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Functional outcomes of temporomandibular joint reconstruction with vascularized tissue

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ABSTRACT

Objective: To determine how current temporomandibular joint (TMJ) reconstruction methods affect functional outcomes.

Methods: Retrospective review from January 2006 to July 2017 at a single tertiary care center. All patients who underwent mandibulectomy with subsequent reconstruction with vascularized free tissue were included in the study. Condylar segments were reconstructed with vascularized free tissue flap in conjunction with autologous tissue or allograft in the joint space. Preoperative, 3 month, 1 year, and 2 year postoperative records were assessed for trismus, need for tube feeds, and Functional Oral Intake Scale (FOIS).

Results: Joint space was reconstructed with autologous tissue ($n = 10$), allograft ($n = 15$) or both ($n = 9$). At three months, FOIS scores significantly decreased from 5.4 preoperatively to 4.8 post operatively ($P = .024$) and need for tube feeds significantly increased from 15.8% preoperatively to 35.1% ($P \leq 0.027$). Trismus significantly decreased from 63.2% to 27% ($P = .006$). At one-year, there were no significant changes in functional status compared to pre-operative state. Patients who had previous RT had significantly worse FOIS scores preoperatively ($p = .002$), at three months ($p < .001$), one year ($p < .001$), and two years ($p = .008$). There was no significant difference in postoperative functional status of patients based on the method of TMJ reconstruction.

Conclusion: Reconstruction of the TMJ with vascularized free tissue is a viable option and yields acceptable long-term outcomes. While functional status may improve or worsen in the immediate postoperative period, long term results mirror preoperative function. Preoperative trismus will likely improve.

Level of evidence: Level 3; Retrospective Comparative Study.

1. Introduction

The TMJ has a functional role in mastication and contributes to normal deglutition, speech, and cosmesis [1]. However, there are no proposed methods for standardized assessment of functional outcomes of TMJ reconstruction. Most common assessments of functional success of TMJ reconstruction have included the comparison of pre- and post-operative trismus as well as the length of time requiring tube feeds [1]. In 2005, Crary et al. created the functional oral intake scale (FOIS) to evaluate and document the change in oral intake of food and liquid in stroke patients. The FOIS is an ordinal scale that reflects the functional oral intake of any patient with dysphagia [2].

Resection of the TMJ may be required when there is involvement of the joint by malignancy, osteomyelitis or osteoradionecrosis. In such cases, reconstruction of the joint is essential for restoring facial symmetry and re-establishing function. Free tissue transfer with bony composite flaps plays an important role in reconstruction of the TMJ, however careful attention to joint anatomy and mechanics is necessary to help prevent late complications [1,3,4]. Currently, there is a paucity of literature regarding reconstructive algorithms or techniques in re-creating the TMJ. The objective of this work is to evaluate our experience with TMJ reconstruction and our long-term functional outcomes.

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2. Methods

2.1. Study population

This study was performed with institutional review board approval. We retrospectively identified 39 patients who underwent mandibulectomy and microvascular free flap reconstruction with condylar reconstruction from a database of all patients within a single institution who underwent head and neck microvascular free flap reconstruction from January 2007 to July 2017. Patients who underwent mandibulectomy without condylar reconstruction were excluded.

2.2. Variables

Main outcome measures were postoperative swallowing functional status at three months, one year and two years postoperatively. Functional swallowing outcomes were assessed with the validated Functional Oral Intake Scale (FOIS). The FOIS score ranges from 1 to 7, with a score of 1 being equivalent to the patient not tolerating anything by mouth and a score of 7 being equivalent to a patient tolerating a total oral diet without restriction. Scores 1 to 3 require enteral supplementation via tube feeds [2]. Functional status was defined as a patient's oral intake as evaluated by the FOIS and need for enteral feeds but was not inclusive of trismus. FOIS scores, presence of trismus, and need for enteral feeds were determined from preoperative and postoperative clinical notes until last follow-up. Trismus was determined in a binary fashion as present or not present, based on clinical history and physical examination from clinic notes. Trismus was defined as inability to open the mouth 3 cm or greater. Need for enteral nutrition was also determined from clinic notes and defined as use of a gastrostomy tube for any amount of nutrition.

