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ORIGINAL ARTICLE

The deep circumflex iliac artery free flap in maxillofacial reconstruction: a comparative institutional analysis

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Abstract

Purpose The aim of the present study was to perform a comparative analysis of the utility, outcomes, and complications of DCIA (deep circumflex iliac artery) flap for the reconstruction of maxillofacial defects between two institutions that continue to use the DCIA flap as a reconstructive resource.

Materials and methods This retrospective analysis included a total of 68 patients (mean age 51.1 years) at the University Hospital of Parma, Parma, Italy, and the University of Maryland, Baltimore, USA, between January 2010 and April 2019.

Results No statistical differences were found in relation to the site of reconstruction ($p = 0.09$), bone graft quantity ($p = 0.93$), rehabilitation with dental implants ($p = 0.464$), length of hospitalization ($p = 0.086$), BMI (0.677), swallow function ($p = 0.419$), medical comorbidities ($p = 0.933$), pre-existing radiation ($p = 0.691$), adjuvant treatment ($p = 0.298$), ECOG-PS pre-and post-surgery ($p = 0.329$; $p = 0.545$), and flap failure: one partial failure observed ($p = 0.412$) and donor site morbidities ($p = 0.742$). A noted trend to increased risk of hernia without the use of a primary mesh repair was observed ($p = 0.059$).

Conclusion The DCIA free flap represents a useful and reliable reconstructive flap for maxillofacial reconstruction. Reconstructive microvascular surgeons should be proficiently trained in this flap technique for its consideration as a first-line option in maxillofacial reconstruction.

Keywords DCIA · Microvascular · Reconstruction · Free flap

Introduction

Composite bone and soft tissue defects created as a result of malignant, benign, or traumatic processes within the maxillofacial region can present as a significant reconstructive challenge. The ultimate goal of the reconstruction is to restore the patient to pre-disease form and function by addressing all aspects of concern including the facial skeleton, deglutition, dentition, trismus, globe/nasal support, and soft tissue/esthetics. Vascularized tissue transfer has become a reliable option for the reconstruction of complex maxillofacial defects. Very often it can meet multiple reconstructive goals in a single procedure allowing for improved quality of life over multiple staged surgeries that become less predictable in situations of massive tissue loss or radiation. There are numerous options when it comes to composite vascularized flaps for reconstruction of maxillofacial defects with the fibula, iliac crest, and scapula being the most common.

The vascularized iliac crest free flap was first described by Taylor et al. in 1979 and is based upon the deep circumflex iliac artery (DCIA) [1]. Since its introduction, it has become a reliable method for the reconstruction of maxillomandibular defects known for its excellent bone quantity and quality [2]. The DCIA and its associated vena comitans are generally of a large caliber rarely subjected to atherosclerosis. The inclusion of the internal oblique muscle with or without the overlying skin can be used to reconstruct complex composite defects. The ability for a two-team harvest and a more hidden esthetic donor site has further popularized this flap. Although still commonly utilized in reconstructive units within Europe, the DCIA flap is rarely selected for maxillofacial reconstruction within North America. Critics of this flap cite the short pedicle length, increased harvest time, flap bulk, and donor site morbidity as reasons for its lack of popularity.

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The main aim of the present study was to perform a detailed analysis of the utility, possible applications, and complications of this flap for the reconstruction of complex defects of the maxillofacial region using a comparative study between two institutions (one in Europe and the other in the USA) that continue to use the DCIA flap as a reconstructive resource was designed. A secondary analysis was to explore possible reasons as to why this flap has fallen out of favor with maxillofacial reconstructive surgeons within North America.

Materials and methods

All patients treated for mandibular or maxillary reconstruction by using a DCIA free flap at the Maxillofacial Surgery Division, Head and Neck Department, University Hospital of Parma, Parma, Italy, and the Department of Oral and Maxillofacial Surgery, University of Maryland, Baltimore, USA, between January 1, 2010, and April 1, 2019, were retrospectively evaluated. This study was approved by the Institutional Review Board for Ethical Human Research at the University of Maryland and the University Hospital of Parma.

