41 Peroneal Artery Flaps: The Free Fibula Flap

Amitabh Thacoor, Daniel Butler, Dariush Nikkhah, and Jeremy Rawlins

41.1 Introduction

The fibula free flap (FFF) provides well-vascularised bone for the microsurgical reconstruction of defects following trauma or cancer. It was first described in 1975 by Taylor [1] for the reconstruction of two large traumatic tibial defects. Its first use in head and neck reconstruction occurred later in 1989 by Hidalgo [2] and it has since become the gold standard for the reconstruction of composite midface and oromandibular defects involving the intraoral mucosa (lining), mandibular bone and external skin (cover) [3].

Originally described as a purely osseous flap, the FFF can also be raised as an osteofasciocutaneous flap by including a skin paddle, which may also be sensate. It provides large calibre vessels with a long vascular pedicle and enough bone length (25 cm) to reconstruct near-total mandibular defects and withstand irradiation, with minimal long-term donor site morbidity [2]. Furthermore, the endosteal and periosteal blood supply safely permits multiple osteotomies, and the donor site is far away from the head and neck area to allow a two-team surgical approach.

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A. Thacoor (✉)
Pan Thames Rotation, London, UK
e-mail: amitabh.thacoor@doctors.org.uk

D. Butler
Bay of Plenty District Health Board, Tauranga, New Zealand

D. Nikkhah
Department of Plastic, Reconstructive and Aesthetic Surgery, Royal Free Hospital, London, UK

J. Rawlins
Department of Plastic Surgery, Royal Perth Hospital, Perth, Australia

41.2 Anatomy

41.2.1 Bony

The lower extremity long bones include the principal weight-bearing tibia and the more slender fibula. Proximally, the fibular head articulates with the lateral condyle of the tibia while distally the fibula forms the lateral component of the ankle mortice. The syndesmosis between the distal fibula and tibia is essential in maintaining the stability of the ankle mortise and, thus, should be respected when planning flap harvest. At the fibular neck, the common peroneal nerve passes from the popliteal fossa, lateral to fibula and into the lateral compartment of the lower leg. Care should be taken when dissecting at this level.

41.2.2 Fascial

Four fascial compartments define the lower leg: anterior, lateral, superficial posterior and deep posterior compartments (Fig. 41.1). The anterior and deep posterior compartments are separated by the interosseous membrane, while the anterior and posterior crural intermuscular septa separate the lateral compartment from the anterior and posterior compartments respectively.

41.2.3 Vascular

The FFF is supplied by the peroneal artery (branching from the tibio-peroneal trunk) and its venae commitantes. The overlying skin is supplied by septocutaneous perforators, carried in the posterior crural intermuscular septum, which should be protected in osteofasciocutaneous flaps. Musculocutaneous perforators through the flexor hallucis longus and soleus muscles may also be additionally present. A skin paddle of 8 × 15 cm may be based on these perforators.

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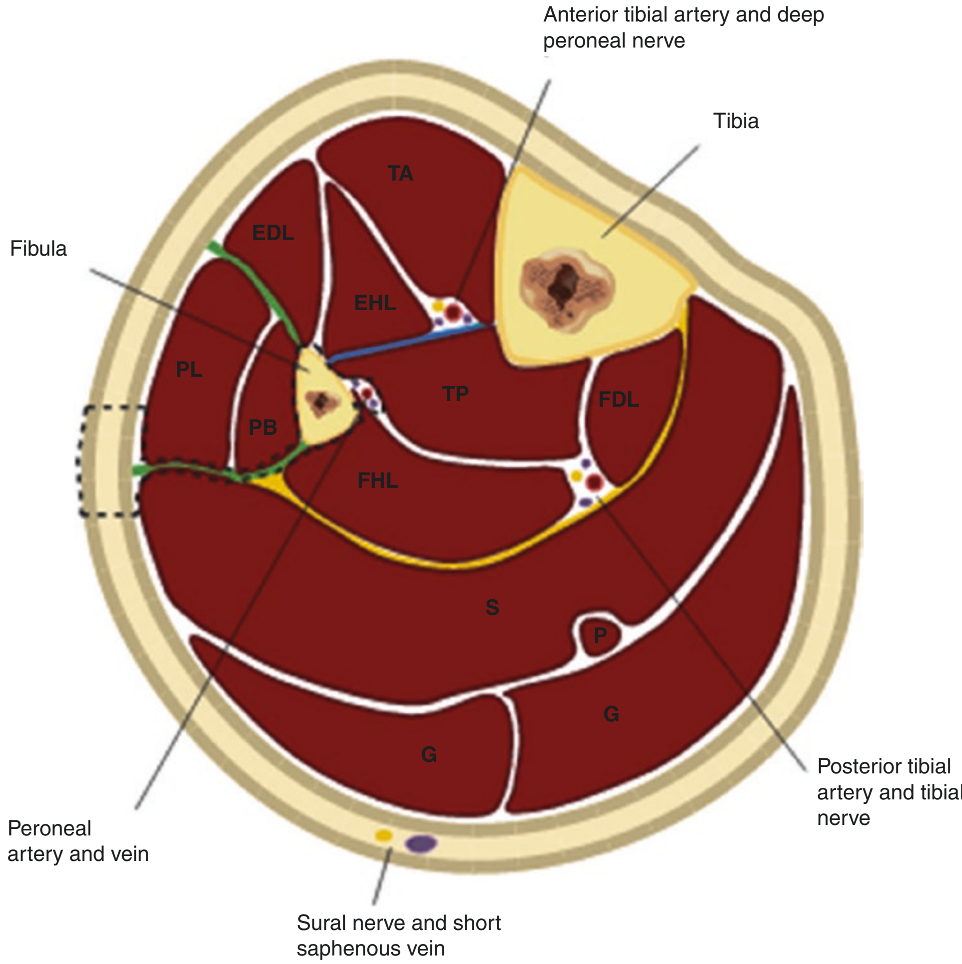

