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2016-06

Wilkman , T , Tornwall , J , Vuola , J & Lassus , P 2016 , ' The free scapular flap with latissimus muscle reduces fistulas in mandibular reconstruction ' , Journal of Plastic, Reconstructive & Aesthetic Surgery , vol. 69 , no. 6 , pp. 802-808 . https://doi.org/10.1016/j.bjps.2016.03.007

http://hdl.handle.net/10138/224056
https://doi.org/10.1016/j.bjps.2016.03.007

publishedVersion

Journal of Plastic, Reconstructive & Aesthetic Surgery (2016) 69, 802—808

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

The free scapular flap with latissimus muscle reduces fistulas in mandibular reconstruction

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Received 15 December 2015; accepted 6 March 2016

KEYWORDS
Scapular free flap;
Mandibular reconstruction;
Complications;
Fistula;
Osteotomy;
Dental implants

Summary *Introduction:* The free scapular chimeric flap is a less common choice for facial reconstruction. This study aimed to evaluate the versatility and safety of the flap, the procedure for a two-team approach, the safety of the osteotomies, the possibility of dental implants and donor-site sequelae and complications.
Patient and methods: We analysed 34 consecutive patients with oral cancer undergoing large resections in the maxillofacial region as well as scapular chimeric free flap reconstruction. We performed 26 mandibular, six maxillary and two orbital reconstructions using a two-team approach, mainly without repositioning the patient.
Results: No flaps were lost. Three patients with a scapular bone and fasciocutaneous flap developed a post-operative fistula, whereas no fistulas developed when the flaps included a muscular component. All osteotomies showed confirmed osseal consolidation. Seven patients received a total of 23 dental implants for oral rehabilitation; no implants were lost.
Conclusions: The scapular flap is reliable and contains sufficient bone to tolerate both multiple osteotomies and osseointegrated dental implants. The flap can be harvested in a slightly tilted decubital position, thus shortening the theatre time. The use of a separate muscle around the scapular bone in mandibular reconstruction is associated with a lower risk of oral fistulas.

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http://dx.doi.org/10.1016/j.bjps.2016.03.007

Introduction

Large defects in patients undergoing resections for malignant tumours require complex modalities of reconstructive surgery, with microvascular tissue reconstruction being the gold standard. Primary healing without complications, a disease-free patient, maxillomandibular continuity with the possibility of dental rehabilitation and full oral function are the optimal goals.[1]

The most common microvascular reconstruction methods for treating bone defects in the maxilla and the mandible are the fibular, the iliac crest (DCIA, deep circumflex iliac artery) and the osseous scapular flaps (scapula). The DCIA provides a good bone stock, but the skin island has fewer options for tailoring defects. The pedicle is fairly short, and the donor area has known complications such as hernias, paraesthesia, chronic pain and gait problems.[2–8] The fibula provides a long osseous part with possibilities for osteotomies and an excellent contouring with a reliable but sometimes short pedicle, thus enabling the reconstruction of an entire mandible.[9] Vascular anomalies of the leg as well as atherosclerotic disease may cause complications in both flap and leg.[10–12]

The scapular bone flap is less common in facial reconstruction, but has some advantages over the fibular or iliac crest free flaps.[13] The scapular flap is recommended mainly for complex facial defects that include a major soft tissue component.[14] According to the literature, the wider use of the scapula is limited by the quantity and quality of the available bone and the subsequent limitations of dental implantations. The need to reposition the patient with the subsequent longer duration of the surgery is also a drawback.[15,16]

The aim of this retrospective study was to evaluate the data on the scapular osseous free flaps with variations in the muscular, cutaneous and osseous parts used in patients with maxillofacial defects. We analysed the safety of the flap, the variability of different flap combinations, complications, donor-site morbidities, the effects of osteotomies on osseal consolidation, the potential for dental implantation and the possibility to raise the flap simultaneously with the other team performing the oncological resection.

Patients and methods

The Research Ethics Board of the Helsinki University Hospital approved the study. Approximately 520 patients are annually assessed pre- and post-operatively by a weekly multidisciplinary head and neck cancer board in the Helsinki University Hospital. During 2006–2013, 718 patients had a defect requiring microvascular reconstruction, with 119 having an osseous component. We included in the study all 34 patients reconstructed with the scapular chimeric flap: eight from the Department of Maxillofacial Surgery and 26 from the Department of Plastic Surgery. We followed the patients from August 2006, when the first patient in the series received treatment, to August 2015, when the last patient underwent surgery in December 2013.