Functional status was also used to determine whether or not there was a significant difference between populations of patients. We analyzed the outcomes with varying reconstructive method of the TMJ, autologous tissue or allograft. Functional outcomes of patients who had undergone prior radiation therapy (RT) were also compared to those patients who had not.

2.3. Statistical methods

Statistical analysis was performed using R software (R Foundation for Statistical Computing, Vienna, Austria). All tests to determine statistical significance were two-sided, and statistical difference was defined as $P < .05$. Differences were calculated between preoperative and 3-month, 1-year, and 2-year postoperative endpoints for those patients who had data available. Differences were assessed using the Wilcoxon signed rank test with continuity correction.

2.4. Reconstructive technique

All patients underwent a two-team approach for resection and reconstruction. The composite flap was harvested during the time of the surgical extirpation. Composite free flaps consisted of fibula ($n = 39$), scapular ($n = 1$) or radial bone (n = 1). The ablative team pre-formed a reconstruction plate to the native mandible when possible and otherwise bent the plate as close to native mandible as possible free hand if the mandible was absent or tumor distorted the contour of the mandible. The composite flap was then harvested and osteotomies were performed. The vertical segment was measured to approximate the distal end directly into the glenoid fossa as compared to the contralateral side. The head of the neocondyle was contoured using a burr to create a smooth surface that would allow minimal restriction of joint mobility. Depending on the type of TMJ reconstruction, either soft tissue autograft or allograft was sutured to the neocondyle over the rounded end of the bone graft (Fig. 1). Decision for autologous tissue or allograft reconstruction of the joint space was determined intraoperatively by the senior authors. Autologous tissue was used if the surgeon determined there was adequate adipo-fascial tissue for resection from the soft tissue portion of the flap. If there was insufficient adipo-fascial tissue to cover the head of the neocondyle, allograft was used. A permanent retention suture was then placed through the plate and secured to the glenoid fossa (Fig. 2). The remainder of the bony flap was then secured to the plate in a standard fashion followed by microvascular anastomosis.

3. Results

Forty-one patients underwent mandibulectomy with microvascular free flap reconstruction with reconstruction of the condyle. There were 28 males and 13 females. Mean age at the time of surgery was 55.2 years. Eight of the patients were current smokers and 17 were current alcohol drinkers at the time of surgery. Twenty-nine percent of the patients had undergone prior radiation to their head and neck, 22% had received prior chemotherapy.

Sixteen patients underwent mandibulectomy for malignant lesions and 25 patients for benign disease. Mandibular defects were as follows: 28 hemimandibulectomies, 4 total, 3 subtotal, 5 only including the mandibular condyle, ramus and angle, and 1 patient underwent removal of a TMJ prosthesis. There were 3 free flap failures.

Autologous tissue (muscle, fascia) alone was used in the joint space in 10 patients, allograft alone was used in 15 patients, and both were used in 9 patients. Exact method of condylar reconstruction could not be determined from operative notes in 7 patients. These patients were included in analysis but excluded from reconstruction specific analysis and comparison.

Functional outcomes of microvascular free flap reconstruction of all patients with condylar reconstruction are shown in Table 1. Of the 41 reconstructions, only 38 patients had preoperative clinic notes that were available for assessment of preoperative functional status. At three month follow-up FOIS scores significantly decreased from 5.4 preoperatively to 4.8 ($P = .024$) and need for tube feeds significantly increased from 15.8% preoperatively to 35.1% at 3 month follow-up ($P \leq 0.027$). However, trismus significantly decreased from 63.2% to 27% ($P = .006$). At one-year follow-up there were no significant changes in functional status as compared to preoperative assessment (mean FOIS score = 5.7; patients with trismus 13%; need for tube feeds 21.7%). Two-year follow-up data is limited, as data on only 12 patients was available due to a combination of death and being lost to follow up.

