A Review of Functional Outcomes Related to Prosthetic Treatment After Maxillary and Mandibular Reconstruction in Patients with Head and Neck Cancer

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Purpose: This review examined literature that reported functional outcomes across 3 categories of prosthetic treatment after microvascular reconstruction of the maxilla and mandible: (1) conventional dental/tissue-supported prosthesis, (2) implant-retained prosthesis, and (3) no prosthesis. Materials and Methods: Library databases were searched for articles related to reconstruction of the maxilla and mandible, and references of selected articles were hand searched. Relevant literature was identified and reviewed with criteria specified a priori. *Results:* Forty-nine articles met the inclusion criteria. Twelve articles reported on function after maxillary reconstruction, with the majority of articles reporting on outcomes for 1 to 6 subjects. Thirty-nine articles reported on function after mandibular reconstruction. Speech outcomes were satisfactory across all groups. Swallowing reports indicated that many patients who received either type of prosthetic rehabilitation resumed a normal diet, whereas those without prosthetic rehabilitation were often restricted to liquid diets or feeding tubes. Patients without prosthetic rehabilitation reportedly had poor masticatory ability, whereas conventional prosthetic treatment allowed some recovery of mastication and implant-retained prosthetic treatment resulted in the most favorable masticatory outcomes. Quality-of-life outcomes were similar across all patients. Conclusions: Several limitations of the current literature prevented definitive conclusions from being reached within this review, especially regarding maxillary reconstruction. However, recognition of these limitations can direct functional assessment for the future. Int J Prosthodont 2008;21:337-354.

Microvascular free flap tissue transfer has become a common treatment strategy for reconstruction of maxillary and mandibular defects, revolutionizing the outcomes of surgically based oncological intervention. There is evidence that microvascular reconstruction achieves positive results, especially when considering

the potential for reestablishment of the form of the mandible and maxilla after surgical resection. Clinically, the perception may be that microvascular reconstruction is also successful in reestablishing function related to the osseous structures of the oral cavity, especially when followed by prosthetic rehabilitation for absent dentition. However, it remains unclear whether this viewpoint is supported by the collective outcomes in the literature. To address the issue of functional gain, the objective of the present review was to examine the literature related to functional outcomes after microvascular reconstruction of the osseous structures of the oral cavity and to assess the impact of such treatment on speech, swallowing, mastication, and quality of life in patients with maxillary and mandibular defects resulting from head and neck cancer. Specifically, the review attempted to delineate outcomes as they related to 3 categories of prosthetic treatment after reconstruction of the maxilla and mandible. The 3 categories were as follows: (1) conventional dental/tissuesupported prosthesis, (2) implant-retained prosthesis, and (3) no prosthesis.

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Materials and Methods

A literature search for research articles related to reconstruction of the maxilla/mandible was conducted using several databases including: MEDLINE, EMBASE, EBMR (Evidence-Based Medicine Reviews, including *Cochrane Database of Systematic Reviews, ACP Journal Club*, and *Database of Abstracts of Reviews of Effects*), and CINAHL (Cumulative Index to Nursing and Allied Health). Keyword terms that were searched included: maxilla, mandible, reconstru*, speech, chew*, swallow*, masticat*, deglutiti*, and quality of life. Terms were limited to studies that were based on human subjects, written in the English language, and published between 1990 and 2006. In addition, the reference lists in potentially relevant articles were reviewed to hand search for other articles that might meet the inclusion criteria.

Inclusion Criteria

To be included, studies were required to be researchbased, to report on microvascular reconstruction of the maxilla and/or mandible, and to convey results related to at least one of the following functional outcomes: speech, swallowing, mastication, and quality of life.

Exclusion Criteria

Studies were excluded if outcomes consisted only of implant survival rates in the reconstructed mandible or maxilla. In addition, studies were excluded if the study population did not consist of head and neck cancer patients, if defects and sites of reconstruction were unclear, or if reconstruction of the soft tissues of the oral cavity was the primary focus of the study. Studies were also excluded when resection of both soft tissues and osseous structures were grouped together and osseous resection results could not be examined separately. Studies in which results related to different prosthetic treatments could not be evaluated separately for each type of prosthetic treatment were excluded. Finally, publications that were solely reviews of other articles were excluded.

Review Method

The review was performed in several stages (Fig 1). First, the question for review was delineated into parts, including: the population (ie, patients with maxillary or mandibular defects), the intervention (ie, any treatment involving reconstruction of the mandible or maxilla), the comparisons (ie, conventional tissue/tooth-supported prosthesis, implant-retained prosthesis, no prosthesis), and the outcomes (ie, at least one of the following: speech, swallowing, mastication, and quality of life).

Next, a single investigator identified relevant literature with a review of abstracts retrieved from the library search of several databases using the specified key words. Full articles were retrieved for abstracts that appeared to meet the parameters of the research question. Review of the full articles further delineated those that were appropriate for inclusion. References cited from the identified articles, as well as from related review articles, were scrutinized for other possibly relevant studies. These were obtained and subjected to the same process as the articles retrieved from the database search. Once the first investigator had collected all relevant articles, a second investigator went through all relevant articles to determine agreement for inclusion. Several articles were excluded on this second round of scrutiny because they were found to be in violation of the inclusion/exclusion criteria.

This group of articles was then categorized according to the type of reconstruction (maxillary, mandibular) and the type of prosthetic treatment (conventional, implant-retained, no prosthetic treatment, or unspecified). A tertiary review of the articles was conducted by the first and second investigators independently, excluding articles that discussed prosthetic treatment but did not differentiate results according to the type of prosthetic treatment that patients received, or that did not specify the type of prosthetic treatment. Authors of studies that did not make mention of whether patients received prosthetic treatment were contacted via e-mail to clarify whether any prosthetic treatment was given, and what type. This was completed for 16 articles in question. Five responses were received from authors, with 1 giving clarification about prosthetic treatment. The remaining articles were then categorized as "unspecified prosthetic treatment" and excluded from further review.

The articles that remained were subjected to a dataextraction process in accordance with a list of parameters designed a priori. The parameters for review and extraction into a database included items related to the following: internal validity (ie, research design, randomization of treatments, and reporting of missing data): external validity (ie, replication potential, interrater and intrarater reliability of assessments, and generalizability); patient characteristics (ie, number of patients included, age, gender, diagnosis, t-stage, and treatment); and construct validity (ie, the outcome measures used and the frequency and timing of their application). In addition, the methods of statistical analyses employed in each study were noted. A judgment of the level of evidence of each study was made using a study design hierarchy¹:



Fig 1 Review method.

- Level 1: Experimental studies (eg, randomized controlled trial) with concealed allocation
- Level 2: Quasi-experimental studies (eg, experimental study without randomization)
- Level 3: Controlled observational studies
- · Level 4: Observational studies without control groups
- Level 5: Expert opinion based on pathophysiology, bench research, or consensus

Results

General Findings

Ninety-six relevant articles were collected by the first investigator. Six review articles were excluded but were used to obtain references for other relevant articles.²⁻⁷ Upon further scrutiny by the second investigator, 16

Iable 1 General Findings Across All Studi

Total no. of patients	1-224
Age (y)	3-88
Mean age (y)	55.5
Male-female ratio	2.4:1
Site of lesion (no. of studies)	
Maxilla	12
Mandible	41
Oropharynx*	10
Oral cavity*	21
Other (lips, cheek, etc)*	9
Reconstruction (no. of studies)	
Mandible	41
Maxilla	12
Both	3
Donor site of flap (no. of studies)	
lliac crest	22
Fibula	26
Scapula	11
Radius	11
Ulna	3
Rib	2
Tibia	1
Reconstruction plate	6
Donor site of flap (no. of patients)	
lliac crest	328
Fibula	534
Scapula	80
Radius	90
Ulna	61
Rib	14
Tibia	1
Reconstruction plate	46
Tongue function reported (no. of studies)	14
Missing data reported (no. of studies)	21
Replication of study possible (no. of studies)	20
Reliability checks reported (no. of studies) Level of evidence (no. of studies)	3
1	0
2	0
3	5
4	40
5	4

*Reported in combination with primary lesion involving the maxilla and/or mandible.

additional articles were excluded because of results that combined soft tissue and osseous outcomes. The remaining articles were categorized according to reconstruction and treatment and then reviewed by both investigators. From this joint review, an additional 25 articles were excluded because of difficulties in determining results for different prosthetic treatment types. A total of 49 articles were found to be acceptable for this review.

