CASE REPORT

Reconstruction of a complicated adjacent non-union of the radius and ulna using a free vascularised double-barrel fibula graft

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SUMMARY

While the free vascularised double-barrel fibula flap has been traditionally used in the reconstruction of defects in the long bones of the lower extremities, the advantages of this type of graft can also be seen in the treatment of adjacent radial and ulnar non-unions of the forearm. The main advantage of the double-barrel fibula flap in treatment of antebrachial non-unions is that it allows for the simultaneous anatomical reconstruction of the radius and the ulna while maximising forearm functionality. In contrast to other procedures, this tailored graft also helps preserve pronation and supination of the forearm. In this article, we chronicle a case in which a microvascular osteomyocutaneous double-barrel fibula flap was used to concurrently reconstruct the radius and ulna of a patient with a severe antebrachial non-union.

BACKGROUND

For decades, the free fibula flap has been a valuable tool in the treatment and reconstruction of severe bone defects. These grafts gained initial success in 1975, with the reconstruction of lower limb defects.¹ Subsequently, these grafts were adapted to a number of other procedures including the reconstruction of long bones in the upper extremities as well as reconstruction of the mandible.^{2–3} The graft's continuing popularity is beholden to several factors: its robust bone volume, ample vascularisation, well-perfused myocutaneous flap and low donor site morbidity.^{4–5}

While the conventional free fibula flap has been used with great success in the treatment of many osseous defects, it is not, however, optimal for the reconstruction of complex radial and ulnar non-unions. Treatment with these traditional grafts produces only a single forearm bone, which causes a loss of antebrachial pronation and supination, and significantly impacts the patient's range of motion.^{6–7} A 'double-barrel' variant of the free fibula flap, also referred to as twin-barrel or folded free vascularised fibula flap,^{8–9} can be used instead in order to avoid this loss of forearm functionality.⁴

Predominantly used in the reconstruction of injuries requiring extra bone volume, the double-barrel free fibula flap consists of two vascularised bone struts created by making a transverse osteotomy in a conventional free fibula graft.⁴ When used to treat a weight-bearing structure requiring increased bone volume, these struts are normally folded parallel to each other to increase osseous hypertrophy and mechanical stability.⁴ However,

when treating a simultaneous radial and ulnar non-union, the double-strut structure allows each bone to be individually reconstructed. This concurrent double-bone reconstruction procedure provides anatomical stability and allows for the preservation of antebrachial pronation and supination thereby optimising a patient's range of motion.^{10–12}

This case report chronicles a reconstruction of an adjacent non-union of the radius and ulna, using a double-barrel free microvascular osteomyocutaneous fibula flap graft.

CASE PRESENTATION

A 49-year-old man was referred to the Department of Plastic and Reconstructive Surgery, Odense University Hospital, Denmark, in 2014, for reconstruction of the radius and ulna in his left forearm. The patient had, in 2012, been involved in a motor vehicle accident in Germany, which had resulted in a complicated fracture of his left antebrachium. This fracture was originally treated in Flensburg, Germany, with plate osteosynthesis of the radius and ulna. Owing to continuing forearm instability, the patient was referred to the Department of Orthopaedic Surgery, Odense University Hospital, Denmark, where he underwent multiple operations in an attempt to correct the defect. These operations were ultimately unsuccessful and the patient subsequently developed a severe non-union of the radius and ulna in his left antebrachium (figure 1A). The patient's main concerns were the pain and severe loss of forearm function associated with the non-union (figure 1B).

TREATMENT

Owing to the extent of the patient's antebrachial instability, coupled with the desire to reconstruct a forearm that was anatomically stabilised and functionally optimised, it was determined there was indication for reconstruction of the patient's left forearm, using a double-barrel free microvascular osteomyocutaneous fibula flap graft transfer.

The operation was performed under general anaesthesia with antibiotic prophylaxis and carried out concurrently by two surgical teams. The first team, consisting of two orthopaedic surgeons, began by making an incision in the patient's left antebrachium at the site of his radial cicatrice. The incision was followed by sharp and blunt dissection of the forearm until the site of non-union was reached. Debridement of the radius and surrounding soft tissue was subsequently performed until

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Figure 1 (A) Preoperative X-ray showing non-union of the left forearm. (B) Preoperative picture showing severe instability of the left forearm.

vital tissue was reached. ~5 cm of the radius was excised in total. Next, an incision was made over the ulna, and the soft tissue was again dissected to the site of non-union. The area was debrided and ~5 cm of necrotic bone tissue removed (figure 2A).

The second team, consisting of two plastic surgeons, began by locating perforators over the patient's right fibula, using a Doppler ultrasound. A lateral incision was made and two sufficiently sized skin flap perforators were visually identified. The distal perforator was sacrificed while perfusion was sufficiently maintained from the proximal perforator. A free microvascular osteomyocutaneous fibula flap, measuring ~14 cm in length, was extracted from the patient's right leg. The harvested graft was subsequently osteotomised, and an intermediate 3 cm bone fragment removed. This tissue gave rise to a double-barrel graft consisting of two well-vascularised bone fragments: a proximal 5 cm fragment and a distal fragment of ~6 cm. These fragments were implanted in the debrided area of the radius and ulna. An end-to-end anastomosis was created with the radial artery while a cutaneous vein anastomosis was created with a 2.5 mm flow coupler device. In total, the warm ischaemia time was 48 min.