Data collected included patient and disease demographics, peri-operative details, flap failure, donor site morbidities, dental implant rehabilitation, length of hospital stay, tracheostomy, use and type of mesh repair, time to ambulation, pre-existing medical comorbidities, swallow function, and Eastern Cooperative Oncology Group performance status (ECOG-PS) [3] prior to surgery and at 3 months post-operatively. Patients were followed for a minimum of 6 months post-operatively (range 6–108 months). Both a bedside swallow evaluation and a modified barium swallow test by the speech and language department was used to assess the swallow function at the University of Maryland Medical Center. A physician bedside swallow evaluation was utilized in the Maxillofacial Surgery Parma Unit. Specifically, the number of days that elapsed from the surgery to when they passed the swallowing test was calculated for all patients and a mean was calculated. Comorbidities were divided into major (i.e., severe cardiovascular pathology, diabetes, immunosuppression, or respiratory system pathologies) and minor medical comorbidities that did not alter systemic homeostasis. Bone quantity and quality were evaluated based upon operative reports and direct observer measurements from post-operative orthopantomogram, cone-beam computerized tomography (CBCT), and computerized tomography (CT) imaging. Statistical analysis was conducted using SPSS version 23 software. Frequency and percentages were used to evaluate the distribution of sex, age, and BMI. The chi-square test was used to compare the differences among the institutions in relation to the variables studied. The p value was set at 0.05.

Results

A total of sixty-eight patients were treated for mandibular or maxillary reconstruction by using a DCIA free flap. In our cohort, 40 patients underwent surgery at the Parma University Hospital (institution 1) and 28 at the University of Maryland (institution 2). A total of 35 males and 33 females (male/female ratio = 1.06), with ages ranging from 16 to 79 (mean, 51.1 years). Diagnoses included primary squamous cell carcinoma of the oral cavity (n = 35), benign tumors of the head and neck (n = 22), osteoradionecrosis (ORN) (n = 4), osteomyelitis (n = 6), and gunshot wound (n = 1). Statistically significant difference was found with presenting pathology, composite flap design (bone only versus bone and soft tissue), use of tracheostomy, time to post-surgical ambulation, use, and type of mesh (see Table 1).

Institution 1 selected the DCIA free flap more often for use with malignant tumors (n = 30) as opposed to institution 2 which selected the DCIA free flap more commonly in both benign tumors (n = 15) or osteomyelitis (n = 5). The patients started ambulation an average of 4 days earlier (6.23 days post-operatively vs. 10.86 days) at institution 2. Donor site mesh closure was performed in 51 patients in total, with a monofilament polypropylene mesh closure being used in all patients at institution 1 (n = 40). Mesh closure was used in 11 patients (39%) at institution 2 with porcine dermis mesh (Strattice™) closure more commonly utilized than a polypropylene mesh. No statistical differences were found with the following variables in relation to the site of reconstruction (p = 0.09), bone graft quantity (p = 0.93), rehabilitation with dental implants (p = 0.464), length of hospital stay (p = 0.086), BMI (0.677), tobacco use (p = 0.577), alcohol use (p = 0.529), swallow function (p = 0.419), medical comorbidities (p = 0.933), pre-existing radiation (p = 0.691), adjuvant treatment (p = 0.298), ECOG-PS before surgery (p = 0.329), ECOG-PS after surgery (p = 0.545), blood transfusion (p = 1.00), and flap failure: total/partial (p = 0.412). One flap (hemimaxillectomy defect with orbital floor extension) experienced partial failure requiring secondary local flap fistula closure and autogenous bone graft reconstruction for purposes of dental implant rehabilitation. The facial artery and vein were the most commonly selected donor/recipient vessels by both institutions. Alternative vessels at institution 2 were divided equally among the lingual artery and superior thyroid artery; however, institution 1 dissected the external carotid superiorly and performed the anastomosis at the level of the mandibular angle/parotid in cases where the facial artery was not available or pedicle length a concern. The use of a venous coupler (Synovis Micro Alliance™) for the venous anastomosis at institution 2 allowed for a direct measurement of donor site vein diameter with 2.5 mm being the most common (n = 12, 48%) followed by 3-mm diameter (n = 8, 28.5%) (see Table 2.)