General findings of the review are presented in Table 1. There was a wide range of total number of patients in each study, as well as a wide age range reported across all studies. Age range reported in Table 1 represents available data from 35 studies, since 13 articles did not report patient age or only reported mean age instead of age range. Mean age values were reported in 30 articles. Studies included both men and women, with the male-female ratio of data being approximately 2.4:1. Site of lesion was recorded for studies when available and included the maxilla and mandible, often in combination with oropharynx, oral cavity, and other less common lesion sites such as the buccal mucosa and the lips. In studies in which structures other than the maxilla or mandible were resected, only data related to the maxilla and mandible were extracted. Missing data related to factors such as patient dropout and death were reported in only 21 of 49 articles. The majority of studies made no mention of reliability checks for interexaminer and test-retest reliability. The evidence ratings across studies ranged between levels 3 and 5, with the majority falling into level 4.

In this review, mandibular and maxillary reconstruction outcomes will be reported separately. Within these 2 anatomic intervention sites, 3 comparisons were noted according to the type of prosthetic treatment reported for each: conventional (including tissuesupported and partial dentures) prosthetic treatment, implant-retained prosthetic treatment, and no prosthetic treatment. In addition, several articles were identified in which the type of prosthetic treatment was difficult to ascertain because it was not reported specifically, and, as such, these articles fell into a category of "unspecified prosthetic treatment." The articles that did not specify the type of prosthetic treatment are listed in Fig 2 for the reader's information but were not included in the final outcome comparison in this review. For each of the comparison groups, functional outcome categories of speech, swallowing, mastication, and quality of life were reported. Some articles reported results related to several types of prosthetic treatment, and thus spanned more than one comparison group. A few articles also reported on both maxillary and mandibular reconstructions, thereby spanning more than one intervention group. A breakdown of studies according to the type of data reported is shown in Fig 2.

Maxillary reconstruction was discussed in 12 of the relevant articles. Reconstruction of the maxilla was completed with osseocutaneous flaps, soft tissue flaps, or a combination of both. Donor sites for osseocutaneous flaps included radial forearm, iliac crest, scapula, and fibula. Donor sites for soft tissue included rectus abdominis and radial forearm. There were 41 articles that reported outcomes related to mandibular reconstruction. Reconstruction of the mandible was completed with osseocutaneous flaps or a combination of both osseous and soft tissue flaps. Donor sites for reconstruction with osseocutaneous flaps included fibula, ilium, scapula, hip, radial forearm, and tibia. Donor sites for soft tissue included pectoralis major and radial forearm.



Fig 2 Number of studies categorized according to reported data. The number in brackets represents the number of articles reviewed in each category. Article reference numbers are represented below each title.

Maxillary Reconstruction: Conventional Prosthetic Treatment

Three articles reported on patients who underwent maxillary reconstruction and received tissue- and/or tooth-supported conventional prosthetic treatment. See Table 2 for a summary of articles, study and patient numbers, and follow-up periods. Note that the number of subjects reported in summary tables refers to the number of patients who received that type of prosthetic treatment, and not the total number of patients enrolled in the study. This occurred because some patients received different types of prosthetic rehabilitation, while others were not rehabilitated with a prosthesis. With respect to speech, a variety of different techniques were used to assess outcomes, including speech intelligibility tests and ratings,^{8,9} nasometry,⁹ and guestionnaires.^{9,10} The results from these studies suggested that satisfactory speech outcomes were achieved, with speech being reported as "excellent"¹⁰ and comparable to that of normal speakers.⁹ Regarding swallowing, 1 study was available for review. A dietary

questionnaire was used to assess swallowing, with results revealing that all patients were able to return to an unrestricted oral diet. Mastication was assessed in other studies via sieving methods and questionnaires.^{9,10} The results from the sieve study indicated that mastication was possible after reconstruction, but not at the level of normal functioning.⁹ The questionnaire results indicated that all patients had excellent chewing scores.¹⁰ Finally, only 1 study reported results related to quality of life (ie, appearance, comfort, convenience, and interaction), indicating that all participants exhibited high scores for all areas.

Maxillary Reconstruction: Implant-Retained Prosthetic Treatment

Six articles reported on patients who underwent maxillary reconstruction and received implant-retained prosthetic treatment (Table 3). As was the case with conventional prosthetic treatment, a variety of speech assessments were completed across the studies. All studies reported satisfactory speech outcomes, with

	Level of	No. of		F	rosthesis		
Reference	evidence	patients	Flap type	Follow-up	type	Outcome measures	Results
Speech							
Genden et al ⁹	3	1	lliac crest, scapula	2.5-6.5 y	1 PMD	Intelligibility: SLP Resonance: nasality, nasal emission, nasometry Subjective speech perception: questionnaire (nonstandardized)	A high intelligibility score (94.5%) and high speech perception score were obtained; the patient scored similarly to normal controls. Nasality and nasal emission were comparable to controls, whereas a higher score was obtained for nasometry during the Zoo Passage.
Matsui et al ⁴²	4	2	Rectus abominis	7 mo-4 y 2 mo	2 PMD	Intelligibility test (standard Japanese language test of 100 syllables)	Intelligibility scores were 68.0% and 77.2%. Plosives were scored as lower in both patients (indicating that they were not as well understood). One patient had a lower score for nasals, and the other for glides. For articulatory sites, both patients demonstrated lower scores for linguovelar sounds. One patient had a lower score for linguodento- alveolar sounds, and the other for bilabial sounds.
Genden et al ¹⁰	4	5*	Radial forearm	6–27 mo	5 PMD	Cornell Medical Index questionnaire	All patients were reported to exhibit excellent speech scores (mean score of approximately 3, with a highest possible score of 3).
Total	3–4	8		6 mo-6.5 y	8 PMD		
Genden et al ¹⁰	4	5*	Radial forearm	6–27 mo	5 PMD	Cornell Medical Index guestionnaire	All patients were able to maintain an unrestricted oral diet 12 d after surgery.
Mastication							
Genden et al ⁹	3	1	lliac crest, scapula	2.5-6.5 у	1 PMD	% of test bolus that patient can chew to pass through a standard sieve after given number of strokes	Patient performance was significantly worse than controls.
Genden et al ¹⁰	4	5	Radial forearm	6–27 mo	5 PMD	Cornell Medical Index questionnaire	All patients exhibited excellent chewing scores (mean score of approximately 3, with a highest possible score of 3).
Total	3-4	6		6 mo-6.5 y	6 PMD		
Quality of life							
Genden et al ¹⁰	4	5*	Radial forearm	6-27 mo	5 PMD	Cornell Medical Index questionnaire	All patients exhibited excellent scores for appearance, comfort, convenience, and interaction.

Table 2	ummary of Speech, Swallowing, Mastication, and Quality-of-Life Outcomes in Studies Reporting on Maxillary
Reconstru	ion in Patients with Conventional Prosthetic Treatment

*1 patient had 1 implant to aid in partial denture retention.