We collected pre- and post-operative data from the patients' hospital records, including histopathological and radiological data, at the Helsinki University Hospital. The follow-up included clinical outpatient visits and radiological examinations with magnetic resonance imaging (MRI) or computed tomography (CT), or both. We recorded the formation of early flap-related complications such as flap necrosis, vascular complications, and the formation of a fistula. In the follow-up, we assessed bone consolidation at 12 months, deglutition and speech performance, shoulder function and pain status and the potential for osseointegrated dental implants and patient survival. The mandibular reconstructions were also analysed separately.

The median age of the patients (22 men and 12 women) at the time of surgery was 62 years (range 39–78 years). The tumour classification included one malignant fibrous histiocytoma, one mucoepidermoid carcinoma, one adenoid cystic carcinoma, one basal cell adenoid carcinoma, one anaplastic carcinoma, one metastatic cutaneous squamous cell carcinoma and 28 epidermoid carcinomas. One patient had received chemoradiation therapy preoperatively; 13 patients had previously undergone resections with microvascular reconstructions and radiation therapy with curative intentions. All but two had stage 4 diseases, and none had distant metastases. Patient follow-up ranged from 15 days (patient died of cardiac infarction in hospital) to 9 years.

The authors performed 34 flap reconstructions (mandibular, maxillary or orbital). Flaps included either a fasciocutaneous component (scapular skin flap or thoracodorsal artery perforator flap) or a musculocutaneous component (latissimus dorsi). The osseal pedicle was based on either the circumflex scapular artery or the angular branch of the vessel, or both. All patients had an angular pedicle. Open-wedge osteotomies, which leave intact the lateral scapular margin with its muscle cuff and an intact periosteum on the lateral side, were performed in part of the flaps as necessary. Some of the flaps included two separate bones based on two pedicles, and some of these separate bones had secondary open-wedge osteotomies resulting in one to four bone segments (Table 1).

We operated on the majority of the patients using a two-team approach with the patient in a slightly tilted decubital position, thus enabling simultaneous resection and preparation of the flap. The lateral border of the latissimus is marked and the scapular tip palpated. The lateral and medial borders of the latissimus muscle are first mobilized. This manoeuvre gives a better exposure to the scapula. Thoracodorsal, circumflex scapulae and angular branch of serratus vessels are identified and dissected. The desired osteotomy region is identified on the bone, and the muscles attached to it are cleared from the bone with a small muscle cuff, including teres major, teres minor and infraspinatus muscles. If the tip of scapula is being used, a part of the serratus anterior muscle origin needs to be dissected. The angular vessel penetrates through the origin of serratus anterior; hence, a small cuff of muscle should be left on the bone. The desired bone is marked according to the model, and osteotomies are performed. The subscapularis muscle is trimmed off the bone leaving a cuff of

muscle attached. In the closure, the reflected muscles are attached by resorbable sutures to the remaining scapular bone or to each other. Patients undergoing bilateral resections and neck dissections underwent surgery in the supine position. MRI and CT proved useful in planning the surgeries. We used three-dimensional (3D) stereolithography models with manually manufactured osseous templates and prebent fixation plates in the beginning of the series, thereby advancing to 3D CT planning with patient-specific resection and reconstruction guides in the end of the series in two patients (Planmeca Oy, Asentajankatu 6, 00210 Helsinki, Finland). Facial and chest CTs were performed in patients as staging and planning procedures preoperatively, and the same scans were used for the 3D planning. The CT scans were carried out with 0.5-mm slices and with 0° tilt of the tube. According to the planning, the length of the scapular bone and the need for a cutaneous lining as well as a muscular component guided the preparation of the flap. Any excess skin and muscle were trimmed at the inset of the flap. We chose the most suitable pedicle for the anatomical circumstances and planned osteotomies. To fixate the osseous reconstruction, we used Synthes MatrixMANDIBLE reconstruction plates in the mandible and Synthes MatrixMIDFACE miniplates in the midface (DePuy Synthes, Synthes GmbH, Luzernstrasse 21, 4528 Zuchwil, Switzerland). The pedicle was positioned medial to the mandible and anastomosed to the vessels in the neck (see Figure 1).