Functional outcomes over time of the patients who received preoperative RT as compared to those who did not receive preoperative RT are shown in Table 2. Patients who had previous RT had significantly worse FOIS scores preoperatively ($p = .002$), at three months ($p < .001$), one year ($p < .001$), and two years ($p = .008$) postoperatively. Similarly, there were worse outcomes for patients who received RT in regards to need for tube feeds. There were significantly more patients with need for tube feeds who were previously radiated preoperatively (< 0.001), at three months ($p = .028$) and one year ($p = .003$). There was no significant difference in the number of patients with trismus at any point before or after surgery (preoperatively $p = .472$, three months postoperatively $p = .442$; one year $p > .999$; two years $p > .999$).

There was no significant difference in postoperative functional status of patients based on the method of TMJ reconstruction. Functional status at each postoperative time point was compared between whether the patient had reconstruction with allograft, autograft or both. At one-year follow-up there was no significant difference in FOIS scores ($p = .995$), trismus ($p = .763$), and need for tube feeds ($p = .814$) (Table 3). Similarly, there was no significant difference in functional outcomes based on method of reconstruction at three months and two years (tables not shown).

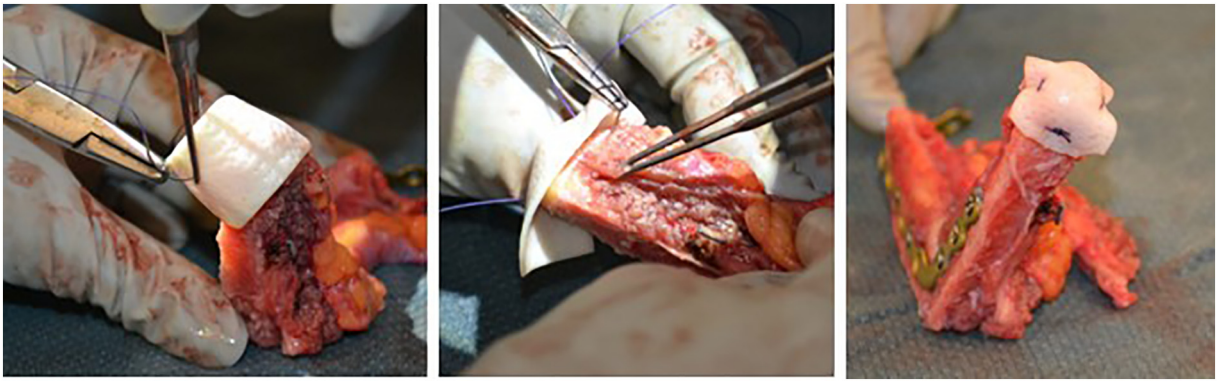

Fig. 1. Allograft placement on the Neo-Condyle.

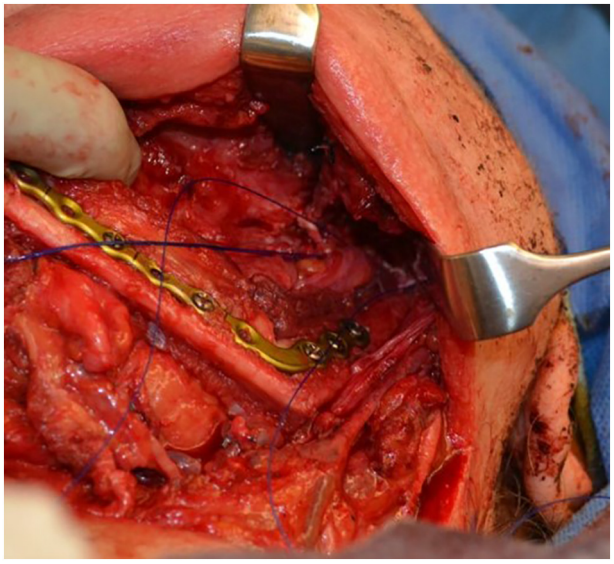

Fig. 2. Placement and securing of the Neo-Condyle into the Glenoid Fossa.

