The Fibula Osteoseptocutaneous Flap Incorporating the Hemisoleus Muscle for Complex Head and Neck Defects: Anatomical Study and Clinical Applications

Yee-Siang Ong, M.R.C.S., F.A.M.S.(Plast. Surg.)
Khong-Yik Chew, M.R.C.S.
Colin Song, F.R.C.S., F.A.M.S.(Plast. Surg.)

Background: In patients with extensive bone and soft-tissue defects, the inclusion of the hemisoleus muscle with the fibula osteoseptocutaneous flap would provide the needed soft-tissue volume to the flap. This study evaluates the reliability and technical considerations for the inclusion of the hemisoleus with the fibula and skin paddle as a chimeric, peroneal artery–based flap.

Methods: The location and size of major arterial branches of the peroneal artery supplying the lateral hemisoleus muscle were investigated in 10 cadaveric injected lower limb specimens. The utility of this design was demonstrated in five clinical cases.

Results: The lateral hemisoleus was noted to be consistently supplied by large muscle branches from the peroneal artery, soleus vessels 1 (proximal) and 2 (distal). The mean diameter and distance from the origin of the peroneal artery for soleus vessels 1 and 2 were 1.8 mm and 2.1 cm, and 1.6 mm and 6.3 cm, respectively. The fibula osteoseptocutaneous flap incorporating the hemisoleus muscle was performed in five clinical cases. All were successful. Either soleus vessel 1 or soleus vessel 2 can be used as the pedicle to the muscle, depending on the specific reconstructive requirements for the reach and placement of the hemisoleus.

Conclusions: The fibula osteoseptocutaneous flap incorporating the hemisoleus muscle can reliably be raised by preserving constant muscle branches that arise from the peroneal artery to supply the lateral hemisoleus. This flap provides the additional bulk in selected cases, with little additional donor-site morbidity. (Plast. Reconstr. Surg. 124: 1956, 2009.)

Complex three-dimensional defects involving the mandible or maxilla with concomitant loss of a significant amount of soft tissue are challenging reconstructive problems. In the mandible in particular, the provision of vascularized bone is the definitive standard for reconstruction. The fibula osteoseptocutaneous flap as described by Wei et al. can reliably transfer good quality bone and skin into the defect. It is the flap of choice for vascularized bone transfer to the head and neck. However, the tissue bulk that is available with this flap is limited. Therefore, in defects with significant soft-tissue loss, the use of a second soft-tissue flap is often necessary to provide the needed bulk to fill dead space and to give a more aesthetic outcome. The use of a second free flap, however, is more technically demanding and prolongs surgery significantly. Double free flaps are more technically demanding and prolong surgery significantly. The inclusion of the hemisoleus muscle with the fibula osteoseptocutaneous flap provides the needed bulk, making simultaneous replacement of missing bone and significant tissue loss possible. This study revisits the blood supply of the lateral hemisoleus and evaluates the reliability of its inclusion into the fibula osteoseptocutaneous flap. Its versatility and utility was demonstrated in five clinical cases of composite defects of the head and neck.

Disclosures: None of the authors has any conflict of interest regarding the content of this article.
MATERIALS AND METHODS
Cadaveric lower limb dissections were performed on 10 injected lower limb specimens (five whole cadaver specimens) to investigate the supply of the lateral hemisoleus muscle. The skin over the posterior compartment of the leg was removed. The gastrocnemius muscle was then removed, exposing the soleus muscle. The lateral hemisoleus was disinserted from its origin and insertion. The flap was cut in the midline of the soleus marked by the median raphe and plantaris tendon. The hemisoleus was then raised lateral to medial to identify vessels supplying the muscle. The number, location, and size of muscle branches from the peroneal artery supplying the lateral hemisoleus were noted. The distance of the vessels supplying the lateral hemisoleus from the origin of the peroneal artery was also noted.

RESULTS
The results of the cadaveric dissection are summarized in Table 1. Two sizable muscle branches (>1 mm) usually arise from the peroneal artery to supply the lateral hemisoleus muscle (Fig. 1). The proximal vessel was designated soleus vessel 1 and the more distal vessel was designated soleus vessel 2. Soleus vessel 1 was present in 10 of 10 specimens and soleus vessel 2 was present in nine of 10 specimens. The mean diameter of soleus vessel 1 was 1.8 mm (range, 1.2 to 2.4 mm) and it arose a mean of 2.1 cm (range, 0.5 to 4 cm) from the origin of the peroneal artery. The mean diameter of soleus vessel 2 was 1.6 mm (range, 1.2 to 2.3 mm) and it arose a mean of 6.3 cm (range, 4.6 to 8.5 cm) from the origin of the peroneal artery.