Table 1 Study variables DCIA flap: comparative institutional analysis

N = 68	Institution #1	Institution #2	*p* value
Gender (F:M)	21:19	12:16	$p = 0.469$
Disease etiology			
Malignant tumor	30	5	$p < 0.01$
Benign tumor	7	15	
ORN	2	2	
Osteomyelitis	1	5	
GSW	0	1	
DCIA flap composition			
Osseous	14	0	$p < 0.01$
Myo-osseous	22	28	
Myo-osteocutaneous	4	0	
Subsite reconstruction			
Mn symphysis	7	4	$p > 0.05$
Mn parasymphysis body	13	12	
Mn angle	8	8	
Hemi-mandibulectomy	0	1	
Hemi-maxillectomy	12	3	
Bone measurements range (cm)			
Length (mean)	6.4–13.7 (9.85)	3.2–12.5 (7.8)	$p = 0.93$
Width	1.8–3	1.5–2.3	
Height	2.4–5	1.9–3.5	
Osteotomies			
Single segment	31	25	$p = 0.507$
Multiple osteotomies	7	3	
Mesh repair			
None	0	17	$p < 0.05$
Polypropylene	40	4	
Porcine dermis	0	7	
Dental implant rehabilitation			
Yes			$p = 0.464$
Osseointegration	22	12	
Failure	2	2	
No	16	14	
Tracheostomy	40	10	$p < 0.01$
Blood transfusion (within 30 days)			
Yes	6	4	$p = 1.0$
No	34	24	
Average time to ambulation (days)	10.86	6.23	$p < 0.05$
Average time to swallow function (days)	10.23	11.39	$p = 0.419$
ECOG-PS (median score)			
Pre-surgery	0	0	$p = 0.329$
1 month post-op	1	1	$p = 0.545$
3 month post-op	0	0	
Patient comorbidities			
BMI range (average)	19.1 – 31.3 (24.7)	20.2 – 34.8 (25.3)	$p = 0.677$
Tobacco use			
Yes	16	11	$p = 1.00$
No	24	17	
Alcohol use			
Yes	12	9	$p = 1.00$
No	28	19	
Pre-existing radiotherapy			
Yes	5	2	$p = 0.691$
No	35	26	
Medical comorbidities			
CV disease	10	6	$p = 0.933$
Diabetes	3	2	
Previous cancer	2	3	
Other	13	9	
None	12	8	

F female, *M* male, *DCIA* deep circumflex iliac artery, *Mn* mandible, *ECOG-PS* Eastern Cooperative Oncology Group performance score, *BMI* body mass index, *CV* cardiovascular

Table 2 Recipient vessel selection and vein diameter

	Institution 1[#]	Institution 2*
Facial	33	19
Lingual		4
Superior thyroid		4
External carotid	7	
Facial vein	31	20
Anterior jugular vein		1
External jugular vein		4
Internal jugular vein	9	1
Venous coupler size (mm)		
1.5		1
2		4
2.5		12
3		8
3.5		1

*2 patients at institution 2 no data available

[#] Venous coupler not used at institution 1

Donor site complications (see Table 3) were divided into wound care issues, gait disturbances, and hernia/bulge with overall equal distribution without statistical significance between the institutions ($p = 0.742$). There was no significant difference between rates of donor site hernia ($p = 0.166$); however, there was an overall trend to increased risk of hernia without the use of a primary mesh repair ($p = 0.059$).

Table 3 DCIA donor site and recipient site complications

	Institution 1	Institution 2	p value
Flap failure			
None	40	27	$p = 0.412$
Partial	0	1	
Complete	0	0	
Recipient site complications			
Wound infection	2	3	$p = 0.83$
ORN (post-adjuvant RT)	1	1	
Cosmesis	1	0	
None	35	24	
Donor site complications			
Hematoma	2	0	$p = 0.742$
Seroma	4	0	
Chronic pain	1	1	
Infection	0	2	
Paresthesia	2	2	
Hernia	0	1	
Bulge/diastasis	0	1	
Gait/limp	1	1	
None	30	20	

ORN osteoradionecrosis, *RT* radiotherapy

Discussion

The vascularized iliac crest free flap has been demonstrated to be a reliable method of reconstruction for defects within the maxillofacial region. Despite its numerous applications, it is often considered a second choice for head and neck reconstruction especially within North America. Arguments against this choice of flap including the difficulty of harvest, pedicle length, and increased donor site morbidity are simply unproven. Zheng et al. used the iliac crest free flap in 23 patients for oromandibular reconstruction with a success rate of 95.6% ($n = 22/23$), similar to other free flap success rates reported within the literature [2]. Our current series had an overall flap success of 98.5% ($n = 67/68$) with one partial necrosis for a maxillary reconstruction at institution 2. Versatility for use in maxillary reconstruction was initially described by Brown and continues to be proven successful in other small series [4–8]. In the current series, although only 22% ($n = 15/68$) of the cases were used for maxillary reconstruction, an interpositional vein or artery graft was not required for additional length to recipient's vessel. Techniques utilized by both institutions to increase pedicle length included dissection of the facial vessels above the angle of the mandible, access of the external carotid artery along the posterior aspect of the mandible within the parotid tissue or shifting of the iliac crest bone osteotomies to am more posterior position along the iliac crest thereby lengthening the DCIA vessels.