4. Discussion

Various non-vascularized techniques have been described to reconstitute the TMJ including free bone grafts and titanium prosthesis [5–7]. When these options are unfavorable, free composite tissue transfer is the preferred method. Reconstruction is commonly completed by fibular free flap, however scapular, osteocutaneous radial forearm free flaps, iliac crest, costochondral and free vascularized second metatarsal have also been shown to have varying success [3,4,8,9,10–13]. Disruption of the TMJ can result in several functional impairments. Disruption of the disc within the bi-arthrodial joint can lead to chronic pain, trismus, and joint instability. Removing and replacing the condyle disrupts the ligamentous support of the joint that creates instability that is necessary for proper mastication, deglutition, and speech [1]. To prevent poor cosmesis and long-term functional deficits, significant care and consideration of postoperative radiation, bone resorption, and fibrosis must be taken into account when reconstructing the TMJ. When using a vascularized free flap reconstruction of the TMJ with minimal debilitation is challenging.

Attempts to preserve the TMJ can only be undertaken after adequate margin control for malignancy that may interrupt the capsule or leave little residual mandible. Preservation of a small bone fragment or interrupted capsule may not prove to be easier to rehabilitate than a completely resected condyle. The joint itself can be reconstructed to prevent contact between the neomandible and the glenoid fossa. Direct bony contact at this articulation can predispose to postoperative inflammation, pain, ankylosis and trismus. There is support for preserving the temporomandibular disc during mandibular resection as studies suggest that this prevents ankylosis [4,11]. Other studies have demonstrated that autologous soft tissue within the joint space is also a viable option [1,8,12,14]. As described in 2007 by Khariwala, Alloderm™ (Allergan, Madison NJ) is used to cover the neocondyle and allows reapproximation of the joint capsule with presumed decreased morbidity. The Alloderm™ is placed at the distal end of the bone flap and placed in the glenoid fossa without additional fixation. The lack of postoperative displacement of the Alloderm™ is theorized to be due to scarring creating a “neocapsule.” Their study claimed normal post-operative facial symmetry, 78% normal occlusion, decreased trismus, adequate jaw opening, minimal jaw drift, and improved ability to chew [15]. However, they did not compare their use of Alloderm™ to their use of autograft for coverage of the neocondyle. It is important to note that periosteum is not recommended as an autograft for joint space reconstruction as this may further develop into bone [16].

Within our study, following reconstruction of the TMJ with either Alloderm™ or autograft, all patients experienced returns to their baseline preoperative functional status at 1 and 2 years postoperatively. At 3 months postoperatively, patients experienced significant improvement in their trismus but also had significantly worse outcomes in their FOIS score and need for tube feeds. Although there was no statistically significant improvement in patient's functional status as a result of surgery, there was no significant worsening in their functional status. These findings are consistent with Wax et al.'s retrospective study of TMJ reconstruction with fibula free flaps [1].

To determine if previous radiation served as a confounding variable to our outcomes, we analyzed those patients that had previous RT

Table 1
Functional outcomes of all patients as compared to preoperative status.

	Preoperative, no. of patients (%), $N = 38$	3 Months, no. of patients (%), $N = 37$	P-value	1 Year, no. of patients (%), $N = 23$	P-value	2 Years, no. of patients (%), $N = 12$	P-value
FOIS	5.4	4.8	0.024	5.7	0.576	5.5	0.054
Trismus	24 (63.2)	10 (27)	0.006	3 (13)	0.105	3 (25)	0.131
Tube feeds	6 (15.8)	13 (35.1)	0.027	5 (21.7)	0.247	2 (16.7)	> 0.999

FOIS = Functional Oral Intake Scale.

Table 2
Functional status differences between non-radiated and previously radiated patients.

	Preoperative RT, no. of patients (%), N = 12	Preoperative no RT, no. of patients (%), *N* = 26	P-value	3 Months RT, no. of patients (%), *N* = 11	3 Months no RT, no. of patients (%), N = 26	P-value	1 Year RT, no. of patients (%), *N* = 5	1 Year no RT, no. of patients (%), *N* = 18	P-value	2 Years RT, no. of patients (%), *N* = 4	2 Years no RT, No. of patients (%), *N* = 8	*P*-value
FOIS score	3.5	6.2	0.002	2.8	5.6	< 0.001	3.0	6.4	< 0.001	3.5	6.5	0.008
Trismus	9 (75)	15 (57.7)	0.472	4 (36.4)	6 (23.1)	> 0.442	0 (0)	3 (16.7)	> 0.999	1 (25)	2 (25)	> 0.999
Tube feeds	6 (50)	0 (0)	< 0.001	7 (63.6)	6 (23.1)	0.028	4 (80)	1 (5.6)	0.003	2 (50)	0 (0)	0.091