We analysed the data using SPSS 20 (IBM Corporation, 1 New Orchard Road, Armonk, NY 10504-1722, USA). For the continuous data, we used the Mann–Whitney *U*-test for group comparisons. For the categorical data, we used the Pearson chi-squared test or Fisher's exact test, when appropriate. The data appear as absolute numbers or median values with a range.

Results

The median duration of the surgery was 10 h 34 min (range 530–933 min): the median time was 626 min for the first 11 patients and the next 12–23 and 23–34 had median durations of 655 and 618 min, respectively. The use of computerized 3D planning did not show differences in the duration. The median blood loss was 1520 ml (650–10,000 ml), and the ischaemia time for the flap was 108 min (70–270 min). The patients underwent post-operative treatment at the intensive care unit (ICU) for a median of 6.5 days (2–22 days), underwent tracheostomy for a median of 7 days (0–34 days) and stayed in the hospital for a median of 18 days (7–50 days). In the majority of patients, two teams of surgeons dissected the scapula at the same time with oncological resection. The functional results are presented in Table 2.

In the 33 patients who survived the immediate post-operative period, all flaps healed clinically. Two early anastomosis revisions were successfully completed. Fistulas developed in three mandibular reconstructions. Donor-site morbidity was low with no immediate site-specific complications. One patient experienced pain and restricted motion at 12 months post-operatively. During the follow-up, 14 patients died, seven of whom died of primary disease with distant metastasis; the median survival was 437 days (range 170–1580 days). The remaining seven patients died of other causes (median 80 days, range 15–1431 days), namely acute cardiac infarction, multiple organ failure, pneumonia or other malignancies (Table 3).

One patient presented with a radiological non-union at the interface of the scapula and the mandible at 12 months. Seven patients with mandibular reconstruction received post-operative osseointegrated dental implants in their scapular bone (23 implants in total). All received

Table 1 Flap-related data.

	N	LD included	Length of scapular bone (mm and range)	Osteotomies	Skin flap (*N* and size)	Pedicle type used
All	34	20	90 (50–130)	19	32 12 × 6 (5 × 3–18 × 7)	14 cfx. 6 ang. 14 bipedicular
Mandible	26	15	100 (50–130)	18	25 14 × 6 (5 × 3–18 × 7)	11 cfx. 2 ang. 12 bipedicular
Maxilla	6	4	60 (50–100)	1	5 15 × 6 (8 × 5–18 × 7)	2 cfx. 3 ang. 1 bipedicular
Orbit	2	1	45 and 60	0	2 5 × 3 and 10 × 5	1 ang. 1 bipedicular

LD: latissimus dorsi muscle.
Osteotomies: One in all but two cases, which involved two and three osteotomies.
Skin flap, size in cm, median and range. Cutaneous flaps used: the parascapular, scapular, latissimus island or thoracodorsal perforator flap.
Pedicle type: cfx. (circumflex scapular artery), ang. (angular branch only), bipedicular (both pedicles used with the subscapular pedicle).

