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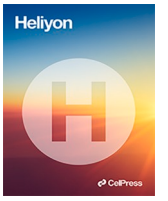

Research article

Osteo-cutaneous microvascular free-flaps are a viable option for reconstructing the temporomandibular joint

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ABSTRACT

Background: There are multiple reconstructive options after mandibular resection and disarticulation of the condyle. The purpose of this study was to assess the clinical outcomes and functionality of osteocutaneous free flaps in the reconstruction of mandibular defects that involve the Temporo-Mandibular Joint (TMJ).

Methods: Our study is a retrospective cohort study involving subjects who underwent mandibular resection and needed TMJ reconstruction with vascularized bony-free flaps from February 2016 to June 2018. Data gathered included patient demographics, post-operative function, maximum interincisal opening (MIO), occlusion status, deviation on opening, and TMJ symptoms. Data points collected from postoperative CT imaging included the following: position of the flap in relation to the glenoid fossa and articular eminence, and closest point of contact.

Results: Eight out of the nine patients who underwent free flap reconstruction of mandibular defects involving the TMJ qualified for the study. The mean age was 39.7 years old. In all 8 cases, virtual surgical planning (VSP) was used. The mean follow-up time was 18.75 months. The flap success rate was 100%. The mean MIO was 37.37 mm. Six patients resumed their premorbid diet, and one patient developed dysphagia and was peg tube dependent. In seven cases the occlusion was intact and reproducible, one case was without sufficient teeth for occlusion. On imaging, the mean distance from the neo-condyle to the glenoid fossa was 14 mm and to the articular eminence 8.68 mm. The point of closest contact in all cases appeared to be the articular eminence.

Conclusion: Vascularized Osteocutaneous-flaps such as FFFs and DCIA flaps provide a good option for the reconstruction of mandibular defects that involve the TMJ. Ipsilateral deviation on opening does not negatively affect clinical outcomes or function. Placing patients in Maxillomandibular fixation for 4–6 weeks may help to prevent condylar sag and provide stable post-operative occlusion.

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1. Introduction

The TMJ has a functional role in mastication and contributes to normal deglutition, speech, and cosmesis [1]. Some disease processes, such as odontogenic tumors, malignant disease, or osteoradionecrosis can result in extensive mandibular defects (Fig. 1) [2]. This in turn can lead to compromise in functionality and esthetics, particularly when lesions involve the condyles [3].

Several options have been previously reported in the literature when reconstructing mandibular defects involving the condyle. These include the use of a condylar head prosthesis on a reconstruction bar. Another described treatment includes the use of a stock or custom temporomandibular joint prosthesis in isolation or in addition to the use of a free bone graft or fibula osteo-cutaneous free flap. Alternatively, the use of bony reconstruction with costochondral grafts or fibula osteo-cutaneous free flaps has been described, where the direct placement of the distal end of the costochondral graft or the fibula flap into the glenoid fossa is performed with or without contouring [4–6].

Alloplastic reconstruction of the condyles with a recon bar and condylar head has been historically associated with several complications like plate fracture and sensory disturbances [7–9]. Custom and stock TMJ prostheses work well but have limitations depending on the amount of bone and soft tissue that is being reconstructed simultaneously [10–12]. Additionally, they are not ideal in wounds with poor recipient beds due to multiple prior surgeries, infection, or irradiation [13–15]. Costochondral grafts have similar limitations [13–17]. The purpose of this study is to assess the clinical outcomes and effectiveness of osteo-cutaneous free flaps in the reconstruction of mandibular defects that include the condylar head, specifically with regards to post-operative function.

2. Materials/methods

2.1. Study design/sample

To address the research objective, the investigators employed a retrospective cohort study design. Approval was granted by the Internal Review Board (IRB) at Cook County Health, Chicago, IL. The study population was composed of all patients that underwent mandibular ablative surgery including the condyles and received TMJ reconstruction using a vascularized bony free flap between February 2016 and July 2021 which revealed a total of 8 patients.

The inclusion criteria for this study include having a complete medical record, being 18 years old or older, needing mandibular resection including the condyle, and having undergone free flap reconstruction for benign or malignant disease. Exclusion criteria include patients who lost to follow-up in the immediate postoperative period.