FOIS = Functional Oral Intake Scale.

separately from non-irradiated patients. We then compared their postoperative functional outcomes to each other. Previously radiated patients did not have any significant improvement in their functional status, however they did not experience any significant worsening either. Patients who did not have previous radiation did have a significant improvement in their trismus at 3 months and 1 year postoperatively. Yet their trismus returned to their preoperative baseline at 2 years postoperatively. FOIS scores remained insignificantly unchanged throughout the 2 year postoperative period. When comparing the functional status of previously irradiated and non-irradiated patients, we found that FOIS scores were significantly better in non-irradiated patients in the pre and post-operative period. Need for tube feeds was also significantly worse in previously irradiated patients except at 2 years post operatively, in which there was no difference. Trismus was not significantly different between the two groups at any time period (Table 2).

These results demonstrated that previous radiation negatively impacts the long-term sequelae on functional status in TMJ reconstruction. However, the degree to which it makes patients more susceptible to worse outcomes in TMJ reconstruction is unclear. Notably, the need for tube feeds in non-irradiated patients increased and were similar to previously irradiated patients at 2 years postoperatively. All patients who had prior radiation or scheduled to undergo postoperative radiation had prior dental consultation. Side effects of external beam radiation such as dysphagia, fibrosis, and neuropathy as well as mucositis and even depression are all possible explanations for our findings [17,18].

Irrespective of exposure to radiation, postoperative trismus outcomes were intriguing. The initial postoperative improvements in trismus could potentially be attributed to rehabilitation of the TMJ. Our patients undergo a physical therapy popsicle-stacking regimen to expand their oral aperture postoperatively. Worsening of trismus over time could be due to patients discontinuing their physical therapy, a development of restrictive scar tissue around the neocapsule of the reconstructed TMJ, contralateral joint ankylosis, or a combination of both.

When comparing Alloderm™ to autologous tissue there was no statistically significant difference between the two methods at any time (Table 3). There were no documented infectious complications to compare between the two methods. Khariwala et al. described the use of Alloderm™ in 2007 and did not note any complications in their limited study size [15]. However, costs of the xenograft could lead surgeons to choose autologous reconstruction when given the option.

Collectively, these findings help our own understanding of TMJ reconstruction and allow us to counsel our patients and adjust postoperative expectations in the setting of prior adjuvant therapy. Furthermore, our study offer insight into making cost effective reconstructive decisions.

Additional studies need to be completed to identify adjunctive therapeutic exercises for the TMJ rehabilitate postoperative trismus in the reconstructed joint.

5. Conclusion

Reconstruction of the temporomandibular joint with vascularized free tissue is a viable option and yields acceptable long-term outcomes. While functional status may improve or worsen in the immediate postoperative period, long term results mirror preoperative function. Preoperative trismus will likely initially improve after TMJ reconstruction. Method of reconstruction does not appear to affect patient's functional status or level of trismus postoperatively. Patients with history of radiation therapy had worse functional outcomes as compared to patients without prior radiation irrespective of the joint space repair method.

Table 3
Functional outcomes at 1 year postoperatively, comparing TMJ reconstruction.

	Preoperative no. of patients (%), *N* = 32	1 year no. of patients with allograft (%), N = 10	1 year no. of patients with autograft (%), N = 4	1 year no. of patients with both (%), *N* = 6	P-value
FOIS	5.2	5.7	5.5	5.2	0.955
Trismus	20 (62.5)	1 (10)	1 (25)	1 (16.7)	0.763
Tube feeds	5 (25)	2 (20)	1 (25)	2 (33)	0.814

FOIS = Functional Oral Intake Scale.

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Disclosures

There are no conflicts of interest for any of the authors mentioned above.