Fig. 41.1 Cross sectional anatomy of the lower leg. Muscles: *TA* tibialis anterior, *EDL* extensor digitorum longus, *EHL* extensor hallucis longus, *PL* peroneus longus, *PB* peroneus brevis, *TP* tibialis posterior, *FHL* flexor hallucis longus, *FDL* flexor digitorum longus, *S* soleus, *G* gastrocnemius, *P* plantaris. Fascial layers: *Anterior and posterior crural septa (green), Interosseous membrane (blue), Transverse crural septum (yellow).* Outline of the free fibula flap (black dotted) based on the peroneal artery and its venae commitantes and septocutaneous perforators through the posterior crural septum (green)

The fibula is supplied by an endosteal and perisosteal blood supply, which allows multiple osteotomies to be performed safely. The peroneal vessels descend along the medial side of the fibula and lie posterior to the tibialis posterior muscle and anterior to the flexor hallucis longus muscle. Abnormal vascular branching patterns are known to exist, with a 0.1–4% incidence of peroneal artery absence and 0.2–7% incidence of arteria perona magna reported [4].

41.2.4 Nerves

The sural nerve, which lies superficially to the posterior border of the fibula and adjacent to the short saphenous vein is prone to iatrogenic injury and may be included for a sensate flap. In the lateral compartment of the leg, the superficial peroneal nerve passes from its position deep to the muscle proximally to passing through the investing fascia in the distal third of the lower leg. This nerve is often encountered when raising the skin island anteriorly and is easily damaged at this stage. The anterior neurovascular bundle (anterior tibial artery and deep peroneal nerve—anterior to the interosseous septum) and the posterior neurovascular bundle (posterior tibial artery and tibial nerve—medial to the flexor hallucis longus and deep to soleus muscle) are encountered during flap harvest and must be protected.

Thus the muscles encountered when raising an FFF include:

- Peroneus longus
- Peroneus brevis
- Extensor digitorum longus
- Extensor hallucis longus
- Tibialis posterior
- Soleus
- Flexor hallucis longus

41.3 Pre-operative Investigations

The role of routine pre-operative imaging prior to FFF harvest remains controversial. All patients planned for an FFF should undergo a physical examination to assess palpable pedal pulses and exclude varicosities [5]. However, a normal physical examination alone may not be sufficient in predicting vascular anomalies as it only identifies 28% of abnormalities present on imaging [4].

The purpose of preoperative imaging is to exclude large vessel branching anomalies, an absent peronal artery, ateria perona magna, peripheral vascular disease and identify the course and location of septocutaneous perforators [6]. Diagnostic modalities available include Doppler ultrasonography, conventional angiography, computed tomography angiography (CTA) and magnetic resonance angiography (MRA).

Doppler ultrasonography is a low-cost and readily available option but provides limited information on the vasculature. Conventional angiography, an invasive technique using arterial catheterization for contrast injection, has been associated with complications from arterial puncture and has largely been superseded by the less invasive CTA and MRA [4]. The additional capability afforded by CTA and MRA in mapping septocutaneous perforators as small as 0.3 mm as well as the relationship between the peroneal vessels and the fibula may facilitate surgical planning by guiding correct placement of the skin paddle to optimize perfusion and safer flap harvest [4, 7]. Current Level 1 evidence exists to support the use of angiography routinely to assess vascularity and reduce of risk of devastating leg ischaemia [5].

Furthermore, pre-operative CT images are also commonly used to aid three-dimensional modelling and virtual planning of osteotomies using a custom-made jig, particularly in mandibular reconstruction. This has been shown to help reduce operative time and increase accuracy in reconstruction [8].

41.4 Flap Design and Markings

The patient is positioned supine with the knee flexed and a sandbag under the ipsilateral hip. A tourniquet is applied. Surface markings include the head of the fibula proximally and the lateral malleolus distally. The axis of the bone is then drawn between these two surface landmarks. The proximal osteotomy is marked at least 7 cm below the head of the fibula to protect the common peroneal nerve. The distal osteotomy is marked at least 7 cm above the projection of the lateral malleolus to project the distal ankle syndesmosis (Fig. 41.2).

Fig. 41.2 Surface markings showing segment of fibula bone required (red arrows) for mandibular reconstruction in a case of osteoradionecrosis

If a skin paddle is included, the location of the perforators are marked using Doppler ultrasound and the skin paddle is designed over the perforators. A skin paddle width of up to 4 cm can be closed primarily.

41.5 Flap Raise/Elevation: A Step-by-Step Guide

- **Step 1: Incision and exposure of lateral compartment**
  A longitudinal incision is made through skin and subcutaneous fat down to muscle fascia to expose the lateral muscle compartment. The fascia is then incised longitudinally to expose the muscles of the lateral compartment—peroneus longus and peroneus brevis (Fig. 41.3). This dissection proceeds posteriorly in the subfascial plane until the posterior crural intermuscular septum is identified. To minimize the risk of iatrogenic damage to the septocutaneous perforators, this intermuscular septum can be identified more proximally on the lower leg first. Once the entire septum is exposed, suitable septocutaneous perforators to the skin can be identified.
- **Step 2: Dissection of lateral compartment muscles off fibula**
  A submuscular dissection then allows the lateral compartment muscles to be dissected off the lateral aspect of the fibula (Fig. 41.4), leaving a 2 mm cuff of muscle on to the fibula (Fig. 41.5). This thin cuff of muscle is essential to

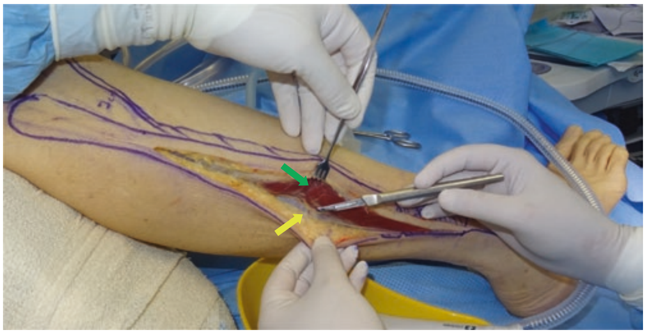

Fig. 41.3 Exposure of the lateral compartment muscles (green arrow). A perforator supplying the overlying skin is visible (yellow arrow), although not harvested in this case