2.2. Data collection

Data collection included a review of the Cook County Health patient registry for a list of patients who needed mandibular resection and TMJ reconstruction between February 2016 to June 2018. Data was collected through a retrospective chart review. The data collected was categorized as follows.

Fig. 1. Mandibular segment including the condyle after resection.

Table 1
Patients data.

Patient	1	2	3	4	5	6	7	8
Age (years)	59	47	31	65	27	26	32	31
Sex/Race	F/Hispanic	M/African American	M/White	M/White	F/African American	M/African American	F/Hispanic	F/Hispanic
Pathology	Ameloblastoma	OKC, SCC	OKC	ORN	OKC	Ameloblastoma	Recurrent Ameloblastoma	Chondrosarcoma
Location of Lesion	R posterior mandible	R posterior mandible	L mandible	L posterior mandible	R posterior mandible	L mandible	L posterior mandible	R posterior mandible
Urken Classification	CRB	CRB	CRBS	CRB	CRB	CRBS	CRB	CRB
Type of Reconstruction	FFF	FFF	DCIA	FFF	FFF	FFF	FFF	FFF
Number Of reconstruction segment	2	2	2	2	2	2	2	2
Vessel coming off anterior vs posterior aspect of reconstruction	Anterior	Anterior	Anterior	Anterior	Anterior	Anterior	Anterior	Anterior
Location of anastomoses (ipsilateral vs contralateral)	Ipsilateral	Ipsilateral	Ipsilateral	Ipsilateral	Ipsilateral	Contralateral	Ipsilateral	Ipsilateral
Radiation Therapy (pre-op - post op)	N/A	No	N/A	Pre-op	N/A	N/A	N/A	No

Table 2
Post-op and Radiographic data.

Patient	1	2	3	4	5	6	7	8
Post-Op Data								
Duration of post-op MMF	Not available	4 weeks	5 weeks	6 weeks	5 weeks	12 weeks	6 weeks	5 weeks
Follow up time (months)	26	15	16	8	2	60	4	19
Flap survival rate	100%	100%	100%	100%	100%	100%	100%	100%
Post-op complications	None	Post op infection	None	Unresolved dysphagia	None	Left neck abscess, right neck hematoma Concern for osteomyelitis (on long-term Abx)	L lower extremity delayed wound healing	None
Articulation point	Fibula head to eminence	Fibula head to eminence	Iliac to eminence	Fibula head to eminence	Not available	Fibula head to eminence	Not available	Fibula head to eminence
Diet	Soft	Regular	Regular	PEG Tube	Full liquids	Regular	Soft	Regular
MIO at 1st F/U after MMF release (mm)	35	29	57	Not available	25	25	Not available	18
MIO at last F/U (mm)	35	45	50	25	40	35	40	29
Occlusion (presence of stable reproducible occlusion)	Non-reproducible (partially edentulous)	Reproducible	Reproducible	Reproducible	Reproducible	Reproducible	Reproducible	Reproducible
Deviation on opening	Ipsilateral	Ipsilateral	Ipsilateral	Ipsilateral	Ipsilateral	Ipsilateral	Ipsilateral	None
Pain, clicking, popping	Not available	None	None	Not available	None	None	None	None
Radiographic Data								
Post-op CT (Yes, No)	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Distance from articular eminence to the fibula head (mm)	20.9	4.8	3	18.7	Not available	3.7	Not available	1
Distance from glenoid fossa to the fibula head (mm)	22.4	12	11.4	24.4	Not available	9.8	Not available	4
Rounding-off of fibula head	Yes	Yes	Yes	Yes	Not available	No	Not available	Yes

- **Patient demographics and defect characteristics:** Patient demographics, underlying pathology, history of radiation therapy, the extent of resection involved characterized by Urken classification for mandibular defects, and planned type of reconstruction (Table 1).
- **Intraoperative data points:** Number of reconstruction segments, the orientation of vascular pedicle as coming off the anterior vs posterior aspect, and location of anastomoses (ipsilateral vs contralateral) (Table 1).
- **Postoperative data collected included**: follow-up duration (months), duration of post-op maxillo-mandibular fixation (MMF), flap survival rate, and post-op complications. Functional outcomes included type of postoperative diet, maximum interincisal opening (MIO: the distance from the mesioincisal edge of the upper right central incisor to the mesioincisal edge of the lower right central incisor) at time of release maxillomandibular of MMF, MIO at last follow-up, occlusion (presence of stable reproducible occlusion), mandibular deviation on opening, pain during function on chewing or mouth opening (yes/no), and presence of clicking or popping (yes/no) (Table 2).
- **Radiographic evaluation (Post-op CT evaluation) included:** rounding-off of the fibular head (yes/no), distance from articular eminence to the fibula head (mm), distance from glenoid fossa to the fibula head (mm), and location of closest articulation point (Table 2).