Rates of donor site complications were similar between both institutions, without any significant difference noted. Interestingly, a mesh repair was used for every patient at institution 1 despite only 65% of those patients ($n = 26/40$) having a significant portion of the internal oblique muscle included in the harvest. Mesh closure at institution 2 was performed in only 11 patients (39%) with all patients having a portion of the internal oblique muscle harvested for use in their reconstruction. The two patients who developed either a hernia or diastasis resulting in noticeable bulge had not received a primary donor site mesh closure. There were no wound infections associated with the use of mesh and hernia occurrence was not found to be related to the use of mesh ($p = 0.059$). Institution 2 selected a mesh repair if the donor site could not be closed in a tension-free fashion. Both institutions used standard suturing with non-resorbable suture securing the iliacus muscle, transversalis muscle, and anchored to pre-drilled holes within the ilium. The lack of statistically significant difference with respect to abdominal hernia suggests that it is not always necessary to use a mesh to close the defect caused by the flap harvest. Although trends for obesity were greater in the institution 2 cohort as evidenced by BMI (average BMI 25.32, maximum 34.8) versus institution 1 (average BMI 24.68, maximum 31.3), neither BMI nor early ambulation established statistical risk for hernia development.

With the aim to demonstrate the impact of this flap on patient functional status, ECOG performance status was analyzed in all patients of our series before and after surgery. No statistically significant differences were evidenced in this item ($p > 0.05$) and only 1 patient who underwent surgery at institution 1 did not return to their original ECOG score due to a permanent gait limp. All remaining patients within the series returned to their original ECOG-PS within 3 months after surgery. Patients at both institutions reported on the positive esthetics of the overall hidden DCIA incision a distinct advantage as compared to the fibula leg incision easily visible and often needing a skin graft for closure and its associated myriad of wound healing issues [9]. Earlier mobilization of patients at institution 2 did not result in a significant difference in overall hospital stay (average 11 days) or complications associated with prolonged periods of immobilization such as venous thrombosis or pneumonia. In a series of 27 DCIA flaps versus 19 fibula flaps, Schardt et al. [10] compared the donor site morbidities using both objective and quality of life subjective assessments. In their series, 63% in the DCIA group and 68% in the fibula group showed no impairment in stair climbing; however, the DCIA patients required walking aids more often for walking and stair climbing as compared to the fibula patient. The authors also reported that persistent pain and altered gait occurred in 11.11% and 59.26% of the DCIA patients respectively, as compared to 5.26% and 21% of the fibula patients. However, from a psychological aspect, patients in the DCIA flap cohort scored higher in the emotional and mental health scores as compared to the fibula donor site. A 2018 systematic review [11] comparing various osteocutaneous donor sites reported an incidence of chronic pain ranging from 8.4 to 26% in the DCIA population compared to the fibula donor site ranging from 7 to 73%. Antalgic gait within the DCIA cohort was reported at 25%; however, many of the studies examined do not report on the actual effect on patient quality of life. In our current series of DCIA flaps, no patient required a walking aid at 3 months with only 6% of patients having a permanent gait disturbance or chronic pain that affected their daily activity. Differences accounting for the lower incidence of permanent gait or pain issues as compared to the previous series could include both time intervals to classify permanent dysfunction and variations in flap harvest techniques. Furthermore, the retrospective nature of the data collection within our series could also make identification of subtle donor site morbidities difficult also accounting for bias. Although the scar is generally considered cosmetic as it can hide in the inguinal region or a skin crease, there was no specific mention of pelvic deformity/depression which could be a concern in a thin patient. In our current series, functional and performance status was recorded after 3 months with at least 6 months follow-up for all patients as compared to 2 months or less as described in the 2018 systematic review. The DCIA flap harvest technique used at both institutions routinely preserves the anterior superior iliac spine and its muscular attachments (i.e., sartorius and tensor lata muscle) as well as the preservation of the lateral femoral cutaneous nerve. Furthermore, physical therapy is started during the hospitalization and continued both in the inpatient and outpatient rehabilitation setting. Bone harvest length could also account for such differences as reported in a study by Liu et al. [12] reporting on a critical DCIA length of greater than 9 cm resulting in increased donor site gait morbidities. In the current series, the mean graft length size at each institution was 9.85 cm and 7.8 cm respectively falling just under a 9-cm average length between the two institutions. Maximum bone length harvest at both institutions averaged at 13 cm of bone allowing for subtotal mandibular reconstruction if necessary.