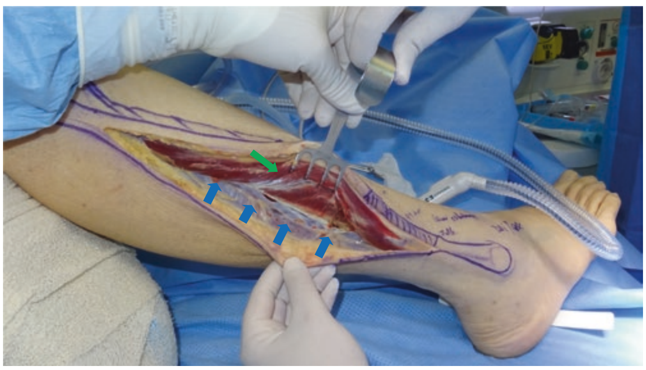

Fig. 41.4 Elevation of the muscles of the lateral compartment (green arrow). Septocutaneous Perforators going through the posterior crural septum are visualised (blue arrows)

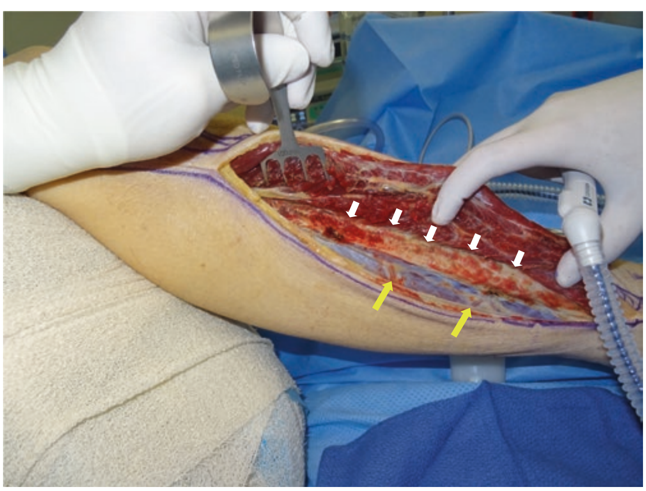

Fig. 41.5 A 2 mm cuff of muscle is left over the fibula to preserve periosteal blood supply (white arrows). Two perforators are also visible, which were not harvested in this case (yellow arrows)

avoid damage to the underlying periosteum. This continues up to the anterior crural septum. Anterior compartment muscle dissection then follows.

- **Step 3: Dissection of the anterior compartment muscles of fibula**
  After the anterior crural septum is divided, the muscles of the anterior compartment—extensor hallucis longus and extensor digitorum longus—are dissected off the anterior surface of the fibula, to expose the interosseous membrane (Fig. 41.6), which is incised longitudinally (Fig. 41.7). This reveals the tibialis posterior muscle. Attention is then focused to the posterior compartment.
- **Step 4: Dissection of the soleus muscle off the fibula**
  The posterior extent of the planned skin island is incised down through the fascia and dissection proceeds up to the

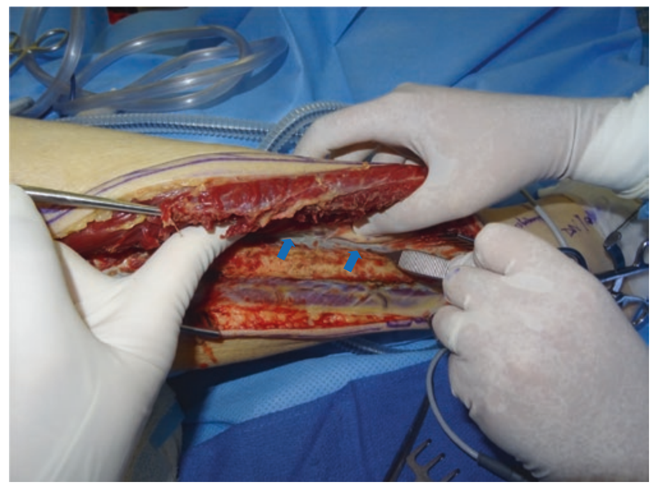

Fig. 41.6 The interosseous membrane becomes visible (blue arrows) following dissection of the anterior compartment muscles

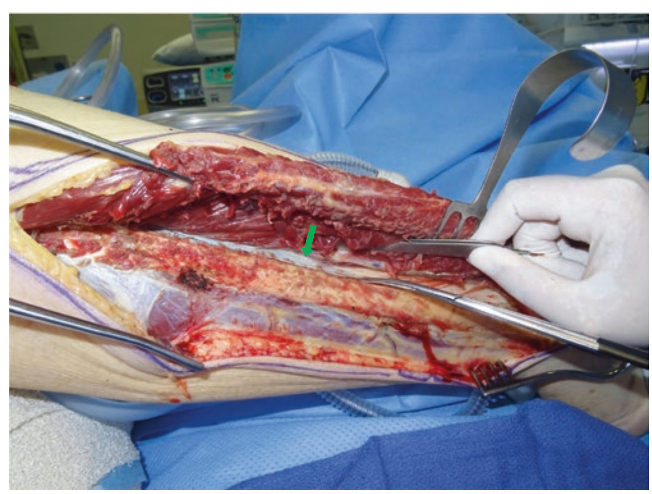

Fig. 41.7 The interosseous membrane becomes visible following dissection of the anterior compartment muscles (green arrow)