2.3. Data analysis

In our study, we employed descriptive data analysis as a fundamental component of our research methodology. This analytical approach played a role in unraveling the essential characteristics and patterns inherent in the collected data, offering valuable insights into the clinical outcomes and functionality of osteo-cutaneous free flaps in the reconstruction of mandibular defects that involve the Temporo-Mandibular Joint (TMJ). Continuous variables were reported as mean ± standard deviation (95% confidence interval). Categorical data were presented in frequencies and percentages (%).

3. Results

Of the 9 patients who underwent bony free flaps reconstruction of the mandibular condyle at our hospital, 1 patient lost their follow-up with no post-operative data collected and was excluded from the study. The mean age in our study was 39.7 years old (range 26–65 years). All 8 patients had disease processes that had extensive mandibular involvement and were not amenable to enucleation and curettage. The underlying pathology included 3 cases of ameloblastoma, 1 case of osteoradionecrosis (ORN), 2 cases of keratocyst (OKC), 1 patient with Chondrosarcoma, and one case of squamous cell carcinoma (SCCA) that developed in the setting of recurrent

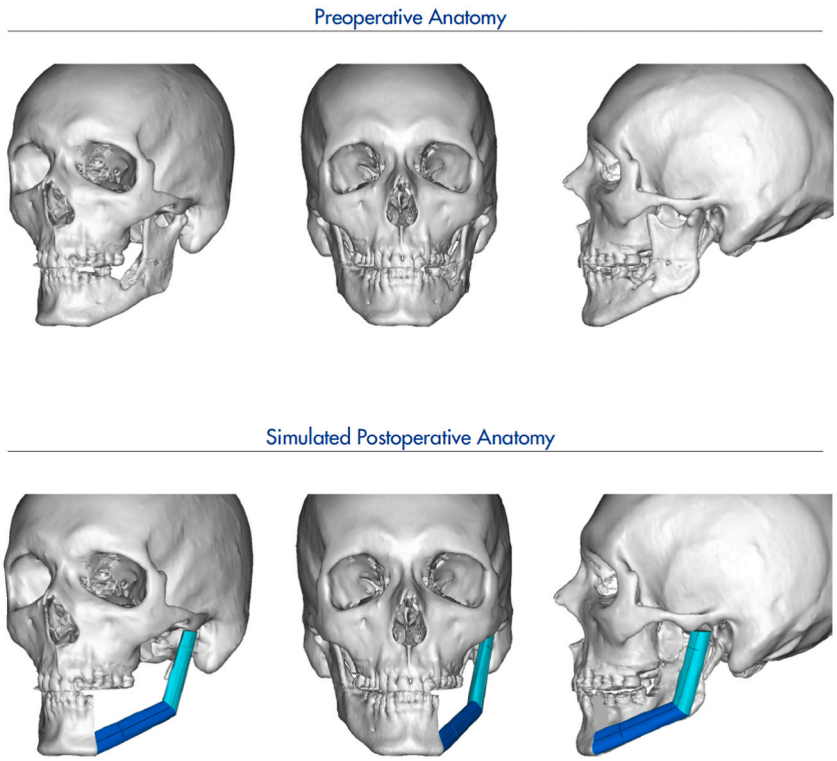

Fig. 2. Virtual surgical planning (VSP).

OKC.

All patients underwent microvascular osteo-cutaneous reconstruction of mandibular defects involving the condyle. Seven patients underwent reconstruction using a vascularized fibula free flap (FFF) and one patient was reconstructed with a deep circumflex iliac artery (DCIA) flap. Using the HCL by Jewer and Boyd classification, all eight patients had resulting defects that were of the H class, involving a unilateral condyle, ramus, and variable portions of the mandibular body. Using the Urken **CRBS** classification for mandibular defects (**C**ondyle, **R**amus, **B**ody, **S**ymphysis) [13], 6 patients were class CRB, and 2 patients were class CRBS (Table 1).