The large quantity of bone able to be harvested both in terms of height and width using the DCIA flap allows for ease in placement of dental implants both in the immediate and delayed setting. Average bone width recorded for both institutions was similar (approximately 2 cm) and often needed some reduction to allow profile recontouring for esthetic and inset purposes. Low bone resorption rates are reported with overall adequate bone retention provided proper oral hygiene and soft tissue management is maintained [13]. Computer-assisted virtual surgical plans and 3D models were used at both institutions to aid in accurate reconstruction and improved functional and esthetic results. The authors found the increased bone height available with the DCIA flap, advantageous to improve lip support and esthetics within the anterior mandible without placement of dentition, or the need for double-barrel fibula techniques [14, 15]. Multiple osteotomies were performed in 14.7% of patients (n = 10/68) with the bony union as evidenced on imaging irrespective of closing or open wedge osteotomies. Split cortex techniques (preservation of the lateral cortex of the iliac crest) were not employed by the authors as the cortical thickness decreases inferiorly losing the advantage of width. Furthermore, the added raw surface of cancellous marrow increases the difficultly for hardware fixation as well as for bleeding and hematoma formation.

In our series, 38 of 68 patients (55.8%) were rehabilitated with dental implants either as an immediate or delayed surgical procedure. The authors in the current series encountered similar problems as described by Laverty et al. [16] in a recent meta-analysis on dental implants within bone flaps of head and neck oncology patients, including early failures and difficulties in the management of the soft tissue and radiation. Although patient financial restraints were not discussed in the above meta-analysis, this was identified as a significant driving factor within our current series for reasons patients not undergoing dental implant reconstruction. Further details will need to be analyzed within our data regarding dental rehabilitation as it was not the primary focus of this research and is planned in future study.

The lack of pliability or excess bulk soft tissue is of concern reported with the DCIA flap. In the current series, a majority of the flaps selected were myo-osseous in design (n = 50, 74%) which could add evidence to the argument against its choice

for use with cases requiring extensive soft tissue reconstruction and selection bias within this series. The authors, however, did not find this to be an issue as the internal oblique muscle provided adequate soft tissue coverage without concern of restricted mobility. There was no long-term fistula identified that required adjuvant procedures except in the one patient that had partial necrosis of the flap with complete muscle necrosis. Skin paddle perforator dissection has been described to both debulk and allow better mobilization of the soft tissue component if necessary.

Based upon our results, the authors could not find any good reason for the bias against the DCIA as the first-line flap for maxillofacial reconstruction. The authors postulate that concerns such as the added time for donor site closure (prevent hernia or need for mesh repair), pedicle length concerns (i.e., maxillary defect reconstruction) or in cases of total mandibular reconstruction (i.e., need for increased bone length) can easily be avoided with appropriate case selection and occur infrequently.

Further study can include a prospective multiple global center design comparing reconstruction with the various bone flaps (i.e., fibula vs. DCIA) and subsites within the maxillofacial region. Perhaps a survey analysis of reconstructive surgeons within the maxillofacial units as to reasons for not selecting the DCIA could also help to shed light as to why this flap is less commonly used. Despite the above-described weaknesses, the study directly highlights the successful use of the DCIA flap at both a European and US reconstructive center.

The DCIA free flap represents a useful and reliable reconstructive composite flap for maxillofacial reconstruction. The large quantity and quality bone along with its soft tissue allow for the ability to provide a functional maxillofacial reconstruction including appropriate dental implant rehabilitation. This flap is not associated with excessive donor site morbidity and most complications can be appropriately managed. As with all flap surgery, appropriate flap selection should be based upon careful patient evaluation and surgeon comfort. The DCIA free flap should be given more consideration as a viable option as an equivalent first-line technique in maxillofacial reconstruction.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethics approval This study was approved by the IRB at the University of Maryland for Ethical Human Research.

Informed consent Not applicable.

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