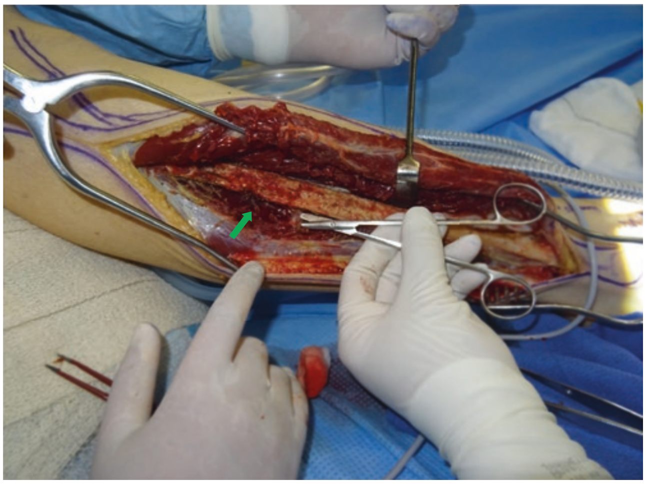

Fig. 41.8 Dissection of the muscles of the posterior compartment (green arrow)

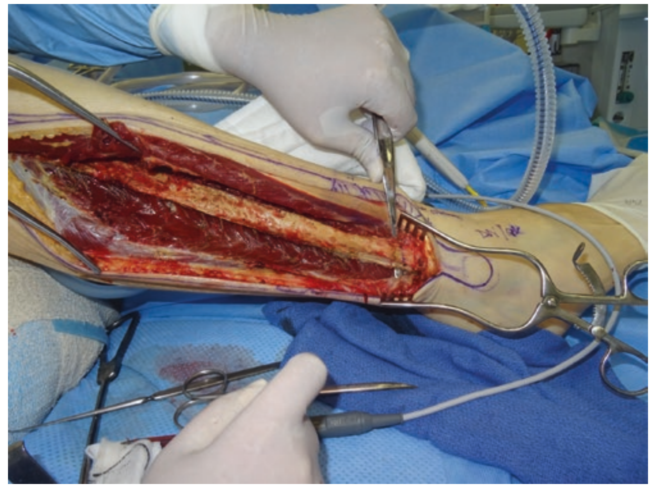

Fig. 41.10 Protection of the pedicle in preparation for the distal osteotomy

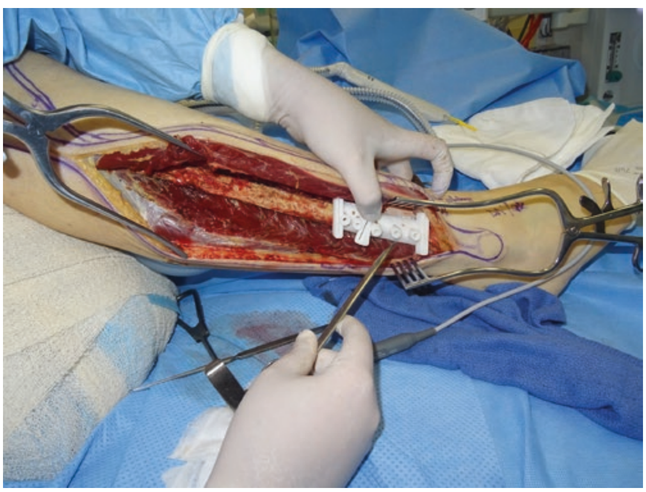

Fig. 41.9 Planning the distal osteotomy using a cutting jig

posterior crural intermuscular septum. The soleus muscle is dissected off the posterior crural septum (Fig. 41.8). As the flexor hallucis longus muscle is poorly visualized at this point, its dissection is best reserved for later (Step 7). There are branches that come off the septocutaneous perforators and pass posteriorly into the soleus muscle. These need to be divided after ensuring that the perforator continues proximally within the septum. Osteotomies can then be performed.

- **Step 5: Distal osteotomy**
  The distal osteotomy location is planned, ensuring it is at least 7 cm proximal to the lateral malleolus (a cutting jig can be used to aid planning—Fig. 41.9). A Howarth elevator (or malleable retractor) is used to get around the distal end of the fibula in a sub-periosteal plane (Fig. 41.10) and the distal osteotomy is performed using an oscillating saw, while the assistant uses saline irrigation to prevent thermal damage to the bone (Fig. 41.11).

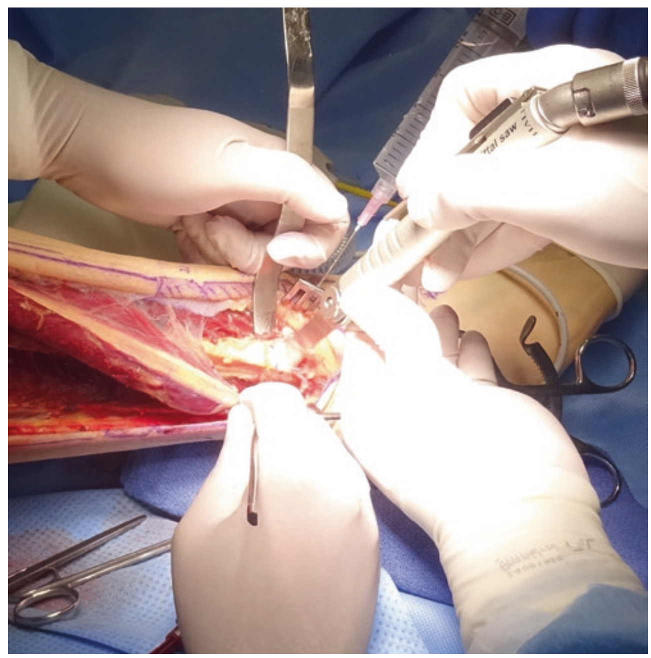

Fig. 41.11 Distal osteotomy with saline cooling

- **Step 6: Proximal Osteotomy**
  The proximal osteotomy is performed, using a similar technique (Fig. 41.12). This osteotomy should be performed at 7 cm below the fibular head regardless of the length of bone required. This gives access to dissect the full length of vascular pedicle. Care should be taken to avoid injury to the deep peroneal nerve during this step. Following completion of the osteotomies, the fibula should be easily retractable laterally to expose the tibialis posterior muscle (Fig. 41.13).