From July of 2007 to January of 2009, the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle was performed on five clinical cases. Table 2 gives a summary of our clinical cases. The mean follow-up was 6 months (range, 4 to 19 months). All flaps survived. In one patient (case 3), necrosis of the skin island was noted on the sixth postoperative day. This was attributed to injury to the septocutaneous vessel supplying the skin paddle during bone osteotomies. A pedicled pectoralis major myocutaneous flap was performed to replace the oral lining. The fibula and soleus muscle flap was noted to be healthy during the reexploration. In fact, the benefit of inclusion of the hemisoleus muscle to obliterate dead space and protect the neck vessels was realized in this case. Despite the salivary leak into the neck, the hemisoleus was effective for sealing the neck vessels and anastomotic site from the detrimental effects of the contamination. This was instrumental in averting the potential loss of the entire flap and even a catastrophic carotid blowout.

Surgical Technique for Harvesting the Fibula Osteoseptocutaneous Flap Incorporating the Hemisoleus Muscle
The fibula is marked and the septocutaneous vessel supplying the skin island located by hand-held Doppler on the posterior border of the fibula. The dimensions of the needed skin paddle and muscle are then marked (Fig. 2). The anterior incision on the skin island is made first to identify the location of septocutaneous vessels. The posterior incision is then made and the soleus and the flexor hallucis longus are then dissected off the posterior crural septum. Any musculocutaneous perforators coming through the soleus muscle to supply the skin can be ligated safely, as the septocutaneous vessels already identified can reliably supply the skin paddle. The septocutaneous vessels are then traced to their origin at the peroneal artery. The flexor hallucis longus muscle covering the posterior aspect of the peroneal artery is detached progressively from the posterior aspect of the peroneal artery. Exposure of the peroneal vessel is performed from distally to proximally, tracing the vessel up the leg. Soleus vessel 2 followed by soleus vessel 1 present as the surgeon progresses up the leg (Fig. 3). Depending on specific reconstructive requirements, either vessel can be used as the vascular pedicle for the hemisoleus. The muscle is then transected distally and in its midline. The sagittal septum separates the medial from the lateral hemisoleus, and its location is marked by the plan-
taris tendon. Proximal division of the muscle is delayed until the end of the procedure. This prevents traction on the pedicle from the weight of the flap during the remaining part of the dissection (Fig. 4). The remaining muscle over the posterior aspect of the peroneal artery is separated from the vessel. At this juncture, the entire posterior aspect of the peroneal artery, the septocutaneous vessel supplying the skin island, and the muscle branch to the lateral soleus muscle can be visualized. Dissection is then moved to the front. The peroneus longus and brevis, the anterior crural septum, the extensor digitorum longus and extensor hallucis longus, and the interosseus membrane are separated progressively from the fibula. The proximal and distal osteotomies are performed and the bone is rotated laterally to facilitate dissection. The distal end of the peroneal artery is medial to the distal end of the bone and is ligated. In the proximal two-thirds, the peroneal artery is covered by the tibialis posterior muscle and a fascial layer. This is opened to expose the artery. The remaining medial attachments of the vessel are divided from distal to proximal up to the tibioperoneal trunk. It is important with this technique to cleanly strip the surrounding muscles from the peroneal pedicle, as doing so enables the surgeon to clearly visualize all vessels supplying the muscle and skin components. Care should be taken when approaching the muscle branch to the soleus muscle to prevent its injury. Once the pedicle is ready, the remaining attachment of the muscle component to the soleus can be completely divided. The weight of the hemisoleus dangling on the muscle branch may irreversibly damage the vessel. To prevent this, two or three temporary sutures are placed hitching the muscle to the periosteum of the bone with the vessel in a relaxed position. These sutures are divided when one is finally ready to inset the flap. The fibula osteoseptocutaneous flap incorporating the hemisoleus muscle can then be harvested when the recipient site is ready (Fig. 5).