In all eight cases, virtual surgical planning (VSP) was utilized. The neo-condyle was virtually planned 1 cm inferior to the glenoid fossa to avoid interferences in 7 of the 8 cases (Fig. 2). Intraoperatively, no fibular head adjustments were required. The mean number of segments used per case was 2 segments (Table 1). Patients were placed in MMF for an average of 6.14 weeks (SD±2.4743) post-operatively. The mean postoperative follow-up time was 18.75 months (range 2–60 months). The flap success rate was 100%. The mean MIO was 37.37 mm (SD±7.6311). Seven patients resumed their premorbid diet, and one patient who had ORN and significant radiation-induced fibrosis developed dysphagia and was peg tube dependent. In 7 cases the occlusion was intact and reproducible, and one case was without sufficient teeth for occlusion. In one case, there was a gradual multifocal resorption of the fibular segment reconstructing the ramus-condyle unit. This however did not have an impact on the patient's function or reproducibility of occlusion.

There was a deviation of the mandible on opening to the ipsilateral side in 7 of the 8 cases, the amount of deviation was not recorded in this cohort. In the 6 patients with postoperative CT data, the mean distance from the neo-condyle to the glenoid fossa was 14 mm (SD±7.1544) and 8.68 mm (SD±7.9668) to the articular eminence. The point of closest contact in those cases was the articular eminence (Table 2).

4. Discussion

Certain pathologies of the mandible have been documented to extend to the condyles. Resection of the condylar head is occasionally indicated to achieve adequate surgical margins. This leads to aesthetic and functional defects [18]. The purpose of this study was to share our experience in restoring the temporomandibular joint and assess the functional outcomes and feasibility of the use of microvascular bony free-flaps in the reconstruction of mandibular defects that involves the TMJ. The current experience supports the findings of prior authors, that microvascular free flaps are a reliable method in reconstructing the TMJ with favorable post-operative outcomes.

Among TMJ reconstruction options are alloplastic total joint replacements, reconstructions with a condylar head prosthesis, non-vascularized bony flaps, and microvascular free flaps [10,11] Reconstruction bars with condylar heads are usually used as an interim treatment due to the high complication risk involved like plate fracture and/or exposure, facial nerve damage, and erosion into the external auditory meatus or skull base [7,8]. Total joint replacement prostheses like TMJ Concepts work well in cases with completed bone growth, benign tumors, and defects that do not have a large soft tissue component [10–12]. The use of free bone grafts for defects involving the TMJ has been widely reported. Free bone grafts can be associated with resorption, degenerative changes, and ankylosis [6,19,20].

Microvascular osteo-cutaneous free flaps like FFF may be of help when replacing the TMJ in cases where the recipient's bed has been disrupted by previous surgeries or radiation therapy and in cases with large soft tissue defects [13–17]. Bone quality of the fibula flap is ideal for mandibular reconstruction. The tubular shape of the flap adapts well to the glenoid fossa [21–23].

In our series which comprises eight cases, the utilization of microvascular free-flaps for reconstructions emerged as a highly effective and viable treatment modality. The observed outcomes were notably favorable, with the restoration of both functional

Table 3
TMJ reconstruction series.

Author	Number of patients	Average age (years)	Flow-up period (months)	Average MIO (mm)	Satisfactory Tx outcome (yes/no)	Pain during function (yes)
1- Wax et al	17	62	41.3	34	11/12 (yes), 1 pt judged cosmesis as unacceptable, 5 did not report	1/11, 6 did not report
2- González-García et al	6	47.3	36	40	5/6 (yes)	1/6
3- Dowgierd et al	11	12.6	52.2	38.75	10/11 (yes),	Not reported
4- Powers et al	5	62	29.2	38.2	5/5 (yes)	None
5- Landa et al	4	29	150	48.5	4/4 (yes)	None
6- Thor et al	4	57.75	36	34	3/4 (yes),	Not reported.
7- Guyot et al	11	41	72	33.6	Not reported	Not reported
8- L Xia et al	4	49.75	8.5	31.5	4/4 (yes)	None
9- Tang et al	43	41.95	26.37	More than 35 in 76.7%, less than 35 in 23.3%	40/43 (yes), patients were dissatisfied with functional recovery	2/43
10- Bond et al	5	40	112.2	30.83	4/5 (yes)	1/5
11- Yoshimura et al	5	61	23	31.2	5/5 (yes)	None
12- Pang et al	15	27.3	75.9	31.29	11/15 (yes),	Not reported
Qaisi et al (Current Study)	8	39.7	18.75	37.37	7/8 (yes),	None

capabilities and aesthetic features achieved successfully. It is noteworthy that none of the patients in our study cohort developed ankylosis, indicating a positive trend in post-treatment conditions.