SLP = speech language pathologist; PMD = partial maxillary denture.

high levels of intelligibility⁹ and patients reporting positive comments about their speech.^{8,12} Residual tongue mobility was reported to play a role in determining patients' success with articulation.⁸ One study reported on swallowing assessed via questionnaire,⁸ indicating that poor residual tongue function and xerostomia were reported to be factors that resulted in more difficulties with swallowing.⁸ Masticatory ability was measured using sieving methods,9 area of occlusal contact using a Dental Prescale (Fuji Film), chewing performance with a low-adhesive, color-developing chewing-gum method,¹³ the T-Scan (Tekscan) to test occlusal force and location of occlusal contacts,14 and questionnaires.^{8,12} One study reported evaluating masticatory function but did not specify how it was measured.¹¹ The consensus across studies was that mastication was improved for patients, but perhaps not to the level of normal function. In 1 study, a control group performed significantly better than treatment groups in

chewing performance with unsalted peanuts.9 However, the majority of patients were able to eat a variety of foods,^{11,12,14} and this was thought to result in great part from the implant-retained prostheses. Tongue mobility and xerostomia⁸ were reported to be factors that affected masticatory performance. Finally, quality of life was assessed by rating cosmetic appearance¹¹ and via questionnaire.^{8,12} The results of these studies suggest that cosmetic appearance was improved¹¹ and that the majority of patients were satisfied with their treatment and had no problems with social activities that involved eating in public.¹² Social reintegration and social contact were reported to improve after receiving an implant-retained prosthesis; however, this may not have been on par with preoperative functioning.⁸ It was also found that women tended to have more awareness and concern about their orofacial health status than men.¹²

Reference	Level of evidence	No. of patients	Flap type	Follow-up	Prosthesis type	Outcome measures	Results
Speech Kazaoka et al ¹ Genden et al ⁹	¹ 5 3	1 3	Fibula Iliac crest, scapula	Unspecified 2.5–6.5 y	1 F, 1 CMD Unspecified F/O, 3 PMD	Unspecified Intelligibility: SLP Resonance: nasality, nasal emission, nasometry Subjective speech perception: questionnaire (nonstandardized)	Good speech was obtained.* High intelligibility scores (95%–100%) were obtained, comparable to normal controls. Slightly lower scores were obtained for speech perception. Nasality was higher for 1 patient than controls, and nasal emission was slightly higher for 2 patients. All patients demonstrated higher nasalance scores compared to controls.
Leung et al ¹²	4	14	llium	≥ 6 mo	23 F, 5 O, [†] unspecified CMD/PMD	Questionnaire written for Asian patients, using visual analog scale	The majority of patients gave positive comments about speech function.
Muller et al ⁸	4	11	lliac crest	38.4 mo (mean)	2 F, 9 O, unspecified CMD/PMD	Researcher-developed semi- structured questionnaire	68% of patients claimed to have improved speech. Articulation was limited by impaired tongue mobility.
Total	3–5	29		6 mo-6.5 y	26 F, 14 O, 1 CMD, 3 PN	٨D	
Swallowing Muller et al ⁸	4	11	lliac crest	38.4 mo (mean)	2 F, 9 O, unspecified CMD/PMD	Semi-structured questionnaire developed by authors	Difficulties transporting bolus to pharynx to induce swallowing were noted as a result of restricted tongue mobility and xerostomia.
Genden et al ⁹	3	3	lliac crest, scapula	2.5-6.5 у	Unspecified F/O, 3 PMD	% of test bolus that passes through a standard sieve after given number of strokes	Patients performed significantly worse than controls.
Kazaoka et al ¹	1 5	1	Fibula	Unspecified	1 F, 1 CMD	Unspecified	The patient could eat a greater variety of foods.*
Matsui et al ¹³	3	2	llium, scapula	Unspecified	1 F, 1 O, 2 PMD	Area of occlusal contact: Dental Prescale Chewing performance: low-adhesive, color-developing, chewing-gum	Occlusal contact did not differ between patients and controls. Chewing performance in patients was significantly poorer than in controls.
Schmelzeisen et al ¹⁴	3	16	Scapula, iliac crest	Unspecified	Unspecified F/O, CMD/ PMD	Masticatory force: T-Scan, miniature force transducer	Average maximum masticatory pressure was 111 N in patients and 275 N in controls. Patients did not reach preoperative masticatory function and were not comparable to controls. During mastication tasks, patients favored nonreconstructed side for chewing.
Leung et al ¹²	4	14	llium	≥ 6 mo	23 F, 5 O, [†] unspecified CMD/PMD	Questionnaire written for Asian patients, using visual analog scale	The majority of subjects could tolerate a variety of food, including meat and vegetables.
Muller et al ⁸	4	11	lliac crest	38.4 mo (mean)	2 F, 9 O, unspecified CMD/PMD	Semi-structured questionnaire developed by authors	83% of patients reported improved chewing ability; 32% rated chewing as less than satisfactory. Patients reported restrictions due to restricted tongue mobility and xerostomia.
Total	3–5	47		6 mo-6.5 y	27 F, 15 O, 5 PMD, 1 CN	ID	
Quality of life	1 -	-	F 11 1			11	o
Kazaoka et al ¹ Leung et al ¹²	4	14	llium	Unspecified ≥ 6 mo	23 F, 5 O, [†] unspecified CMD/PMD	Questionnaire written for Asian patients, using visual analog scale	The majority of patients found no problems with social activities involving eating in public. Overall satisfaction with treatment was good.
Muller et al ⁸	4	11	lliac crest	38.4 mo (mean)	2 F, 9 O, unspecified CMD/PMD	Semi-structured questionnaire developed by authors	Functional impairment was not fully compensated but contributed to general well-being and relief of disease-related social restrictions. Prostheses aided in gaining subjective confidence and aided social reintegration. Increased social contact was the biggest change after prosthesis insertion.
Total	4–5	26		6–38.4 mo	26 F, 14 O, 1 CMD		

Table 3Summary of Speech, Swallowing, Mastication, and Quality-of-Life Outcomes in Studies Reporting on MaxillaryReconstruction in Patients with Implant-Retained Prosthetic Treatment

*These results were reported in the study; however, assessment methods were unspecified.

[†]Numbers were reported in the study; however, they were unspecified for maxillary vs mandibular prostheses.

SLP = speech language pathologist; F = fixed prosthesis; O = overdenture; CMD = complete maxillary denture; PMD = partial maxillary denture.

	Loval of	No. of			Outcomo	
Reference	evidence	patients	Flap type	Follow-up	measures	Results
Speech						
Yazar et al ¹⁵	4	6	Fibula	3-24 mo	Unspecified	5 of 6 patients had normal speech*
Swallowing						
Yazar et al ¹⁵	4	6	Fibula	3-24 mo	Unspecified	5 patients tolerated a regular diet, 1 soft*
Quality of life						
Yazar et al ¹⁵	4	6	Fibula	3–24 mo	Unspecified	Excellent cosmesis found in 5 patients, good in 1 patient*

 Table 4
 Summary of Speech, Swallowing, Mastication, and Quality-of-Life Outcomes in Studies Reporting on Maxillary

 Reconstruction in Patients without Prosthetic Treatment
 Prosterior

*These results were reported in the study; however, assessment methods were unspecified.

Maxillary Reconstruction: No Prosthetic Treatment

One study reported on speech, swallowing, and quality of life in patients who underwent maxillary reconstruction without receiving any prosthetic treatment; however, outcome measures were not specified.¹⁵ See Table 4 for summaries of patient numbers and followup periods from this article. The results indicated that speech was normal in the majority of patients (5 of 6), and the same number of patients was able to tolerate a regular diet. Cosmetic appearance was the only quality-of-life outcome mentioned, and this was found to be excellent in 5 of 6 patients. It should be noted that 5 of 6 patients were reported to have residual dentition, which allowed them to recover speech and eating function.