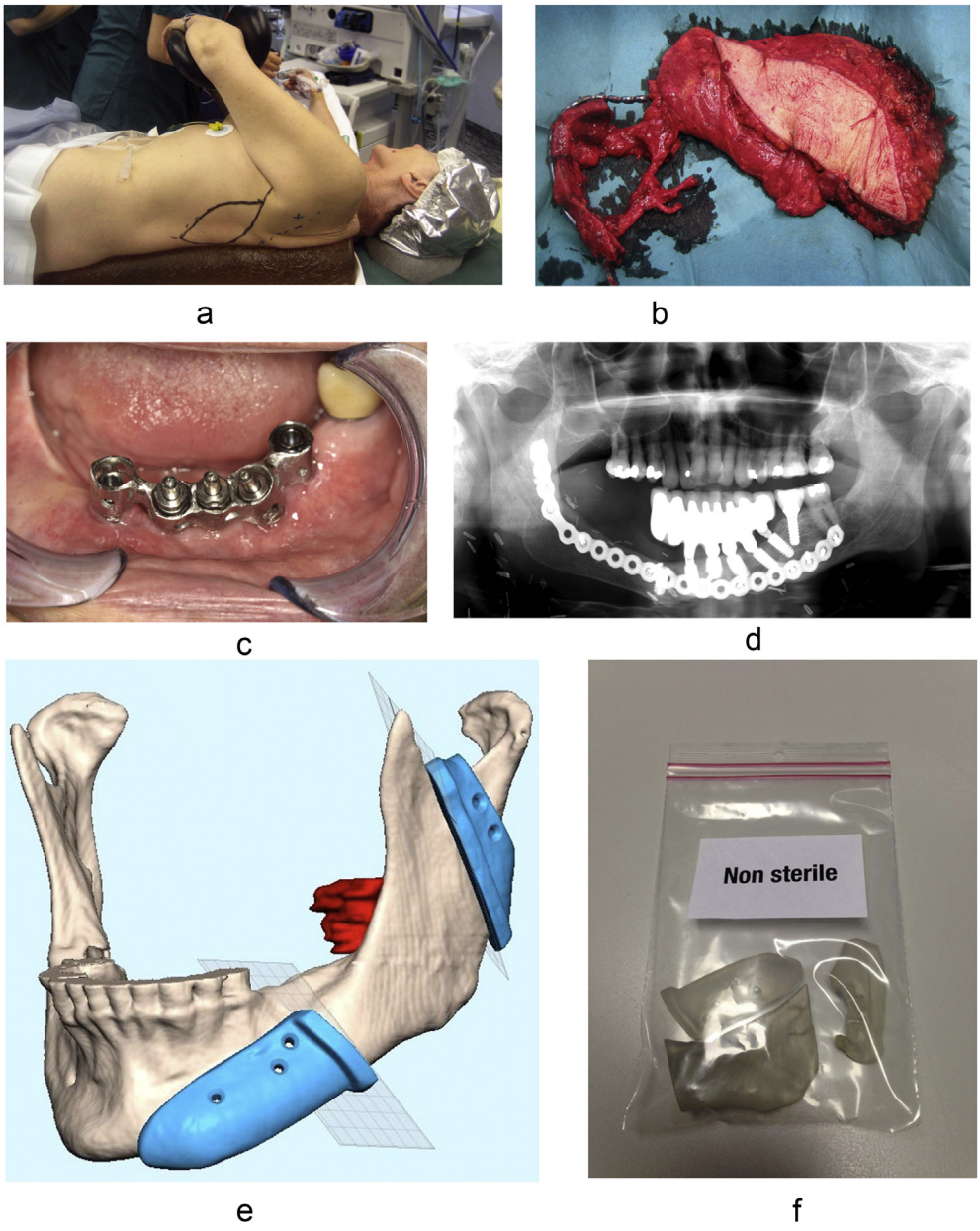

Figure 1 a. Positioning of the patient for enabling a two-team approach, b. The chimeric scapular flap with osteotomies. One osteotomy in the separate bone based on the marginal branch of the serratus pedicle and one in the separate bone based on the circumflex scapular vessels; both pieces also osteotomized in the middle, producing a four-piece bone. The flap also includes the latissimus muscle with the circumflex scapular, subscapular, thoracodorsal and marginal branch of the serratus vessels, c. Orthopantomography of a patient with dental implants in the scapular flap, d. Clinical oral image of a dental reconstruction based on the implants, e. 3D planning of mandibular resection and planned guides for osteotomies, f. Manufactured guides for osteotomies in the mandible and the scapula.

radiation therapy (60—70 Gy): three preoperatively only and four post-operatively for their scapular reconstruction. No implant failures were documented.

Mandibular reconstructions

Open-wedge osteotomies were performed in 19 scapular flaps, none of which showed failures of osseal consolidation. We observed no association between open-wedge osteotomy and fistula formation ($p = 0.215$). Two flaps

Table 2 Functional results.

Deglutition	Speech
17 normal oral	25 good
6 partly orally	2 intelligible
5 only PEG	1 non (permanent tracheostomy)
6 no data available	6 no data available

PEG: percutaneous endoscopic gastrostoma.
Speech: Good, near normal. Intelligible (i.e., able to speak on the phone).

Table 3 Complications.