ILLUSTRATIVE CASE

A 63-year-old man presented with a T4N0M0 squamous cell carcinoma of the floor of the mouth invading into the submental area and his chin skin (Fig. 6). Wide resection and bilateral neck dissection were performed. The resultant defect involved the loss of the mandible (angle to angle), total glossectomy, and the entire chin and part of the submental skin (Fig. 7). For reconstruction, a fibula osteoseptocutaneous flap incorporating the hemisoleus muscle was harvested. A large skin island measuring 24 × 11 cm was harvested based on a single septocutaneous vessel to simultaneously reconstruct the tongue/floor of mouth and the external skin defect (Fig. 8). The hemisoleus was used to replace tissue loss in the submental area. As the submental area is located in the neck close to the expected site of microanastomoses, soleus vessel 1 was used as the pedicle to the muscle component. Recovery was uneventful, and the patient was discharged home on the twelfth postoperative day. Radiation therapy was commenced 1 month later. At 2-month follow-up, all his wounds were healed and the additional bulk provided by the hemisoleus gave significantly more fullness to the submental area than was possible with an
Fig. 3. From the posterior incision, the flexor hallucis longus (FHL) is separated from the posterior crural septum and the septocutaneous vessel is traced to the posterior aspect of the peroneal artery. The dissection is then continued up the leg following the peroneal artery. Large muscle branches from the peroneal artery to the hemisoleus muscle can be visualized from posteriorly, the septocutaneous vessel to the skin paddle and the muscle branch to the hemisoleus muscle.

Table 2. Summary of Clinical Cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Abnormality</th>
<th>Defect</th>
<th>FOCH Flap Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>63</td>
<td>Advanced tongue squamous cell carcinoma</td>
<td>Ascending ramus-to-ascending ramus mandible defect, total glossectomy, loss of chin and all submental tissue, bilateral modified radical neck dissection</td>
<td>16-cm bone, 24 × 10-cm skin, and 9 × 19-cm hemisoleus based on S1</td>
<td>Muscle to fill dead space in the floor of the mouth and submental area</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>24</td>
<td>Fibrous dysplasia of the mandible and maxilla with bony ankylosis of the mandible and the maxilla</td>
<td>Hemimandibular defect with intraoral skin defect and inferior maxillectomy defect</td>
<td>12-cm bone, 10 × 6-cm skin, and 7 × 10-cm hemisoleus based on S2</td>
<td>Muscle to fill dead space in the maxilla and as interpositional tissue to prevent recurrence of bony fusion between the mandible and maxilla</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>57</td>
<td>Anterior floor-of-mouth squamous cell carcinoma</td>
<td>Angle-to-angle mandible defect and right radical neck dissection</td>
<td>11-cm bone, 16 × 6-cm skin, and 7 × 9-cm hemisoleus based on both S1 and S2</td>
<td>Muscle to fill dead space in the neck after radical neck dissection</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>54</td>
<td>Anterior floor-of-mouth squamous cell carcinoma</td>
<td>Anterior mandibular defect, total glossectomy</td>
<td>12-cm bone, 20 × 8-cm skin, and 8 × 12-cm hemisoleus based on S1</td>
<td>Muscle to replace tissue loss in the submental area</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>44</td>
<td>Recurrent buccal squamous cell carcinoma</td>
<td>Angle-to-parasympyseal mandibular defect, through-and-through loss of cheek tissue, and submental muscle resection</td>
<td>10-cm bone, 20 × 6-cm skin paddle, and 6 × 8-cm hemisoleus based S2</td>
<td>Muscle to fill dead space in the retromolar trigone and submental space</td>
</tr>
</tbody>
</table>

FOCHS, fibula osteoseptocutaneous flap incorporating the hemisoleus muscle; S1, soleus vessel 1; S2, soleus vessel 2.
osteocutaneous flap alone (Fig. 9). Donor-site morbidity was acceptable, and there were no issues with ambulation (Fig. 10).