Mandibular Reconstruction: Conventional Prosthetic Treatment

Seven articles reported outcomes for patients who underwent mandibular reconstruction and received tissue and/or tooth-supported conventional prosthetic treatment (Table 5). Speech outcomes were measured via speech intelligibility tests¹⁷ and survey.¹⁶ One study reported evaluating speech outcomes but did not specify how this was completed.¹⁸ The majority of results reported in these studies suggest that speech was generally considered satisfactory in the postoperative period. Patients were rated as having high intelligibility and were said to have reached "normal" levels of speech function. Swallowing outcomes were evaluated through patient-answered questions, 16,17 the ability to swallow a specific bolus,¹⁷ and the type of diet tolerated.^{16,17} One study did not report how swallowing outcomes were measured.¹⁸ The results from these studies indicated that the majority of patients were able to tolerate a regular diet and that there were no significant swallowing difficulties. Masticatory outcomes were evaluated via patient-answered questions in 3 studies^{16,17,19} and a food-rating questionnaire in 1

study.²⁰ Other studies assessed the patients' ability to manipulate a solid bolus,¹⁷ a sieve analysis of a chewed bolus, chewing cycle time, preferred chewing side, number of chewing strokes required to masticate a bolus,^{19,21,22} and occlusal force.²⁰ One study did not specify how mastication outcomes were measured.¹⁸ The results from these studies suggested that patients were able to resume some degree of masticatory function after receiving a conventional prosthesis; however, in the majority of cases, they were not able to reach normal levels of functioning. One study reported that patients were able to reach presurgical levels of functioning, though this was compromised.²² Patients with reconstructed mandibles tended to require a higher number of chewing strokes to comminute food²¹ and were significantly different as a group when compared to normal controls.²⁰ Occlusal force did not seem to be related to functional masticatory abilities.²⁰ Finally, regarding quality-of-life issues, overall well-being was assessed via patient-answered questions in 2 studies.^{17,19} One study focused on esthetic outcomes as the only quality-of-life measure, assessed via survey and observer judgments.¹⁶ The results revealed that patients reported satisfactory overall well-being, including such factors as body weight, general condition, employment status, level of daily activity, level of social activity, and psychologic status.¹⁷ Patients' postoperative scores were lower than the preoperative scores collected 1 to 7 days prior to surgery using quality-oflife questions, but the differences were not statistically significant.¹⁹ Esthetic and cosmetic outcomes were reported to be satisfactory in the majority of patients.^{16,17}

Mandibular Reconstruction: Implant-Retained Prosthetic Treatment

Sixteen articles reported on patients who underwent mandibular reconstruction and received implant-retained prosthetic treatment (Table 6). Speech ability was assessed via questionnaires,^{8,12,16,23,24} informally in conversation,^{24,25} by patient self-assessment,^{25,26} and through reading of a standard passage.²⁴ One study

Reference	Level of evidence	No. of patients	Flap type	Follow-up	Prosthesis type	Outcome measures	Results
Speech Patel et al ¹⁷	4	12	Silastic implant, pectoralis major, iliac crest	Unspecified	Unspecified	Intelligibility Articulation	Speech scores for patients reconstructed with iliac crest were the best, though not significantly different from other flap types.
Hidalgo et al ¹⁶	4	6	Fibula, scapula	11 y (mean)	Unspecified	Survey (validated and study- specific questions)	Five patients were easily intelligible, 1 patient was intelligible with effort.
Savant et al ¹⁸ Total Swallowing	4 4	116 134	Pectoralis major	Unspecified 11 y	Unspecified Unspecified	Unspecified	The majority of patients had normal speech.
Patel et al ¹⁷	4	83	Silastic implant, pectoralis major, iliac crest	Unspecified	Unspecified	Subjective questions: diet type, ability to swallow Ability to comminute a solid bolus of peanuts	No significant differences between flap types.
Savant et al ¹⁸ Hidalgo et al ¹⁶	4	116 6	Pectoralis major Fibula, scapula	Unspecified 11 y (mean)	Unspecified Unspecified	Unspecified Survey (validated and study-specific questions)	Minimal swallowing problems were found.* 4 patients tolerated a regular diet, 2 required a soft diet
Total Mastication	4	205		11 y	Unspecified		
Patel et al ¹⁷	4	83	Silastic implant, pectoralis major, iliac crest	Unspecified	Unspecified	Subjective questions: ability to chew Test to measure adequacy of oral comminution Ability to comminute solid bolus	No significant differences between flap types were found.
Marunick et al	²¹ 3	1	Unspecified	3–37 wk	1 CMD	Frito corn chip test food: masticatory performance, chewing cycle time, preferred chewing side, number of chewing strokes, sieve method	The patient demonstrated steadily increasing masticatory performance from pretreatment to postsurgery to the final evaluation. Time required to complete a certain number of chewing strokes decreased over the evaluation period. Number of strokes to reach swallowing threshold decreased from pretreatment to postsurgery but increased postdelivery. Patient was less efficient in terms of masticatory efficiency compared to controls.
Hidalgo et al ¹⁶	4	6	Fibula, scapula	11 y (mean)	Unspecified	Oral excursion	Oral excursion ranged from 25–40 mm (mean: 33.3).
Curtis et al ²⁰	4	3	lliac, fibula	≥ 6 mo	3 PMD	Food scale questionnaire (easy to difficult) Occlusal force	Patients scored lower on food scale questionnaire (scores ranging from 50 to 80) compared to controls (all scores of 100). All patients exhibited much lower occlusal force than controls.
Savant et al ¹⁸ Roumanas et a	4 a) ²² 4	116 23	Pectoralis major Fibula	Unspecified Presurgery, postsurgery, 4 mo postdelivery	Unspecified 7 CMD, 16 PMD	Unspecified 3 g peanut and carrot test foods: masticatory performance, swallowing threshold performance including number of chewing strokes and chewing time before swallow	Dentures restored satisfactory mastication.* Preoperatively, patients had poor masticatory function. This decreased postsurgically but improved postdelivery. Performance between the affected side and nonaffected side was significantly different at all 3 time points. Swallowing threshold performance did not change across 3 time points.
Garrett et al ¹⁹	4	33	Fibula	Presurgery, postsurgery, 4 mo postdelivery	5 CMD, 28 PMD	3 g peanut and carrot test foods: masticatory performance, swallowing threshold performance including number of chewing strokes and chewing time before swallow	Masticatory performance was difficult presurgery, and became more difficult postsurgery. After prosthetic treatment, 88% of patients could masticate on the nondefect side, while half could not masticate on the defect side.
Total Quality of life	3-4	265		Presurgery- 11 y	13 CMD, 47 PMD		
Patel et al ¹⁷	4	83	Silastic implant, pectoralis major, iliac crest	Unspecified	Unspecified	Overall well-being (subjective questions: functional status, how close to preop status)	Overall well-being was satisfactory. Patients reconstructed with iliac crest had better cosmesis scores, but this was not significantly different from other flap types.
Hidalgo et al ¹⁶	4	6	Fibula, scapula	11 y (mean)	Unspecified	Esthetics: survey (validated and study-specific questions) and judged by 2 observers	Esthetics were judged excellent in 4 patients and good in 2 patients.
Garrett et al ¹⁹	4	33	Fibula	Presurgery, postsurgery, 4 mo postdelivery	5 CMD, 28 PMD	Esthetics: visual analog scale Patient satisfaction questionnaire (Kapur et al)	Patients scored lower presurgery than postsurgery on questionnaire items, but these scores were not significantly different between assessment times.
Total	4	122		Presurgery- 11 y	5 CMD, 28 PMD		

 Table 5
 Summary of Speech, Swallowing, Mastication, and Quality of Life Outcomes in Studies Reporting on Mandibular
 Reconstruction in Patients with Conventional Prosthetic Treatment

*These results were reported in the study; however, assessment methods were unspecified. CMD = complete mandibular denture; PMD = partial mandibular denture.