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References

[1] Wax MK, Winslow CP, Hansen J, et al. A retrospective analysis of temporomandibular joint reconstruction with free fibular microvascular flap. Laryngoscope 2000;110:977–81.
[2] Crary MA, Mann GD, Groher ME. Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. Arch Phys Med Rehabil 2005;86:1516–20.
[3] . González-García, R, MD; Naval-Gías, L, MD, DMD,PhD; Rodríguez-Campo, F, MD; Martínez-Chacón, J, MD; Gil-Díez Usandizaga, J, MD; Vascularized fibular flap for reconstruction of the condyle after mandibular ablation. Journal of Oral Maxillofacial Surgery, 2008, 66:1133–1137.
[4] Thor Andreas, Rojas Rafael Acosta, Hirsch Jan-Michael. Functional reconstruction of theTemporomandibular joint with a free fibular microvascular flap. Journal of Plastic and Reconstructive Surgery and Hand Surgery, July 2009;42(5):233–40.
[5] Van Loon JP, de Bont GM, Boering G. Evaluation of temporomandibular joint prostheses: review of the literature from 1946 to 1994 and implications for future prosthesis designs. J Oral Maxface Surg 1995;53:984–97.
[6] Wolford LM, Pitta MC, Reiche-Fischel O, Franco PF. TMJ Concepts/Techmedica custom-made TMJ total joint prosthesis: 5-year follow-up study. Int J Oral Maxillofac Surg 2003;32:268–74.
[7] Mercurg LGDDS. MS. The use of alloplastic prostheses for temporomandibular joint reconstruction. J Oral Maxillofac Surg 2000;70(75):58.
[8] . Petruzzelli, G. MD, PhD; Cunningham, K. MD; Vandvender, D. MD; Impact of mandibular condyle preservation on patterns of failure in head and neck cancer. Otolaryngology–head and neck Surgery (2007) 137, 717–721.
[9] Bond SE, Saeed NR, Cussons PD, Watt-Smith SR. Reconstruction of the temporomandibular joint by the transfer of the free vascularised second metatarsal. Br J Oral Maxillofac Surg 2004;42:241–5.
[10] Saeed NR, Kent JN. A retrospective study of the costochondral graft in TMJ reconstruction. Int J Oral Maxillofac Surg 2003;32:606–9.
[11] Guyot L, Richard O, Layoun W, et al. Long-term radiological findings following reconstruction of the condyle with fibular free flaps. J Craniomaxillofac Surg 2004;32:98–102.
[12] . Wallace, CG. M.B.Ch.B., M.S.; Chang, YM. D.D.S.; Tsai, CY. D.D.S.; Wei, Fu-Chan M.D. Harnessing the potential of the free fibula Osteoseptocutaneous flap in mandible reconstruction Plast Reconstr Surg, January 2010 – Vol 125, Iss 1 – p305–314.
[13] Mehta, RP. MD; Deschler, D. MD; Mandibular reconstruction in 2004: an analysis of different techniques. Current opinion in Otolaryngology & Head and neck surgery. August 2004-Vol vol. 12-Iss 4. p288–293.
[14] Umeda H, Kaban LB, Pogrel MA, Stern M. Long-term viability of the temporalis muscle/fascia flap used for temporomandibular joint reconstruction. J Oral Maxillofac Surg 1993;51:530–3. [discussion 534].
[15] Khariwala, S. MD; Chan, J. MD; Blackwell, K. MD; Alam, D. MD. Temporomandibular joint reconstruction using a vascularized bone graft with Alloderm™. J Reconstr Microsurg, Jan 2007, vol 23–1, 25–30.
[16] Mackie EJ. Osteoblasts: novel roles in orchestration of skeletal architecture. Int J Biochem Cell Biol 2003;35(9):1301–5.
[17] Brain Lin BA, Heather Starmer MA, Christine Gourin MD. The relationship between depressive symptoms, quality of life, and swallowing function in head and neck cancer patients 1 year after definitive therapy. Laryngoscope 2012;122(7):1518–25. Jul.
[18] Hutcheson KA, Lewin JS, Barringer DA, et al. Late dysphagia after radiotherapy-based treatment of head and neck cancer. Cancer 2012;118:5793–9.