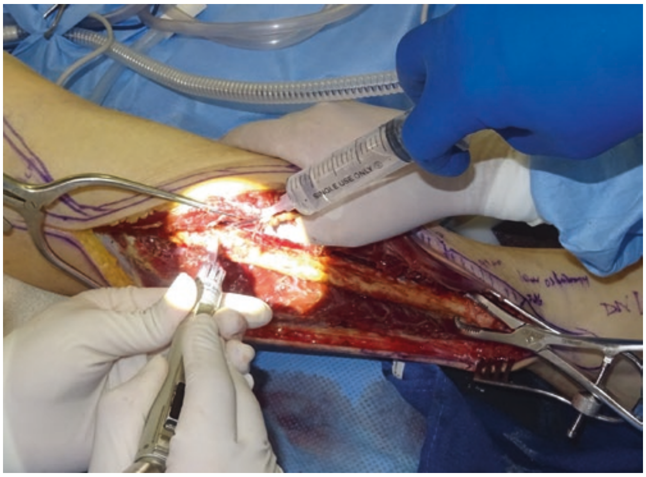

Fig. 41.12 Proximal osteotomy

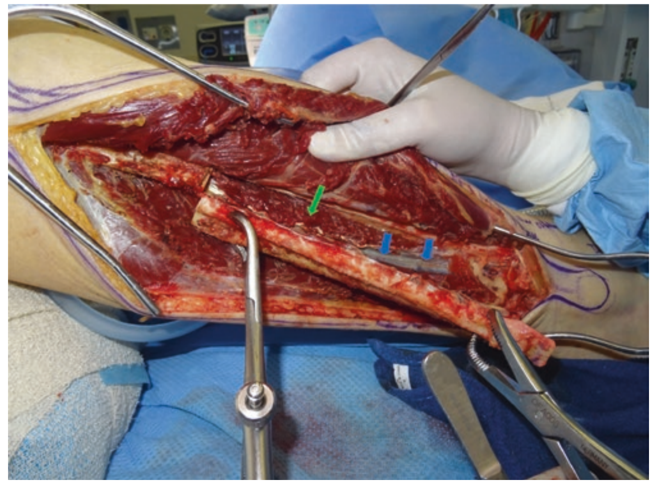

Fig. 41.14 Identification and dissection of the peroneal vessels (Blue arrows) through tibialis posterior (green arrow)

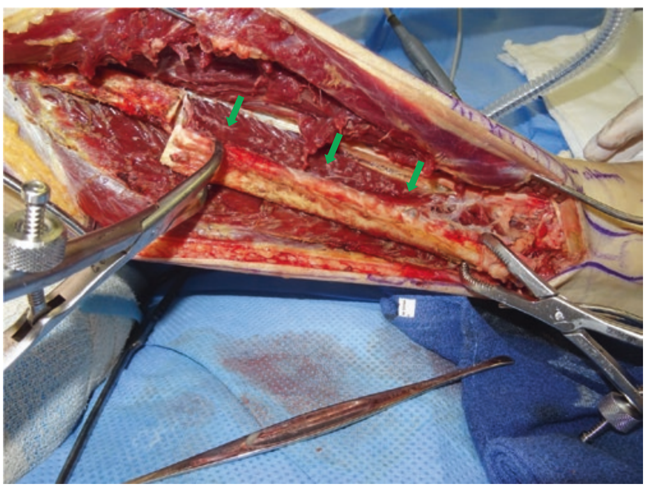

Fig. 41.13 Retraction of the fibula following osteotomies to expose the chevron-shaped tibialis posterior muscle (green arrows)

Fig. 41.15 Excision of proximal fibula before discarding to facilitate proximal dissection of pedicle (white arrow)

- **Step 7: Identification of the peroneal vessels**
  The distal end of the fibula is dissected underneath the interosseous membrane to identify the peroneal vessels. The distal end of the peroneal vessels are exposed and carefully clipped and divided. Tibialis posterior muscle is then dissected off the peroneal vessels from distal to proximal, and the flexor hallucis muscle (now better visualized) is dissected off the fibula, thereby islanding the flap (Fig. 41.14). Dissection should proceed until the origin of the pedicle from the tibioperoneal trunk. In order to facilitate proximal dissection of the pedicle, a window can be created by excising and discarding a portion of the proximal fibula (Figs. 41.15 and 41.16). Proximally, the tibial nerve and posterior tibial vascular bundles are encountered and should be carefully protected.

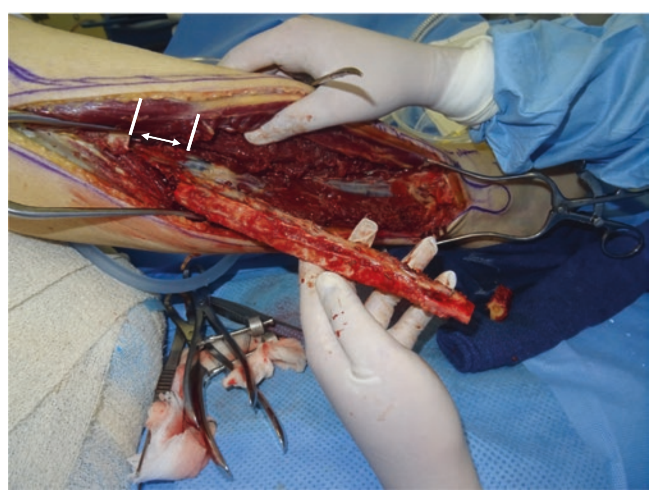

Fig. 41.16 Window created following discarding of proximal fibula

- **Step 8: Vessel clamping**
  The tourniquet is deflated and haemostasis performed. The peroneal artery and its associated venae commitantes can then be carefully inspected. The proximal end of the pedicle is clamped and transected and the flap safely detached.
- **Step 9: Wedge osteotomies**
  In cases of mandibular reconstruction, a cutting jig is placed over the fibula and secured with screws (Fig. 41.17). A Howarth elevator is used to protect the pedicle while wedge osteotomies can then be performed with an oscillating saw (Fig. 41.18) (Video 41.1).
- **Step 10: Closure**
  Following successful osteotomies (Fig. 41.19) and preparation of the recipient vessels (Fig. 41.20), the leg wound can be closed primarily or by split thickness skin grafting. A skin paddle of up to 4 cm wide can be closed primarily but split thickness skin grafting is required for larger defects. The leg is then immobilized in a posterior leg splint.