Table 6	ummary of Speech, Swallowing, Mastication, and Quality of Life Outcomes in Studies Reporting on Mandibula
Reconstru	ion in Patients with Implant-Retained Prosthetic Treatment

Reference	Level of evidence	No. of patients	Flap type	Follow-up	Prosthesis type	Outcome measures	Results
Speech							
Hidalgo et al ¹⁶	6 4	5	Fibula, scapula	11 y (mean)	Unspecified F/O, CMD/ PMD	Survey (validated questions and study-specific questions)	All patients were easily intelligible.
Muller et al ⁸	4	57	lliac crest	38.4 mo (mean)	8 F, 49 O, unspecified CMD/PMD	Researcher-developed semi- structured questionnaire	68% of patients claimed to have improved speech. Articulation was limited by impaired tongue mobility.
McGhee et al ²	²³ 4	6	Fibula	6–12 mo	Unspecified F/O, CMD/ PMD	Survey (unspecified)	Patients had improved articulation.
Gurlek et al ²⁵	4	20	Fibula, iliac crest	47 mo (mean)	Unspecified F/O, CMD/ PMD	Subjective assessment by patient and objective assessment by speech pathologist (unspecified)	50% of patients judged themselves to have normal speech (40% when assessed by SLP). 35% judged themselves to have occasional misarticulations (30% by SLP). 15% judged themselves to have frequent misarticulation (25% by SLP), and none perceived themselves to have unintelligible speech (5% by SLP).
Urken et al ²⁴	4	10	Iliac crest	Variable	Unspecified F/O, CMD/ PMD	Questionnaire Intelligibility: Rainbow passage and conversation	Patients with reconstruction perceived their speech as better than those who were not reconstructed. SLP judgment of intelligibility did not differ between the 2 groups.
Huband ²⁶	5	1	Hip	Unspecified	1 0, 1 CMD	Patient report	Family members noticed improvements in patient's speech.
Baima ²⁷	5	1	Fibula	Unspecified	1 F, 1 PMD	Unspecified	Excellent articulation was obtained post- operatively.*
Leung et al ¹²	4	14	llium	≥ 6 mo	23 F, 5 O, [†] unspecified CMD/PMD	Questionnaire written for Asian patients, using visual analog scale	The majority of patients gave positive comments about speech function.
Total	4–5	114		6 mo-11 y	32 F, 55 O, 1 CMD, 1 PN	1D	
Swallowing	s ,	-	F 'h 1	11 (11		A second
Hidaigo et al	5 4	5	Fibula, scapula	TT y (mean)	F/O, CMD/ PMD	study-specific questions)	4 patients tolerated a regular diet, 1 required a soft diet.
Muller et al ⁸	4	57	lliac crest	38.4 mo (mean)	8 F, 49 O, unspecified CMD/PMD	Semi-structured questionnaire developed by authors	Difficulties transporting bolus to pharynx to induce swallowing were noted as a result of restricted tongue mobility and xerostomia.
McGhee et al ²	23 4	6	Fibula	6–12 mo	Unspecified F/O, CMD/ PMD	Survey (unspecified)	All but 1 patient was able to tolerate a regular diet without difficulty.
Gurlek et al ²⁵	4	20	Fibula, iliac crest	47 mo (mean)	Unspecified F/O, CMD/ PMD	Patient and SLP assessment of diet	40% of patients judged themselves to have a normal diet (35% by SLP), 35% with minimal restrictions (30% by SLP), 20% with mechanical soft diet (25% by SLP), and 5% liquid diet only (10% by SLP).
Urken et al ²⁴	4	10	Iliac crest	Variable	Unspecified F/O, CMD/ PMD	Diet: gastrostomy, liquid, puree, soft, solid (assessed with VFSS, analyzed for 7 gross abnormalities)	Reconstructed patients ate a solid diet. Nonreconstructed patients had to cut food into small pieces. No significant differences in abnormalities in swallowing mechanism between reconstructed and nonreconstructed groups.
Total Mastication	4	98		6 mo-11 y	8 F, 49 O		
Hidalgo et al ¹⁶	6 4	5	Fibula, scapula	11 y (mean)	Unspecified F/O, CMD/ PMD	Oral excursion	Oral excursion ranged from 37–50 mm (mean: 43.2 mm).
Curtis et al ²⁰	4	5	lliac, fibula	≥ 6 mo	Unspecified F/O, 2 CMD, 3 PMD	Food scale questionnaire (easy to difficult) Occlusal force	Patients scored lower on food scale questionnaire (scores ranging from 70 to 100) compared to controls (all scores of 100). 2 patients exhibited occlusal forces comparable to controls, while 3 patients exhibited occlusal forces much lower than controls.
Muller et al ⁸	4	57	lliac crest	38.4 mo (mean)	8 F, 49 O, unspecified CMD/PMD	Semi-structured questionnaire developed by authors	83% of patients reported improved chewing ability. 32% rated chewing as less than satisfactory. Patients reported restrictions due to restricted tongue mobility and xerostomia.

Table 6 (continued)Summary of Speech, Swallowing, Mastication, and Quality-of-Life Outcomes in Studies Reporting on
Mandibular Reconstruction in Patients with Implant-Retained Prosthetic Treatment

Reference	Level of evidence	No. of patients	Flap type	Follow-up	Prosthesis type	Outcome measures	Results
McGhee et al ²³	4	6	Fibula	6–12 mo	Unspecified F/O, CMD/ PMD	Survey (unspecified)	5 of 6 patients were able to chew without difficulty.*
Ohya et al ³⁰	4	8	Pectoralis major, reconstruction plate, deltopectoral	≥ 6 mo	8 O, unspecified CMD/PMD	4 grade scale: normal, soft, liquid, tube feeding	5 patients were able to to maintain a grade 1 normal diet, 3 patients a grade 2 soft diet.
Urken et al ²⁴	4	10	lliac crest	Variable	Unspecified F/O, CMD/ PMD	Questions for patients to assess their own eating capability Intercisal opening Occlusal force Jaw range of motion Masticatory function	Reconstructed patients had a rotary grinding motion, while nonreconstructed patients did not. Reconstructed patients were able to masticate in a manner closer to their preoperative state. Normal controls had the highest occlusal forces.
Nakai et al ²⁸	4	13	Fibula, tibia	39–91 mo (mean: 58 mo)	13 F, unspecified CMD/PMD	Questionnaire classifying foods according to chewing difficulty Occlusal force (Dental Prescale)	Patients who underwent a tongue resection experienced much worse masticatory efficiency. Those without tongue resection had high efficiency, regardless of occlusal force. Tongue mobility had a significant role in masticatory function.
Huband ²⁶	5	1	Hip	Unspecified	1 O, 1 CMD	Patient report	Patient was able to enjoy a wide variety of foods.
Baima ²⁷	5	1	Fibula	Unspecified	1 F, 1 PMD	Control of food bolus	Patient was able to control a bolus of food.
Ueda et al ²⁹	4	7	Scapula, fibula	Unspecified	7 F, unspecified CMD/PMD	Masticatory efficiency: questionnaires by Ueda et al	Mean score was 39.4 points after mandibulectomy. Mean score was 58.8 points with implant-supported prosthesis.
Leung et al ¹²	4	14	llium	≥ 6 mo	23 F, 5 O, [†] unspecified CMD/PMD	Questionnaire written for Asian patients, using visual analog scale	The majority of subjects could tolerate a variety of food, including meat and vegetables.
Schmelzeisen e	tal ¹⁴ 3	16	Scapula, iliac crest	Unspecified	Unspecified F/O, CMD/ PMD	Masticatory force: T-Scan, miniature force transducer	Maximum masticatory pressure in patients averaged 111 N, while controls averaged 275 N. All patients demonstrated improved mastication, but did not reach preoperative levels and were not comparable to controls. Patients favored nonreconstructed side for chewing.
Matsui et al ¹³	3	3	llium, scapula	Unspecified	3 F, 1 PMD, 2 CMD	Area of occlusal contact: Dental Prescale Chewing performance: low- adhesive, color-developing, chewing-gum method	Occlusal contact did not differ between patients and controls. Chewing performance in patients was significantly lower than in controls.
Roumanas et al ^a	22 4	15	Fibula	Presurgery, postsurgery, 4 mo postdelivery	15 O, 3 CMD, 12 PMD	3g peanut and carrot test foods: masticatory performance, swallowing threshold performance: no. of chew strokes, chewing time before swallow	Preoperatively, patients had poor masticatory function. This decreased postsurgically but improved postdelivery. Almost all patients could masticate on both sides postdelivery. Swallowing threshold performance did not change across 3 time points.
Garrett et al ¹⁹	4	16	Fibula	Presurgery, postsurgery, 4 mo postdelivery	16 O, 3 CMD, 13 PMD	3g peanut and carrot test foods: masticatory performance, swallowing threshold performance: no. of chew strokes, chewing time before swallow	Masticatory performance was difficult presurgery and became more difficult post- surgery. After prosthetic treatment, almost all patients could masticate on both affected and nonaffected sides.
Total	3–5	177		Presurgery -11 y	55 F, 94 O, 11 CMD, 30 PMD		
Quality of life Hidalgo et al ¹⁶	4	20	Fibula, scapula	11 y	Unspecified F/O, CMD/ PMD	Esthetics: survey (validated questions and study-specific questions) and judged by 2 observers	Esthetics was judged excellent in 4 patients and fair in 1 patient.
Muller et al ⁸	4	57	Iliac crest	38.4 mo (mean)	8 F, 49 O, unspecified CMD/PMD	Semi-structured questionnaire developed by authors	Functional impairment was not fully compensated but contributed to general well-being and relief of disease-related social restrictions. Prostheses aided in gaining subjective confidence and social reintegration. Increased social contact was biggest change after prosthesis insertion.