Bone consolidation	Flap complications	Fistulas	Shoulder function
24 verified 1 non-union 10 data unavailable	6 minor 2 reanastomoses	3	17 good 7 intermediate 1 poor 9 unavailable

Bone consolidation assessed at 12 months from CT. Minor flap-related complications (infection with no need to reoperate, wound-edge dehiscence). Fistulas requiring operative intervention. Shoulder function: Good: normal range of movement, pain free, no restrictions in daily activities; Intermediate: Pain or limited range of movement; Poor: Pain and no movement above 90°of elevation/flexion.

had a three- and four-piece osteotomy without these complications. The type of pedicle (circumflex scapulae or angular artery or both) did not associate with fistula formation ($p = 0.513$) or with bone consolidation ($p = 0.5$). All patients had an angular pedicle, though it was not used in all flaps. No fistulas occurred in the 15 flaps that included the latissimus dorsi muscle, but the 11 flaps that included a fasciocutaneous component only developed three fistulas ($p = 0.032$; Table 4). The patient's age at surgery ($p = 0.97$), the length of the bone ($p = 0.27$), the ischaemia duration of the flap ($p = 0.41$) or the total duration of the surgery ($p = 0.86$) showed no statistically significant association with flap-specific complications or patient outcomes.

Discussion

In this series of 34 consecutive free scapular reconstructions, the only intraoral fistulas that we encountered developed in the mandibular reconstructions lacking a muscle component. To our knowledge, this report is the first to show the benefits of a muscular component in preventing fistulas in free flap mandibular reconstructions. Including the muscle in the flap involved wrapping it around the scapular bone and osteosynthesis material, thus providing an extra layer of protection. A post-operative fistula in mandibular reconstruction is a major complication commonly resulting in additional surgery, reosteosynthesis and re-reconstructions. In oncological cases, an intraoral fistula may delay or even prevent the start of the subsequent oncological treatment, thus emphasizing the importance of primary healing. Studies have shown that musculocutaneous flaps possess some advantages in complex 3D reconstructions,[17] and filling out dead spaces in the neck appears to reduce the incidence of fistulas. Other researchers have described similar results with open fractures.[18] Based on these experiences, we changed our protocol and included a muscle component in scapular chimeric flaps in mandibular reconstructions. This applies even more to patients at high risk for complications, such as patients with co-morbidities or those who previously underwent radiotherapy or multiple operations.

In our data, all scapular flaps were clinically stable, and CT confirmed bone consolidation in all but one patient regardless of the presence of an open-wedge osteotomy. Regarding bone consolidation or fistula formation, using the circumflex scapulae or the angular branch pedicle or both pedicles was safe. Moreover, open-wedge osteotomies proved to be safe in flaps based on either pedicle.

Sullivan described successful osteotomies in the scapular flap in 1990. A review by Disa and Cordeiro in 2000, however, found that many considered the scapular flap unsuitable for osteotomies and implants.[1,19] Conversely, a recent study by Z. Hasan et al. showed that osteotomies, as well as dental implants, can be used successfully in complex reconstructions.[20] We therefore conclude based on our data that choosing a pedicle for the scapular bone and performing open-wedge osteotomies on each piece of the bone is safe.

In this series, seven patients received a total of 23 dental implants in their scapular flap with no documented failures despite having received radiation therapy. The amount of bone was not a limiting factor in any of the other patients. These patients neither required implantation nor wished to undergo additional surgeries, or they had an active disease. A patient requesting implantation must undergo thorough evaluation, as dental implants alone are not a solution for every patient. Previous studies have described the use of dental implantation in free osseous flaps as oral rehabilitation,[21] and long follow-up results are available. Patients can

Table 4 Results: mandibular reconstructions and complications.

Mandibular reconstruction $n = 26$	Fistulas 3/26	Consolidation of bone 19/20
Bone length	n.s. ($p = 0.29$)	n.s. ($p = 0.54$)
Type of flap (with muscle vs. without muscle)	0/15 versus 3/11 ($p = 0.032$)	12/12 versus 6/7 ($p = 0.368$)
Osteotomy (with osteotomy vs. without osteotomy)	1/18 versus 2/8 ($p = 0.152$)	14/14 versus 4/5 ($p = 0.263$)
Pedicle type (Cfx. vs. Ang. vs. Bipedicular)	2/12 versus 0/2 versus 1/12 ($p = 0.531$)	11/12 versus 2/2 versus 12/12 ($p = 0.5$)

Pedicle type: cfx. (circumflex scapular artery), ang. (angular branch only), bipedicular (both pedicles used with the subscapular pedicle). Consolidation of osteotomies at 12 months. Three patients died within a year, three patients missing data.
n.s.: not significant.

undergo implantation as a second surgery or in the primary setting.[6] Radiation therapy, functional mastication, mucosal versus cutaneous lining and bone stock influence the choice of dental rehabilitation.[15] We conclude that the use of osseointegrated dental implants in the scapular bone in oral rehabilitation is possible and safe.