The first surgical team then performed a simultaneous osteosynthesis of the radius and ulna, using the newly constructed double-barrel graft (figure 2B). The graft was joined to the radius, using a reconstruction plate, and attached with 8 locking screws and 2 cortical screws. A 10 hole limited-contact plate, bent towards the elbow and attached with six locking screws and two cortical screws, was used to join the graft to the ulna. Thereafter, forearm stability was achieved. The new skin island flap on the forearm, measuring 10×3 cm, was sutured closed

Figure 2 (A) Operative picture after resection. (B) Placement of the double-barrel free fibula graft.

Figure 3 (A) Postoperative X-ray showing osteosynthesis. (B) Postoperative wound healing.

Figure 4 (A) Resulting pronation and (B) Supination of the left forearm.

leaving an inset surgical drain. Finally, a 90° external brace was placed on the patient's left arm extending from shoulder to wrist.

There were no significant immediate postoperative complications at the graft site, and the entire skin flap survived.

OUTCOME AND FOLLOW-UP

The reconstruction of the patient's radius and ulna with a double-barrel free fibula graft was successful (figure 3A) and without any significant immediate postoperative complications around the site of osteosynthesis (figure 3B).

The donor site, however, became infected 3 days after the surgery, and the patient was admitted to his local hospital where surgical wound revision was carried out. Subsequently, a large granulated skin defect developed at the donor site, which was further complicated by an area of exposed tendon. The defect was ultimately treated with skin graft transplantation.

The patient's recovery was compromised by an unrelated accident 3 months after the surgery, which resulted in proximal fracture of the humerus in his left arm. This fracture was immobilised with a brace for 3 weeks, thus necessitating a pause in the patient's physical therapy and ultimately extending the time of rehabilitation.

Radiographic healing of the radius and ulna could be seen 6 months after the initial surgery (figure 4A) and, 8 months postsurgery, the patient had regained a great deal of function in his left arm. The active range of motion at the elbow spanned from 10° to 105°. Active forearm pronation was measured to be

Figure 5 (A) Six-month postoperative X-ray. (B) Tenth-month postoperative X-ray.

25° (figure 5A) and supination to be 15° (figure 5B). The patient's passive forearm pronation and supination were 70° and 30°, respectively. Wrist dorsiflexion was 30° and palmar flexion 15°. The radial deviation was 10° and ulnar deviation 20°. The patient had normal sensation and free movement of his hand and fingers. At the patient's 10-month follow-up, there was continuing radiographic evidence showing union of the radius. A non-union persists at the distal ulna (figure 4B) but, despite minimal weight-bearing discomfort, the patient is satisfied with the result and has refused further surgical treatment.

DISCUSSION

The free fibula flap graft has been a valuable surgical tool in the reconstruction of varied osseous defects and has been used for years with great success. However, in the case of a complicated antebrachial non-union, this traditional graft is limited due to the fact that it only provides for the recreation of a single forearm bone. Therefore, the double-barrel free fibula flap graft is an attractive alternative when reconstructing adjacent radial and ulnar non-unions, because it allows for the maximisation of forearm functionality and preservation of antebrachial pronation and supination.

There have, over the past three decades, been a few previous examples of case studies in the literature describing this novel treatment. Jones *et al*⁴ was one of the first to propose the use of a free vascularised double-barrel free fibula flap graft to reconstruct an antebrachial non-union in a patient with adjacent radial and ulnar bone defects. Although they achieved radiographic union after 4 months, they were unsuccessful in restoring pronation and supination of the patient's forearm.⁴ More recent literature, from Saint-Cyr *et al*,¹⁰ Santanelli *et al*¹¹ and Zhen *et al*,¹² highlights cases of simultaneous anatomical reconstruction of adjacent radial and ulnar defects where varying degrees of forearm pronation and supination were restored.

In our case, the patient's radius and ulna were simultaneously reconstructed using a double-barrel free fibula flap. As previously described, the patient regained much of his forearm mobility with full sensibility and finger functionality. However, due to an unrelated proximal humerus fracture and subsequent immobilisation, the patient's rehabilitation and recovery were delayed. The effect of this subsequent fracture could be seen in the delay in antebrachial healing at 6 months, as well as in the reduction in the patient's active pronation and supination from 30° and 30°, respectively, to 25° and 15° after immobilisation treatment. At 10-month follow-up, although union of the radius was achieved, non-union in the distal ulna still remained. The forearm is stable, however, and the patient is satisfied with the result, experiencing only occasional discomfort related to weight-bearing. It is interesting to note that a minor surgical revision would most likely correct this non-union, but in accordance with the patient's wishes, no further treatment will be pursued.

A complicated non-union of the forearm is, by its very nature, a challenging condition with a narrow range of treatments for providing satisfactory outcomes with respect to anatomical stability, range of motion and long-term functionality. A double-barrel free fibula graft is an attractive alternative to a

single-bone reconstruction of antebrachial non-unions, because it allows for the simultaneous reconstruction of both the radius and the ulna, while retaining forearm pronation and supination functionality.

Learning points

- ▶ The conventional method for treating simultaneous complicated radial and ulnar non-union fractures uses a conventional free fibula flap and produces a single forearm bone. This treatment results in the loss of antebrachial pronation and supination thereby limiting the patient's range of motion as well as the arm's long-term functionality.
- ▶ The use of a double-barrel free fibula graft allows for the concurrent reconstruction of both forearm bones, and preserves pronation and supination of the antebrachium.
- ▶ Indications for the use of a double-barrel free fibula graft include: severe anatomical and functional instability in the radius and ulna, and the potential to maximise forearm functionality by preserving antebrachial pronation and supination.

Contributors ECF is the primary and corresponding author. SSP was involved in researching and drafting the article. JAS and OS were involved in the planning and execution of the operation as well as providing critical revisions to the article.

Competing interests None declared.

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