Table 6 (continued) Summary of Speech, Swallowing, Mastication, and Quality-of-Life Outcomes in Studies Reporting on Mandibular Reconstruction in Patients with Implant-Retained Prosthetic Treatment

Reference	Level o evidence	f No. of e patients	s Flap type	Follow-up	Prosthesis type	Outcome measures	Results
McGhee et al ²³	4	6	Fibula	6-12 mo	Unspecified F/O, CMD/ PMD	Survey (unspecified)	Patient satisfaction was high.*
Gurlek et al ²⁵	4	20	Fibula, iliac crest	47 mo (mean)	Unspecified F/O, CMD/ PMD	Patient self-assessment	Cosmesis: 75% of patients judged themselves as excellent and 25% as good. Social activity: 75% judged the same as preoperative state, 25% worse than preoperative state. Eating in public: 80% reported yes, 20% no. Return to work: 75% reported yes, 25% no.
Huband ²⁶	5	1	Hip	Unspecified	1 0, 1 CMD	Patient report	Friends/family members noticed improvement in patient's appearance.
Leung et al ¹²	4	14	llium	≥ 6 mo	23 F, 50, [†] unspecified CMD/PMD	Questionnaire written for Asian patients, using visual analog scale	Majority of patients found no problems with social activities involving eating in public. Overall satisfaction with treatment was good.
Garrett et al ¹⁹	4	16	Fibula	Presurgery, postsurgery, 4 mo postdelivery	16 O, 3 CMD, 13 PMD	Esthetics: visual analog scale Patient satisfaction questionnaire (Kapur et al)	Patients scored lower presurgery than postsurgery on questionnaire items. However, these scores were not significantly different between assessment times.
Total	4-5	134		Presurgery -11 y	31 F, 71 O, 4 CMD, 13 P	MD	

*These results were reported in the study; however, assessment methods were unspecified.

[†]Numbers were reported in the study; however, they were unspecified for maxillary vs mandibular prostheses.

SLP = speech language pathologist; F = fixed prosthesis, O = overdenture; CMD = complete mandibular denture; PMD = partial mandibular denture; VFSS = videofluoroscopic swallow study.

Table 7	Summary of Speech, Swallowing,	Mastication, and	l Quality-of-Life Outcomes in	Note Studies Reporting on Mana	dibular
Reconstru	ction in Patients without Prosthet	ic Treatment			

Reference	Level of evidence	No. of patients	Flap type	Follow-up	Outcome measures	Results
Speech						
Shpitzer et al ³	4	57	Fibula, reconstruction plate with pectoralis major or radial forearm	12–126 mo	Intelligibility: whether patient was understood by untrained listener Questionnaire	Speech intelligibility was slightly better in the group reconstructed with fibula. Forty-two patients had normal speech; 15 had intelligible speech.
Savant et al ³⁴	4	18	lliac crest	Unspecified	Unspecified	15 of 18 patients had normal speech.*
Seikaly et al ³²	4	10	Fibula	3–6 mo	Intelligibility: CAIDS single words and sentences	Postoperative intelligibility scores did not change significantly from preoperative scores. Patients' single word and connected speech postoperatively consistently achieved preoperative levels.
Rogers et al ³³	4	57	Fibula, radial, scapula	Presurgery, 6 mo, 12 mo, > 16 mo	University of Washington Questionnaire	Speech scores decreased from preoperative to 6 mo posttreatment. Scores were relatively stable from 6 mo to the last assessment
Total	4	142		Presurgery- 126 mo		
Swallowing						
Puxeddu et al ^a	⁶ 4	12	lliac crest	6–64 mo	Diet: liquid, soft, full Questionnaire	1 patient maintained a liquid diet, 8 a soft diet, 3 a full diet.
Shpitzer et al ³	4	57	Fibula, reconstruction plate with pectoralis major or radial forearm	12–126 mo	Diet: normal, soft/blended, feeding tube Questionnaire	29 patients maintained a normal diet, 22 a soft diet, 6 were feeding-tube dependent.
Savant et al ³⁴	4	18	lliac crest	Unspecified	Unspecified	16 of 18 patients had no swallowing problems.*
Komisar ³⁵	4	8	lliac crest and reconstruction plate	2 у	Diet: poor (G-tube required), fair (liquid/ puree), good (soft), excellent (regular)	Swallowing was fair in 5 patients and good or excellent in 3 patients. Diet was poorer in the reconstructed group.

Table 7 (continued)	Summary of Speech, Swallowing, Mastication, and Quality-of-Life Outcomes in Studies Reporting on
Mandibular Reconstru	uction in Patients without Prosthetic Treatment

Reference	Level of evidence	No. of patients	Flap type	Follow-up	Outcome measures	Results
Seikaly et al ³²	4	10	Fibula	3–6 mo	MBS of liquid, pudding, cookie consistencies	No aspiration or penetration was noted with any bolus at any of the assessment times. There was a trend indicating more problems with cookie swallows posttreatment that may have been related to xerostomia, but no significant differences were noted.
Rogers et al ³³	4	57	Fibula, radial, scapula	Presurgery, 6 mo, 12 mo, > 16 mo	University of Washington Questionnaire	Swallowing scores decreased from preoperative to 6 mo posttreatment. There was a slight increase in scores from 6 to 12 mo, and a small decrease from 12 mo to the last assessment.
Total	4	162		Presurgery -126 mo		
Mastication						
Puxeddu et al	³⁶ 4	12	lliac crest	6-64 mo	Questionnaire	Better recovery in mastication in reconstructed patients was observed vs nonreconstructed patients.
Savant et al ³⁴	4	18	lliac crest	Unspecified	Unspecified	Most patients regained acceptable mastication due to intact dentition on unaffected mandible.*
Shpitzer et al ^s	³¹ 4	57	Fibula, reconstruction plate with pectoralis major or radial forearm	12–126 mo	Intercisal opening Occlusion	All but 1 patient with condylar resection had normal occlusion. Average intercisal opening was 29.5 mm.
Komisar ³⁵	4	8	lliac crest and reconstruction plate	2 у	Rated as poor (no ability to change consistency of food), fair (limited ability), good (soft diet), excellent (regular diet)	3 patients had poor mastication, 3 had fair, 2 had good. Mastication was poorest in patients with reconstruction.
Rogers et al ³³	4	57	Fibula, radial, scapula	Presurgery, 6 mo, 12 mo, > 16 mo s	University of Washington Questionnaire	Chewing scores decreased from preoperative to 6 mo posttreatment. There was a slight increase in scores from 6 to 12 mo, and a slight decrease from 12 mo to the last assessment.
Total	4	152		Presurgery- 126 mo		
Quality of life Puxeddu et al	³⁶ 4	12	lliac crest	6–64 mo	Performance Status Scale and Functional Assessment Cancer Therapy General Scale	All 12 reconstructed patients noted better physical well-being, sociofamily relationship, and emotional and general functional well-being than nonreconstructed patients.
Shpitzer et al ²	31 4	57	Fibula, reconstruction plate with pectoralis major or radial forearm	12–126 mo	Questionnaire Esthetics: clinical exam and patient perception	44 patients had good/excellent facial appearance, 12 were acceptable, and 1 was poor.
Savant et al ³⁴	4	18	lliac crest	Unspecified	Cosmetic appearance (unspecified)	All 15 patients with intact bone had excellent results.
Komisar ³⁵	4	8	lliac crest and reconstruction plate	2 у	Cosmesis: photos and interviews, rated as excellent (no deformity), good (minimal deformity), fair (significant depression from loss of mandible), poor (bulky tissue transfer to face) Quality of life (no. of hospitalizations)	Cosmesis was better in patients who underwent reconstruction. Five patients had good or excellent cosmesis.
Rogers et al ³³	4	57	Fibula, radial, scapula	Presurgery, 6 mo, 12 mo, > 16 mo	University of Washington Questionnaire	Composite scores drop from preoperative assessments to 6 mo posttreatment on. Scores for appearance, activity, recreation, and shoulder disability followed the same pattern. Scores for pain increased from preoperative to posttreatment.
Total	4	152		Presurgery- 126 mo		