**DISCUSSION**

The fibula osteoseptocutaneous flap is the flap of choice for head and neck bony defects.\(^1\)\(^2\) Its only disadvantage is that it is unable to provide adequate bulk when there is significant soft-tissue loss. Wei et al. recommend that the bone be harvested with a minimal cuff of muscle.\(^3\) The paper-thin posterior crural septum with the septocutaneous vessel within can then be freely moved over the bone to give more freedom in the inset of the skin component. The fibula osteoseptocutaneous flap incorporating the hemisoleus muscle is a chimeric design that includes the hemisoleus with the fibula osteoseptocutaneous flap as an independent component.\(^7\) Our cadaveric study demonstrated that sizable muscle branches, soleus vessels 1 and 2, consistently arise from the peroneal artery to supply the lateral hemisoleus. This enabled the independent bone, skin, and muscle components to be reliably raised as a single peroneal artery–based chimeric flap. Selection of which vessel to use as the pedicle of the hemisoleus muscle component depends on the specific requirements of the defect. Soleus vessel 1 is located very near the origin of the peroneal artery and is used when the muscle flap is needed in the immediate vicinity of the anastomotic site. When the muscle is needed farther away from the anastomotic site, soleus vessel 2 should be used (Fig. 11).

To including more bulk with the fibula flap, some authors have advocated harvesting the flap with at least a 1-cm cuff of the flexor hallucis longus muscle. This approach was also purported to be able to include septocutaneous and
musculocutaneous perforators supplying the skin island. However, this “blind” approach may not always be reliable with regard to inclusion of vessels supplying the skin, and loss of the skin component may occur. The excessive bulkiness of the bone/muscle/skin composite makes inset more difficult. Furthermore, the “extra” bulk is tethered to the bone and cannot be freely moved to the area where it is needed. It is thus of limited usefulness. Therefore, when an additional muscle component is needed to address a specific area of deficiency, the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle is far superior in terms of versatility and reliability.

The feasibility of inclusion of the lateral hemisoleus with the fibula flap was first demonstrated by Baudet et al. as an osteomuscular flap. However, in earlier descriptions, the muscle and bone are harvested en bloc. The soleus remains tethered to the bone, limiting its mobility and freedom of movement. The fibula osteoseptocutaneous flap incorporating the hemisoleus muscle harvests the muscle component based on a selected sizable muscle branch, giving the muscle an independent, free vascular pedicle. This design can reliably include the entire hemisoleus. This piece of well-vascularized muscle is mobile on its own muscle branch and can be inset independent of the skin and bone components. Only one set of anastomoses is needed to revascularize the entire composite tissue.

Mathes and Nahai classified the lateral hemisoleus as a type 2 muscle with a dominant pedicle and minor pedicles arising from the peroneal artery. The dominant pedicle is located most proximally and corresponds to soleus vessel 1 noted in our study. The minor pedicle corresponds to soleus vessel 2. It is generally recommended not to harvest a flap based on minor (secondary) pedicles. This is generally not an issue with the harvest of the conventional pedicled lateral hemisoleus muscle flap for defects of the middle third of the leg. The more distal “minor” pedicle (corresponding to soleus vessel 2) is usually divided to increase the reach of the flap.

Fig. 7. Photographs showing the tumor excised and the resultant large composite defect.

Fig. 8. Photograph showing the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle harvested with the entire lateral hemisoleus muscle based on soleus vessel 1 ($S1$) and a skin island measuring $24 \times 10$ cm.
and the muscle is perfused by the more proximally located “major” pedicle (soleus vessel 1). For the harvest of the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle, however, greater flexibility in the vessel that supplies the lateral hemisoleus is needed. Our cadaver study noted that soleus vessel 1 is usually slightly larger than soleus vessel 2. However, as

Fig. 9. Photographs of the patient at 2-month follow-up. Note the significant filling of the submental and neck area by the hemisoleus muscle.

Fig. 10. Donor-site morbidity was acceptable. The patient was able to ambulate without any difficulty and was able to tiptoe (right). Reattachment of the flexor hallucis longus muscle to the interosseous membrane under the appropriate tension during closure of the donor site ensures adequate great toe flexion (left).
demonstrated in our clinical cases, either one is capable of adequately perfusing the entire lateral hemisoleus. With the free-style approach to harvesting flaps, the muscle may be based on any vessel, provided it is of adequate size. The caveat for the use of soleus vessel 2 as the muscle pedicle is therefore that it must be sizable (>1 mm).\textsuperscript{16,17} Therefore, calling soleus vessel 2 a minor pedicle is perhaps inaccurate and misleading and should be avoided. Furthermore, it should be noted that the muscle component based on the peroneal artery is almost always reliable. At least one large vessel from the peroneal artery is always present. This is in contrast to the septocutaneous vessel supplying the skin paddle, which may be absent in 5 percent of cases, necessitating maneuvers for skin island salvage.\textsuperscript{11}