While one patient exhibited resorption of a fibular segment over time, it is essential to highlight that this occurrence did not adversely impact either function or occlusion. Remarkably, the majority of our patients, specifically seven out of eight, were able to resume a soft to regular diet, showcasing the overall positive impact of the treatment approach.

The measurement of Maximum Intercuspation Opening (MIO) across all patients yielded satisfactory results, with a mean value of 37.4 mm. This comprehensive assessment underscores the successful and multifaceted outcomes achieved through the application of microvascular free-flaps in the context of our study.

Despite the observed ipsilateral deviation of the mandible during mouth opening, patients did not report any concerns, and the occlusion remained stable and reproducible. Following the removal of the mandibular condyle and the introduction of a fibula-free flap or another type of free tissue graft for reconstruction, various alterations occur in the temporomandibular joint region. These changes include distortion of muscle attachment, spatial disarrangement of articulation components, and variations in shape between the neo-condyle and the native contralateral condyle. Together, these factors may contribute to the deviation of the mandible during function [24,25].

Table 3 summarizes twelve previous series on the application of FFF for the reconstruction of temporomandibular joints [1,3,4,13,16,20,26–31]. The utilization of fibula flaps for TMJ reconstruction was documented by Hirsch et al. in their series. Both our study and their study reported similar patient experiences, no pain on chewing, comparable maximum incisal opening, and achieved excellent functional outcomes. Similar to their experience, (VSP) was utilized in all our cases [26–32]. VSP aids in the precise planning and positioning of the reconstruction.

In our series, we placed patients in maxillomandibular fixation (MMF) for average of 4–6 weeks to avoid condylar sag secondary to flap weight. This is in line with other authors such as Powers et al. who reported 7–14 days of MMF while Yoshimura et al. had postoperative MMF applied for 10–21 days (mean, 15.8 days) [24,29]. Other authors reported no use of MMF. Wax et al. reported other technique of stabilizing the fibula flap by suturing the flap head to the articular disk or directly to the lip of the mandibular fossa in cases where the disk had to be sacrificed [1]. One of our patients stayed in MMF for 12 weeks due to take back and exploration of area medial to proximal segment.

Pang et al. and González-García et al. reported on patients developing ankylosis after osteo-cutaneous free flap reconstruction of the TMJ [4,13]. This was not encountered in our series. Ankylosis was reported in a total of 5 out of the 138 patients (3.6%) summarized in Table 3.

To our knowledge, our study is the first series to report on the direct articulation of the DCIA flap into the mandibular fossa when reconstructing the temporomandibular joint. This was utilized in a patient who had lower extremity vascular anatomy that was not amenable to a fibula free flap harvest. DCIA flaps provide similar benefits to those of the fibular free flap, and maybe used when patients are not candidates for fibula free flap reconstruction.

Weaknesses of the current series include the retrospective nature of the study, small sample size, and relatively short follow up period (18.75 months).

5. Conclusion

Vascularized Osteocutaneous-flaps such as FFFs and DCIA flaps provide a good option for the reconstruction of mandibular defects that involve the TMJ. Ipsilateral deviation on opening may be commonly encountered after surgery but does not negatively affect clinical outcomes or function.

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Ethics statement/confirmation of patients' permission

The hospital Institutional Review Board granted permission for the study. Patients' permission was not required as no identifying data are presented.

Data availability

Has data associated with your study been deposited into a publicly available repository? No, data will be made available upon request.

CRediT authorship contribution statement

Mohammed Qaisi: Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Conceptualization. **Thaer Al Azzawi:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Fanti Joseph:** Software, Resources. **Biraj Shah:** Validation, Resources, Formal analysis. **James Murphy:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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