*These results were reported in the study; however, assessment methods were unspecified. MBS = modified barium swallow. reported speech outcomes but did not specify which measures were used.²⁷ Overall, in postoperative assessments, more patients were reported to have intelligible or normal speech than they were to have speech that was difficult to understand. Residual tongue mobility was reported to play a role in determining patients' success with articulation.⁸

With respect to swallowing outcomes, methods of assessment ranged from diet survey and questionnaires^{8,16,23-25} to videofluoroscopic swallow studies.²⁴ The results suggest that the vast majority of patients were able to tolerate a soft or normal diet postoperatively. More patients tolerated a normal diet than those who could only tolerate a soft diet. Poor residual tongue function and xerostomia were reported to be factors that resulted in more difficulties with swallowing.⁸ Radiation therapy may have played a role in symptoms of xerostomia, since 57% of all reported patients underwent radiation therapy at some point during treatment. Differences between those who received radiation therapy and those who did not could not be discerned. since the results were not reported separately. In regard to mastication, assessment methods included questionnaires^{19,20,28,29} general chewing ability,^{8,12,23} occlusal force, 14,20,24,27,28 oral excursion, 16 bolus control, 27 chewing performance,^{13,19,22} and diet tolerance.^{26,30} The results from these studies suggest that reconstruction of the mandible followed by rehabilitation with an implant-retained prosthesis had a positive effect on masticatory outcomes. Many studies reported that patients were able to masticate a variety of foods without difficulty,^{12,23,26,27,30} and that they demonstrated improved masticatory performance.^{8,19,22,29} The results suggested that some patients preferred to chew on the nonreconstructed side,¹⁴ while others were able to masticate on both sides.^{19,22} Occlusal force was reportedly lower in patients with mandibular reconstruction than in normal controls.^{20,24} It was unclear whether patients could reach preoperative levels of function, with some reports indicating that patients were on par with controls²⁴ or reached presurgical levels,22 while others indicated that patients performed more poorly than controls.^{13,14} Tongue mobility^{8,28} and xerostomia⁸ were reported to be factors that impacted patients' masticatory performance.

Finally, quality of life was measured using patient or observer ratings^{16,25,26} and surveys or questionnaires.^{8,12,16,19,23} In terms of cosmetic appearance and esthetics, the majority of patients had good or excellent outcomes. Quality of life was reportedly improved for most patients after receiving an implant-retained prosthesis; however, it was not on par with preoperative functioning.^{8,25} Social reintegration and social contact were reported to improve after receiving an implant-retained prostedied prosthesis,⁸ and the majority of patients were able to eat in public comfortably and return to work.²⁷

Mandibular Reconstruction: No Prosthetic Treatment

Six articles reported on patients who underwent mandibular reconstruction without any prosthetic treatment (Table 7). Speech outcome was measured via intelligibility tests^{31,32} and quality of life questionnaires.³³ One study reported speech outcomes but did not specify which measures were applied.³⁴ Overall, the results from these studies suggest that the majority of patients demonstrated positive speech outcomes. Most patients had intelligible speech and sufficient speech ability for normal communication. In 1 study in which several reconstruction techniques were used, patients who were treated with a fibular flap demonstrated slightly better intelligibility than patients treated with other reconstruction techniques.³¹ Swallowing outcomes were measured via ratings of diet tolerance,^{31,35,36} modified barium swallow tests,³² questionnaires,^{31,33,36} and unspecified techniques.³⁴ The results from these studies suggest that most patients were able to tolerate a soft or normal diet postoperatively, and very few patients were noted to have swallowing problems. However, there were reports of patients who were required to consume liquid diets or required feeding tubes.^{31,36} Xerostomia was identified as a possible factor in difficulties with cookie boluses.³² Measurement of mastication was completed via rating scales and guestionnaires, 33,35,36 intercisal opening and occlusion,³¹ and unspecified techniques.³⁴ Postoperative masticatory outcomes varied between studies. One study indicated that recovery of mastication was better in reconstructed patients than in nonreconstructed patients,³⁶ while another indicated that mastication was poorest in reconstructed patients compared to nonreconstructed patients.³⁵ Patients who were able to achieve satisfactory masticatory outcomes appeared to do so because of residual dentition.³⁴ Other patients had poor masticatory outcomes, with many unable to masticate a solid diet.³⁵ It was reported that postoperative masticatory ability was not as good as the preoperative state.33

With respect to quality of life, cosmetic appearance,^{31,34,35} number of hospitalizations,³⁵ and questionnaires^{33,36} were used to assess outcomes. The results suggest that the majority of patients had satisfactory cosmetic appearance outcomes. In terms of overall quality-of-life outcomes, reconstructed patients indicated better physical well-being, sociofamilial relationships, and emotional and general functional well-being than patients who underwent composite resection without reconstruction of the mandible.³⁶ All scores for the University of Washington Quality of Life Scale (including composite scores, appearance, recreation, and shoulder disability scores) decreased from preoperative assessments to postoperative evaluation times, with the exception of pain scores, which increased across this time period.³³

Discussion

Several reports exist to describe outcomes associated with reconstruction of the maxilla and mandible. Reconstructive techniques, assessment methods, patient numbers, and evaluation points varied substantially across the studies included in this review, making it difficult to reach firm conclusions about outcomes related to different types of prosthetic interventions after reconstruction. However, with caution, some general conclusions can be drawn regarding results associated with each of the prosthetic comparison groups for both the maxilla and mandible.

The literature that was available on reconstruction of the maxilla allowed for comparison of outcomes between 3 groups of prosthetic treatment: (1) conventional tissue/tooth-supported prostheses, (2) implantretained prostheses, and (3) no prosthetic rehabilitation.

For speech outcomes related to maxillary reconstruction, no clear distinction could be made between the type of prosthetic treatment or the absence of prosthetic treatment. In the limited number of studies available, reports described speech as "normal" or "intelligible." However, because of the unspecified assessment methods and small patient numbers in the study describing patients without prosthetic treatment, it is uncertain whether this can be applied to the general population of patients within this category.

For swallowing results, a comparison between patients receiving implant-retained rehabilitation and those in the other 2 groups could not be made, since there were no studies reporting swallowing outcomes for those with implant-retained prostheses. For the other 2 groups, most patients with conventional prosthetic treatment for the maxilla and those without prosthetic treatment were reported to be able to return to a normal diet, with very few patients requiring a soft diet. However, for patients without prosthetic treatment, their return to a normal diet was largely the result of their residual dentition.

With respect to mastication, a comparison could not be made between patients without prosthetic rehabilitation and the other 2 groups, since there were no studies reporting on mastication outcomes for those without prosthetic rehabilitation. Masticatory function for the other 2 groups was reported to be satisfactory with either conventional or implant-retained prosthetic rehabilitation, and most patients could return to an unrestricted diet. However, it is noteworthy that when patients in both groups were compared to normal controls, neither type of prosthetic rehabilitation restored masticatory function to a level that could be considered on par with normal controls.