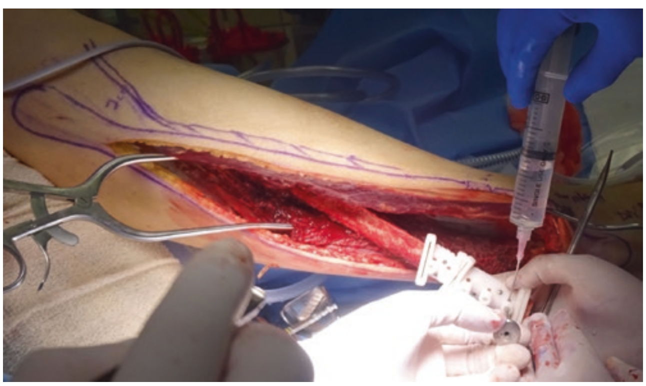

Fig. 41.17 Wedge osteotomies performed under warm ischaemia

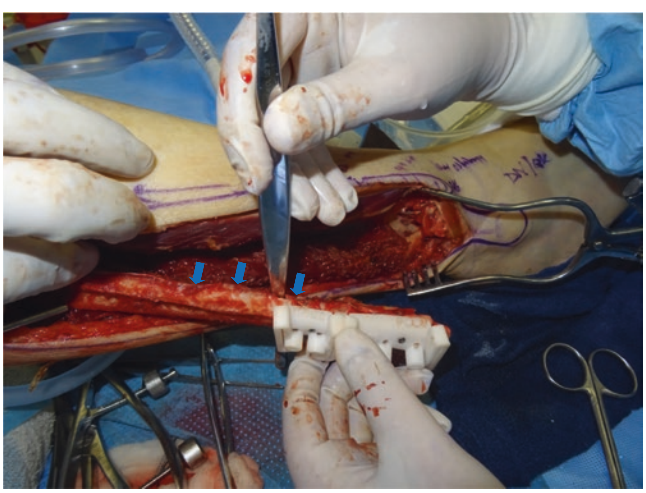

Fig. 41.18 Protection of the pedicle (blue arrows) using a Howarth elevator during wedge osteotomy

Fig. 41.19 Successful osteotomies and application of custom designed plates for bespoke mandibular reconstruction after osteoradionecrosis

Fig. 41.20 Successful preparation of recipient vessels, in this case the facial artery (red arrow) and common facial vein (blue arrow) in the neck for mandibular reconstruction

41.6 Core Surgical Techniques in Flap Dissection

Markings The proximal osteotomy site should be at least 7 cm from the head of the fibula to prevent inadvertent damage to the deep peroneal nerve (Fig. 41.21). The distal osteotomy site should be at least 7 cm from the lateral malleolus to protect the integrity of the distal fibular ligaments and preserve ankle stability. The axis of the posterior border of the fibula is marked between the head of the fibula proximally and the lateral malleolus distally. This corresponds to the posterior crural septum, where the septocutaneous perforators are located. If an osteocutaneous FFF is

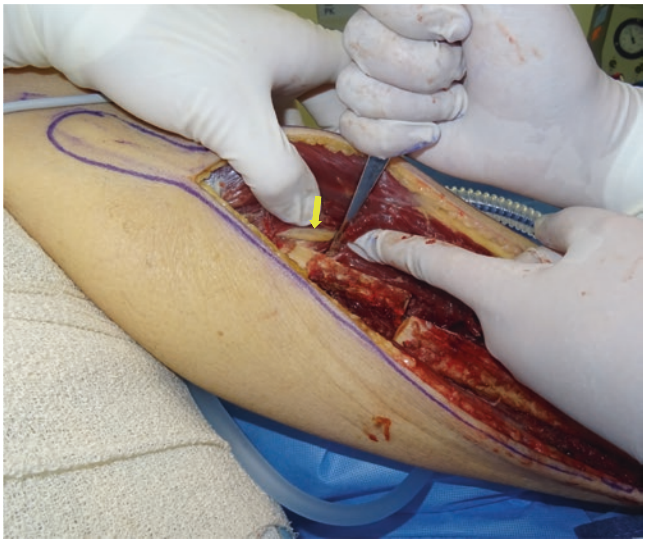

Fig. 41.21 Location of the deep peroneal nerve

raised, the skin paddle is centred over the posterior border of the fibula, to include skin perforators identified by Doppler ultrasound.

Elevation of lateral muscle compartment The anterior margin of the skin flap is incised first down to the muscles of the lateral compartment. Lateral traction is applied to the anterior skin flap while counter-traction is applied to the peroneal muscles anteriorly using cat's paw retractors. The peroneal muscles can be sharply dissected from the deep fascia up to the posterior crural septum. Septocutaneous perforators will become visible and must be carefully preserved, if a skin paddle is included. The lateral compartment muscles are dissected off the surface of the fibula, leaving a 2 mm cuff of muscle to preserve perosteal blood supply. This is continued up to the anterior crural septum, which is incised to access the anterior compartment.