Previous reports have identified repositioning of the patient during surgery as a drawback.[1,19] In the present study, we show that the scapular composite flap can be dissected simultaneously with tumour resection using a two-team approach. We initially positioned the patients in a lateral position, but with experience, began using slightly tilted decubital position as described in the literature,[22,23] which allowed the oncological surgeon to perform the resection simultaneously, thus reducing the time spent in the theatre.

A large series studied by Urken et al. involved 210 mandibular reconstructions and a scapular flap reconstruction recommended for large soft tissue defects.[14] The advantages of the scapular flap include its long and reliable pedicle, the opportunity to use both scapular and parascapular skin islands and the option to include the latissimus dorsi muscle.[22] Dos Santos[24] presented the vascular basis for the scapular osteomusculartaneous free flap, which Swartz had already used in 1986 in a series of mandibular reconstructions.[25] Although the pedicle is short if harvested with the main nutrient artery, a long pedicle can be achieved if one chooses the angular branch of the thoracodorsal artery.[26] The scapular tip can also be used for both maxillary and mandibular reconstructions.[27,28] The pedicle is also reliable in elderly patients with atherosclerotic disease,[29] seldom found in the thoracodorsal system though it often affects the lower extremities, and is especially problematic in the fibular flap.[13,30] Our series suffered no flap losses. Takushima et al. analysed 178 patients and found that the scapular flap was more reliable than the fibular and iliac crest, with significantly lower rates of flap failure. They also concluded that, in demanding reconstructions, the chimeric scapular flap is better than a combination of two free flaps.[31] Dowthwaite et al. found that large reconstructions with the scapular system are more reliable in the elderly patients with comorbidities and have less complications compared to the fibular flap.[32] We used the scapular flap in both complex defects and less complex reconstructions, such as mandibular reconstructions in which large soft tissue resections are not a real option for the fibular flap.

The donor-site morbidity was low, with few and mild long-term restrictions for the patient.[33,34] It is difficult to assess the pure impact of the flap dissection on shoulder movement as the resection with neck dissection and subsequent radiation therapy causes scarring, muscle contractions and neuropathy in the neck and shoulder. In radical lymph node dissection with resection of the spinal accessory nerve, one must keep in mind the additional burden of shoulder function. In the DCIA, the donor area has suffered complications such as hernias, paraesthesias, chronic pain and gait problems.[12] The fibula can have anomalies in the pedicle, and atherosclerotic disease can cause complications in both flap and leg.[11] Ankle pain and instability, as well as sensory nerve damage and scarring of the deep flexor muscles are known donor-site sequelae.[2–8] Studies have shown the donor-site morbidity of the scapular flap to be lower than that of the fibular flap, especially in elderly patients, while the results for the reconstruction site are similar.[24,33,35] In a review of the literature as well as in the experience of the authors, of the available osseous free flaps, the donor site of the scapula yields the lowest rate of local complications, yet provides a normal range of shoulder function after 12 months.[12] Only one patient saw a permanent reduction in shoulder function.

Conclusions

The scapular chimeric flap is a reliable and versatile option in composite reconstructions of the head and neck region. Open-wedge osteotomies can be safely performed and do not raise the risk of fistulas or non-consolidation of the bone. Moreover, the vascularity of the bone can be safely based on either the circumflex scapular vessels or the angular branch of the serratus vessels. If dental implants are necessary, bone stock is not a limiting factor. The donor-site morbidity is considered to be low and is well tolerated by the patient. Lastly, the use of the latissimus dorsi muscle around the bone and the plate in mandibular reconstruction is associated with a reduced risk for intraoral fistulas.

Funding

None.

Conflict of interest

None.

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