Finally, quality-of-life assessments were found to focus primarily on cosmetic appearance, which was found to be largely satisfactory across studies for both conventional and implant-retained prosthetic rehabilitation and for patients without prosthetic rehabilitation. Studies that reported on social functioning also reported positive outcomes for both conventional and implant-retained prosthetic rehabilitation.

In conclusion, the current state of the literature on maxillary reconstruction does not allow for discrimination between the 3 prosthetic treatment categories. Only 1 study reported on patients without prosthetic rehabilitation, making comparison to either type of prosthetic treatment difficult. It should be noted that the outcomes collated within this review were based on very small patient numbers. Because so few studies reported on outcomes in maxillary reconstruction, and the included studies consisted of very small subject numbers, interpretation of these results must be made with caution.

The literature that was available on reconstruction of the mandible allowed for comparison of outcomes between 3 comparison groups of prosthetic treatment: (1) conventional tissue/tooth-supported prostheses, (2) implant-retained prostheses, and (3) no prosthetic rehabilitation. The results that were reported for speech outcomes related to mandibular reconstruction with no soft tissue involvement of the tongue suggest that satisfactory speech outcomes were achieved across the 3 comparison groups. With respect to swallowing, the majority of patients who were in the tissue/toothsupported prosthesis and implant-retained prosthesis groups were able to resume a normal diet for the most part. This was not the case for patients who did not receive prosthetic rehabilitation. Many of these patients were restricted to liquid diets or feeding tubes. The presence of xerostomia was reported to play a critical role across all swallowing outcomes. Results for masticatory ability were more diverse across the 3 comparison groups. It is not surprising that patients who did not receive any prosthetic treatment performed most poorly in mastication tasks across the 3 groups, unless they had residual dentition. Patients rehabilitated with a conventional prosthesis were able to achieve some degree of masticatory function; however, it usually did not approximate normal levels. Most patients in this group were able to chew soft foods. The masticatory results for patients who were rehabilitated with an implant-retained prosthesis appeared to be the most favorable of the 3 comparison groups, with some studies reporting masticatory function that was on par with normal control subjects. Patients in this group were reported to be able to chew a variety of consistencies,

with tongue mobility and xerostomia playing a role in the level of function. On the other hand, quality-of-life outcomes did not appear to differentiate the 3 comparison groups, since most patients reported what could be considered satisfactory quality-of-life outcomes regardless of type of or presence of prosthetic rehabilitation.

Limitations of Current Studies

Having provided a synopsis of the literature on the topic of maxillary and mandibular reconstruction followed by prosthetic rehabilitation, it is necessary to highlight several issues and limitations of the included studies that prevent this review from reaching definitive conclusions. These limitations relate to patient and defect site heterogeneity, collapsing of data across prosthetic categories, the assessment methods used to determine functional outcomes, the time frame in which the evaluations took place, and the number of patients included.

It may be questioned why results were amalgamated if flaws existed in the studies that were reviewed. This exercise was important because it highlighted necessary issues to consider when designing future studies in this field of research. The first major issue in data reporting that was identified within this review was related to the heterogeneity associated with the patient population defect sites. For example, osseous reconstruction and soft tissue reconstruction results were often compiled, making it impossible to ascertain the results that were related to osseous reconstruction versus soft tissue reconstruction, thus leading to exclusion of some studies. In addition, many studies did not report on tongue involvement and function, which could lead to confusion in distinguishing the impact of tongue function on outcomes from those based solely on reconstruction of the osseous defect.

The issue of heterogeneity also arose in the reporting of prosthetic treatment, with many studies combining outcomes related to tissue/tooth-supported conventional prostheses and implant-retained prostheses, thereby making it difficult to ascertain the difference in outcomes for patients who received different types of prosthetic treatment. As such, these studies were excluded, and data from these articles were not used in this review. Furthermore, in the implant-retained prosthesis group, some studies did not specify whether the prosthesis was fixed or if it was an overdenture. In studies that did specify whether prostheses were fixed or were overdentures, outcomes were not reported separately for each type. Therefore, conclusions regarding implantretained prosthesis type could not be drawn. Related to the heterogeneity of prosthetic treatment was the fact that many studies reported that patients had residual

dentition but did not provide details such as how many occlusal contacts were present. Moreover, many studies did not report whether patients were treated with a prosthesis for a completely edentulous condition versus a partially edentulous condition. When this information was reported, outcomes were not delineated separately for each condition. Hence, the effect of dental condition on outcomes could not be established.

The method of measurement and assessment of functional outcomes was also an issue in many studies. In assessment of speech outcomes, many studies used rating scales that were not standardized, used study-specific intelligibility tests, or made use of listeners who were familiar with the patients. Using nonstandardized rating scales or tests makes it difficult to compare outcomes with other studies, and the use of listeners who are familiar with patients may bias the assessment of the outcomes. For swallowing outcomes, the vast majority of studies used diet tolerance as the only measure, with very few studies completing modified barium swallows to objectively assess swallowing function. Mastication was assessed in a wide variety of ways. Many studies completed rating scales and patient reports, with very few using objective methods to assess masticatory efficiency. Many quality-of-life outcomes focused solely on cosmesis and appearance. Of these, there was a wide variety of questionnaires used, both validated and researcher-created. Many articles did not specify exactly how cosmesis ratings were completed. It appeared that symmetry of facial contour was the main factor in the rating, which does not take into account the replacement of missing dentition. Thus, the common trend in the reporting of these outcomes was that there was a lack of use of standardized, objective measures. Finally, some studies reported on functional outcomes but did not specify how they were measured, leading to questionable interpretation of the results. The issue of assessment method was prominent in this review, since inclusion of studies using solely standardized and objective measures would have resulted in only a handful of studies from which to evaluate outcomes. Therefore, specifics on assessment protocol must be addressed in future studies.

Another issue in the review of the literature was related to the time frame in which the patient evaluations took place. Many studies included only post-operative assessments without any information on the patients' preoperative state. It has been shown that preoperative assessments are important in establishing a baseline for function to which later assessments can be compared.^{19,22,37-39} This allows for evaluation of whether postoperative function reaches preoperative levels. Related to this issue, the vast majority of studies in this review performed only 1 follow-up assessment, without considering trends over time. Because

comparison between preoperative and postoperative outcomes has proven to be important, comparing several follow-up assessments to track progress is important as well.^{19,22,38,40,41} Also, the follow-up periods differed greatly between studies, with some assessing patients a few weeks or months postoperatively, and others recalling patients several years after surgery. In the case of patients recalled several years after treatment, the question of how accurately the sample represents the entire population must be raised. In addition, some authors did not report the point in time at which they were completing the functional outcome assessments. Finally, the number of patients enrolled varied greatly across studies. Some studies included only a handful of patients, whereas others included a greater number, making it difficult to compare outcomes across studies. Also, in studies in which sample sizes were very small, meaningful interpretation of data is questionable.

The limitations of the reviewed literature lead to the view that, at present, it is not possible to draw firm comparative conclusions between the prosthetic treatments considered in reconstruction of the maxilla and mandible.

Future Directions

In this review, it was not feasible to make any conclusions about the type of free flap used for reconstruction and the associated outcomes. In the future, it may be interesting to pursue this line of research, especially in relation to the maxilla and whether rehabilitation with a conventional tissue/tooth-supported prosthesis after reconstruction with soft tissue is comparable to rehabilitation with an implant-retained prosthesis after reconstruction with an osseous flap. Unfortunately, only tentative conclusions can be reached about the outcomes associated with both maxillary and mandibular osseous reconstruction and associated prosthetic rehabilitation until some of the limitations related to functional outcome assessments are addressed. This is especially the case for speech and swallowing outcomes, for which many reports relied on subjective methods of information gathering. In addition, because subject numbers in this patient population were so limited, consensus on appropriate measures of function should be reached so that comparisons across institutions can be readily achieved.

Acknowledgments

The authors would like to acknowledge the support of the Alberta Heritage Foundation for Medical Research (no. 200600309).

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