Elevation of the anterior muscle compartment The anterior compartment muscles are dissected off the fibula. The surgeon's non-dominant thumb can be used to help retract the muscles and improve visibility of the interosseous membrane and also gauge the desired thickness of muscle retained on the surface of the fibula (Fig. 41.6). The interosseous membrane must be fully released to allow subsequent lateral retraction of the fibula to expose tibialis posterior muscle.

Elevation of the posterior muscle compartment The soleus muscle is bluntly separated from the flexor hallucis longus muscle, and is then dissected off the posterior aspect of the fibula. Large perforators through the gastrocnemius muscle emerge and need careful ligation.

Distal and proximal osteotomies Once the osteotomy sites have been marked, the overlying periosteum is incised and subperiosteal dissection using a Howarth elevator is performed. Following completion of the osteotomies, the fibula is retracted laterally using bone hooks (Fig. 41.13). This exposes the chevron-shaped tibialis posterior muscle.

Dissection of the peroneal vessels An avascular plane exists between tibialis posterior and the peroneal vessels. Tibialis posterior can therefore be dissected off the length of the peroneal vessels using a combination of bipolar cautery and ligation of side branches, which can be traced proximally to their junction with the posterior tibial vessels. Several side branches supplying tibialis posterior and soleus come into view, and must be ligated. Flexor hallucis longus muscle is now better visualized and can be dissected off the fibula. The vessels are clamped and ligated distally. In order to increase pedicle length and facilitate dissection proximally, a portion of fibula bone is excised and discarded to create a window for better visualization (Figs. 41.15 and 41.16). Once the desired pedicle length is obtained, the peroneal vessels are inspected, clamped and divided proximally. The flap can now be safely detached.

Wedge osteotomies In cases of mandibular reconstruction, a preoperative computer-generated plate contouring model and cutting jig may be designed to aid planning of osteotomies. Following complete elevation of the flap, the cutting jig is carefully placed over the fibula and secured in place with screws. Windows are made behind the planned osteotomy sites, where a malleable retractor is placed to protect the pedicle. Wedge osteotomies can then be safely performed under warm ischaemia (Figs. 41.17 and 41.18).

Closure The leg wound can be closed over a suction drain. A defect resulting from a skin paddle of up to 4 cm wide can be closed primarily, and split thickness skin grafting is required for larger defects. The leg is then immobilized in a posterior leg splint.

41.7 Clinical Scenario A: Surgeons Dariush Nikkhah, Qadir Khan, and Jeremy Rawlins

A 26-year-old fit and well male patient was diagnosed with a large mandibular odontogenic myxoma extending into the overlying soft tissue (Fig. 41.22). Following multidisciplinary assessment, surgical management by subtotal mandibulectomy and reconstruction with a free fibula osteocutaneous flap was recommended. The Pro Plan software was used preoperatively to aid surgical planning of intra-operative wedge osteotomies and bony plating. The peroneal artery was anastomosed to the recipient facial artery, a vena comitans was anastomosed to the recipient common facial vein and the skin paddle was used to reconstruct the floor of the mouth (Fig. 41.23). Complete resection was achieved and good chin projection and evidence of bony union was demonstrated on an early orthopantomogram (Fig. 41.24). The patient was also fitted with osseointegrated implants and has had an uneventful 12-month outcome (Videos 41.2 and 41.3).

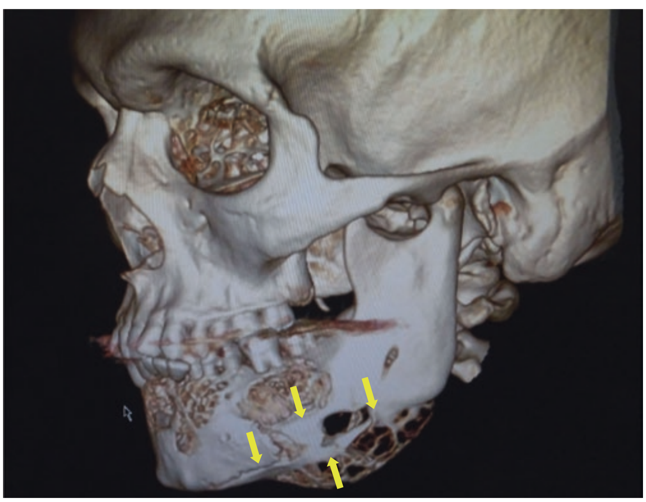

Fig. 41.22 Pre-operative CT scan showing left mandibular odontogenic myxoma (yellow arrows)

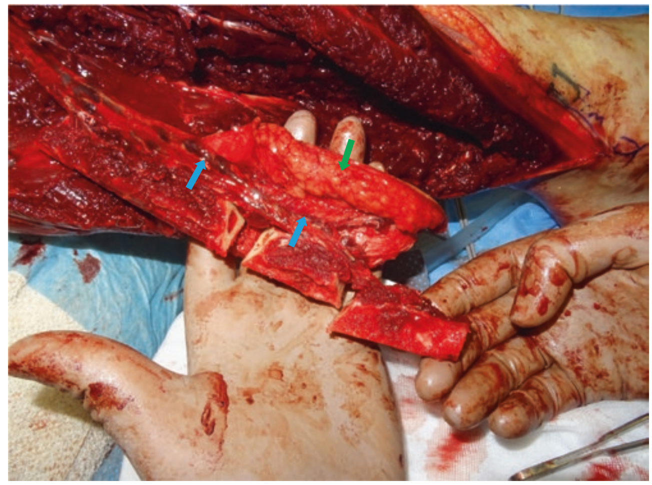

Fig. 41.23 Osteocutaneous fibula flap following osteotomies. Skin paddle (green arrow) peroneal pedicle (blue arrows)