The advantage of the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle is that it allows the freedom of various components to address the three-dimensional requirements of the defects. Insetting the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle is more challenging and requires greater precision both in its planning and in its execution. The peroneal artery is firmly adherent to the bone, and the septocutaneous vessel is embedded with the posterior crural septum. These are therefore protected from traction injury from the weight of the tissues. The muscle branch, in contrast, is unsupported and quite susceptible to traction injury from the weight of the soleus muscle dangling off its pedicle. It is our practice therefore to suture the muscle to the periosteum of the bone immediately after raising the muscle component with the muscle branch completely tension free. The muscle component is also generally inset first into the defect. The suspension sutures are removed and the muscle is partially inset into the defect. This is followed by skin components and bone with miniplates or reconstruction plates. Once the flap is secured, microanastomosis can then proceed safely.
As compared with the fibula osteoseptocutaneous flap, there seems to be only minimal additional donor-site morbidity by inclusion of the soleus muscle. Patients were all able to ambulate without any difficulty kicking-off or tiptoeing. This is consistent with our experience with the use of the pedicled hemisoleus flap in coverage of lower limb defects. Ankle plantar flexion is adequate, the pedicled hemisoleus flap in coverage of lower is consistent with our experience with the use of without any difficulty kicking-off or tiptoeing. This

leus muscle. Patients were all able to ambulate

ever, there seems to be only minimal addi-
tional morbidity in particular has to be eval-
uated further as more experienced is gained with its use. The flap is a little more technically de-
manding, with a definite learning curve. It also
takes slightly longer to harvest but can usually be
completed in less than one tourniquet time (un-
der 2 hours).

Limitations of this present work should be
noted. Our clinical experience with the use of the fibula osteoseptocutaneous flap incorporating the hemisoleus muscle is limited to five patients. The donor-site morbidity in particular has to be evaluated further as more experienced is gained with its use. The flap is a little more technically demanding, with a definite learning curve. It also takes slightly longer to harvest but can usually be completed in less than one tourniquet time (under 2 hours).

Department of Plastic Reconstructive and Aesthetic  
Surgery  
Singapore General Hospital  
Outram Road  
169608 Singapore  
wchinho@hotmail.com

REFERENCES

Plast Reconstr Surg. 2006;118:122e–133e.
3. Wei FC, Chen HC, Chuang CC, Noordhoff MS. Fibular osteoseptocutaneous flap: Anatomic study and clinical application.  
4. Wei FC, Seah CS, Tsai Y, Liu SJ, Tsai MS. Fibula osteocutaneous flap for reconstruction of composite mandibular de-
fects.  
6. Wei FC, Demirkan F, Chen HC, Chen IH. Double free flaps in reconstruction of extensive composite mandibular defects in head and neck cancer.  
8. Harrison DH. The osteocutaneous free fibular graft.  
9. Schusterman MA, Reece GP, Miller MJ, Harris S. The osteo-
cutaneous free fibula flap: Is the skin paddle reliable?  
10. Urken ML. The osteocutaneous free fibula flap: Is the skin paddle reliable? (Discussion).  
12. Kawamura K, Yajima H, Kobata Y, Shigematsu K, Takakura Y. Clinical applications of free soleus and peroneal perfora-
tor flaps.  
15. Chuang DC, Chen HC, Wei FC, Noordhoff MS. Compound functioning free muscle flap transplantation (lateral half of soleus, fibula and skin flap).  
17. Mardini S, Tsai FC, Wei FC. The thigh as a model for free style free flaps.  
19. Kramers-de Quervain IA, La¨uffer JM, Ka¨ch K, Trentz O, Stu¨ssi E. Functional donor-site morbidity during level and uphill gait after a gastrocnemius or soleus muscle-flap pro-
cedure.  
21. Babovic S, Johnson CH, Finical SJ. Free fibula donor-site morbidity: The Mayo experience with 100 consecutive har-
vests.  
22. Vail TP, Urbaniaik JR. Donor-site morbidity with use of vas-
cularized autogenous fibula grafts.  