitation. Patients undergoing ablative and reconstructive head and neck procedures are told the risks, benefits, and alternatives to prosthetic rehabilitation prior to surgery, with the attending clinician most often stating the reality of timing of placement of a prosthesis and projection of realistic expectations. Many patients and their families are not familiar with the limitations of a dental prosthesis and have unrealistic expectations of both cosmetic and functional outcomes. The importance of a team approach for these patients' physical and psychologic needs must be anticipated. Anatomic limitations and clinician expectations are discussed both pre- and postsurgery. In the immediate recovery period, the dental attendings frequently come in contact with these patients and their families; observation of the oral cavity by the dental team often establishes maximum oral hygiene (especially during and after radiation therapy) and allows the clinician to predict whether a prosthesis could maximize oral function.

This retrospective analysis demonstrated that not all patients were candidates for prosthetic intervention. The dentists or prosthodontists cannot and are not expected to control the nutritional status, swallowing, and speech in this population, in addition to the demographics, surgical characteristics, reconstruction, and remaining dentition. The proposed GMFO is an amalgamated assessment of patient functional status following mandibular resection and reconstruction. It is a practical outcome measure instrument that could be easily used by the multidisciplinary members of the surgical and dental specialties. However, it should be subjected to subsequent field testing for reliability, validity, and response to change prior to implementation. Restoring mastication is usually expected to be a contribution solely performed by dentists. Understandably, a Grade I GMFO rating in this population should be the gold standard for which the head and neck cancer team strives.

Conclusion

Considering the ethical and organizational difficulties in designing a prospective trial evaluating functional outcomes of prosthetic intervention after mandibular resection and reconstruction, our study highlights several important issues. Patients who had prosthetic intervention after mandibular reconstruction (group II) had significantly better functional outcome compared to patients who did not have prosthetic intervention (group I), even after adjusting for confounding variables. Overall, prosthetic intervention is beneficial; however, for patients with few mandibular teeth remaining after surgery, a smaller prosthesis with a short occlusal table could be more beneficial than a larger prosthesis with a long occlusal table. Prosthesis, amount of tongue defect, xerostomia, flap interference, number of mandibular teeth remaining, number of tooth-to-tooth contacts, and reconstruction type were independent predictors of GMFO for these patients.

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Literature Abstract

Prevalence of cusp fracture in teeth restored with amalgam and with resin-based composite

This cross-sectional study of a single private practice evaluated the prevalence of cusp fracture in teeth restored with amalgams and resin-based composites. A total of 10,869 posterior restored teeth (10,082 amalgams and 787 resin-based composite) were examined in 1,902 adult patients seen consecutively in this practice. Patient age, type of restoration, number of restored surfaces, presence of cuspal fracture and caries under fracture were recorded. χ^2 tests with Yates correction were used to evaluate statistical significance among categories. A higher percentage of cusp fracture was found in older (55–96 years) compared to younger (18–54 years) patients for both types of restorations ($P < .001$). Overall, no significant difference in percentage cusp fracture was found between the two restoration types. A marginally significant greater percentage of cusp fracture was found in teeth restored with resin-based composites compared to amalgams for the older patients only ($P = .05$). Cusp fracture was found to be higher in teeth with multisurface restorations compared to single-surface amalgam restorations in the younger group ($P < .001$). Use of a logistic regression model to control for the independent variables in this nonrandom sampling would have been more appropriate. Other limitations include a lack of data collection on the age of the restoration and type of posterior tooth, as well as skewed sampling (12 times more amalgam than resin-based composite restorations).

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