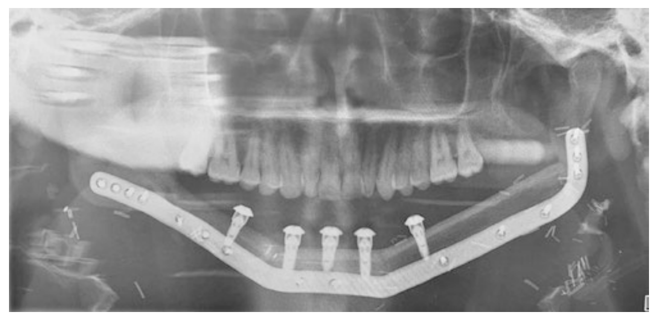

Fig. 41.24 Post-operative radiograph showing successful bony union and excellent symmetry

41.8 Clinical Scenario B: Surgeons Dariush Nikkhah, Qadir Khan, and Jeremy Rawlins

A 73-year-old male patient was diagnosed with osteoradionecrosis of the mandible following treatment for a previous SCC of the floor of the mouth. A decision was made to proceed with partial mandibulectomy and reconstruction with an osseous free fibula flap. The Pro Plan software was used preoperatively to aid surgical planning of intra-operative resection, wedge osteotomies and bony plating (Figs. 41.25 and 41.26). Following resection (Fig. 41.27), the peroneal artery was anastomosed to the recipient facial artery, a vena comitans was anastomosed to the recipient common facial vein. Complete resection was achieved and good post-operative mandibular contour was achieved (Fig. 41.28).

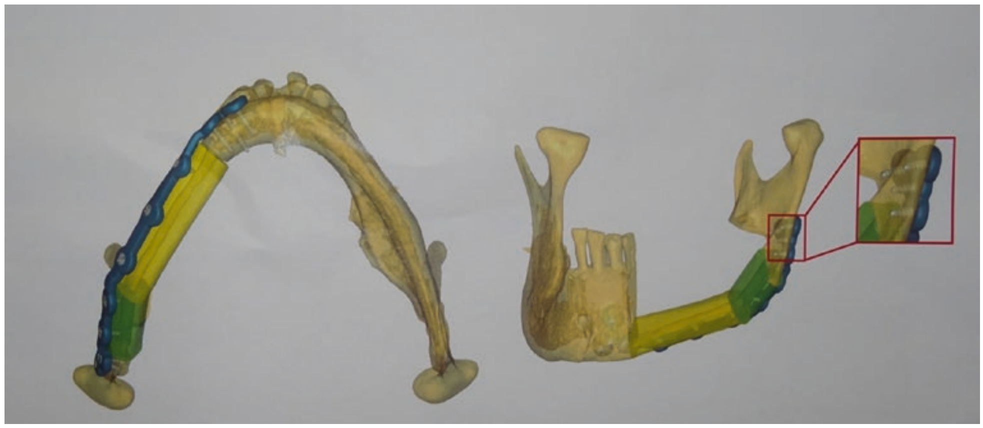

Fig. 41.25 ProPlan software for planning of osteotomies and bony plating

Fig. 41.26 Cutting jig used to aid surgical bony resection

Fig. 41.27 Resulting defect with mandibular plate visible

Fig. 41.28 Post-operative photograph demonstrating good mandibular contour

41.9 Pearls and Pitfalls

Pearls

- If an osteocutaneous flap is chosen, care must be taken not to damage the posterior crural septum, which carries most septocutaneous perforators to the skin paddle.
- Although septocutaneous perforators must be preserved in osteocutaneous flaps, musculocutaneous perforators may also be included to augment circulation where inadequate septocutaneous perforators are encountered.
- Always leave a thin cuff of muscle (at least 2 mm) over the fibula during flap elevation to preserve periosteal blood supply.
- In order to facilitate visualisation and dissection of the fibula pedicle proximally, a section of fibula (around 6 cm) may be removed and discarded.
- A thicker cuff of FHL can also be included in the flap to improve vascularity or to add bulk to obliterate dead space.

Pitfalls

- During dissection of the anterior compartment muscles, the anterior tibial vessels and deep peroneal nerve must be identified and protected by medial retraction using Langenbeck retractors.
- One should be mindful of the tibial nerve, which lies in very close proximity to the peroneal pedicle during dissection.
- If an osteocutaneous flap is raised, care must be taken not to damage the sural nerve and short saphenous vein during the posterior skin margin dissection by staying in a supra-fascial plane initially.
- The interosseous membrane should not be incised flush on to the fibula, but instead 5 mm away from it to avoid injury to the vascular pedicle and to aid in flexor hallucis longus repair.
- If less than 7 cm of fibula is left distally, a diastasis screw can be used to ensure ankle stability.

41.10 Selected Readings

- Taylor GI, Miller GDH, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular techniques. Plast Reconstr Surg. 1975;55:533–44.
  This paper illustrates the first published description of the free fibula flap in the reconstruction of two cases involving extensive bone and soft tissue loss secondary to trauma.
- Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. Plast Reconstr Surg 1989;84:71–9.
  This paper describes the first use of the free fibula flap in mandibular reconstruction. Twelve segmental mandibular defects were reconstructed using osseous and osteocutaneous free fibula flaps. Although all flaps survived, the author reported that the septocutaneous blood supply was generally inadequate to support the skin island for intraoral soft-tissue reconstruction.
- Wei FC, Chen HC, Chuang CC, Noordhoff MS. Fibular osteoseptocutaneous flap: anatomic study and clinical application. Plast Reconstr Surg. 1986;78(2):191–200.
  This anatomical study of 20 cadaver legs and 15 clinical cases demonstrates adequate circulation to the skin of the lateral aspect of the lower leg from the septocutaneous branches of the peroneal artery alone, and contrasts the original findings by Hidalgo (above).
- Alolabi N, Dickson L, Coroneos CJ, Farrokhyar F, Levis C. Preoperative angiography for free fibula flap

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This paper is the only published Level 1 evidence on the use of pre-operative angiography in free fibula harvest. It concludes that there is low-quality evidence to suggest a necessity for routine pre-operative angiography in all patients undergoing free fibula harvest.

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