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Radius graft pedicled on the anterior interosseous artery for recurrent ulnar nonunion

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KEYWORDS
Bone transplantation; Recurrent pseudarthrosis; Ulna fracture

Summary
Recurrent ulnar nonunion challenges the functional prognosis and raises major problems concerning the best therapeutic strategy to follow. The case of a female patient presenting recurrent nonunion of the ulnar diaphysis despite successive treatments is reported. The radius graft pedicled on the anterior interosseous artery from a retrograde approach obtained bone union in 3 months with no functional sequelae. For the first time, we propose a therapeutic alternative calling on a proximally pedicled anterior interosseous flap. This technique can be performed under locoregional anesthesia and does not sacrifice the main artery of the forearm. However, the size of the graft does not entirely compensate for segmentary bone loss. The radius graft pedicled on the anterior interosseous artery is an inventive technique that can solve the problem of difficult ulna nonunions without the disadvantages of vascularized fibula harvesting.

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Introduction
The literature on isolated ulnar pseudarthroses is scarce. This is a relatively infrequent complication and its management with conventional surgery produces good results [1,2].

However, when nonunion becomes recurrent, it challenges the patient’s long-term functional prognosis and creates major problems in choosing which therapeutic strategy to follow. Based on a clinical case, we detail a new technique calling on a radius graft pedicled on the anterior interosseous artery with retrograde flow.

Clinical case
We report the case of a 61-year-old right-handed female patient, a farmer, nonsmoking, who presented recurrent malunion 20 months after a closed fracture of the middle third of the right ulnar diaphysis. Union was not achieved despite successive treatments including compression plate osteosynthesis, surgical curettage of the pseudarthrosis with decortication and corticocancellous autologous graft, followed by pulsed electromagnetic field therapy associated with vitamin D (Fig. 1).

In this context, we first discussed free fibula grafting, but this was deemed to be too heavy and disproportionate in terms of cavitory bone loss. For this reason, we performed a radius graft pedicled on the anterior interosseous artery with retrograde flow.
Surgical technique

The surgery was performed under locoregional anesthesia on a surgical table with arms and using a pneumatic tourniquet with moderate exsanguination.

The approach extended from the Lister tubercle distally to the ulnar crest, which exposed the malunion, and allowed harvesting the vascularized bone graft as well as the dissection of the anterior interosseous pedicle (Fig. 2).

First, the malunion area was approached to remove the plate and screw fixation, excise the devascularized tissues, and carry out medullary permeabilization of the proximal and distal extremities of the ulna. This resulted in loss of cavitary bone substance, which was trimmed in a wedge shape to receive the graft.

We then harvested the vascularized radial graft via the posterosuperior branch of the anterior interosseous artery sized to adapt to the ulnar substance loss.

With the wrist in pronation, the approach was posterior along a line joining the first approach proximally and the Lister tubercle distally. The extensor pollicis longus muscle was identified and retracted toward the ulna and the extensor pollicis brevis toward the radius. The dorsal side of the radius was thus exposed and the proximal and distal posterior branches of the anterior interosseous artery were identified. The interosseous membrane was incised proximally 5 cm. We then ligated the anastomosis between the proximal posterior branch of the posterior interosseous artery. The corticocancellous graft, vascularized on the proximal posterior branch of the anterior interosseous artery, was harvested on the dorsal side of the radius. It measured 8 mm wide by 2 cm long. The pedicle was released distally and proximally. The transplant was carefully passed through the interosseous membrane and embedded in the prepared wedge-shaped ulnar cavity. It was first fixed with two Kirchner wires. A seven-hole interlocking plate stabilized the assembly. The wound was closed on two planes with a drain in place. The arm was immobilized for 10 weeks with a long-arm cast with the elbow bent at 90° and in supination (Figs. 3 and 4).

Results

Bone union was achieved at 3 months from the vascularized bone graft, 29 months after the fracture. At 6 months from
the last intervention, the functional result was very satisfactory because the patient presented no pain and the mobility values were complete in flexion and extension of the wrist and the elbow, as well as in pronosupination. The scar was noninflammatory, nonadherent, and relatively inconspicuous (Fig. 5).

**Discussion**

Isolated malunions with no ulnar substance loss are rare and respond to conventional surgical graft decortication treatment. However, recurrent malunions resistant to traditional techniques are truly problematic in terms of therapeutic strategy.

Pedicled vascularized bone transplantation has found its main indications in bone reconstruction in the wrist and hand [3–8]. The advantage of these vascularized grafts is the contribution of living osteogenic tissue with low resorption, which provides early healing and better mechanical resistance. Pediculated transfers are grafted in a single procedure on the same operative site under locoregional anesthesia.

Anterior interosseous flaps were described by Martin et al. in 1989 [6] and Hu et al. in 1994 [4,5]. Their vascular supply comes from the proximal posterior perforating branch of the anterior interosseous artery that crosses the interosseous membrane 8–12 cm above the radiocarpal space in its most frequent anatomical variation (type 1) (Fig. 6). This procedure is normally used in its retrograde flow form for bone substance loss within the wrist and the hand. In their article describing the procedure, Hu et al. [5] reported one case of direct pedicle (anterograde flow) for bone loss in the distal third of the forearm. They also discuss the use of this procedure for the proximal third, provided that the dissection of the anterior interosseous artery is continued upstream by resecting the interosseous membrane 5 cm proximally.

The authors report for the first time a case in which this flap was used in its purely osseous, proximally pedicled form for nonunion of the upper third of the forearm. This allowed us to solve the difficult problem of recurrent ulnar malunion. Its rapid healing and good functional result are in agreement with the results of other series described in the literature for this vascularized graft but with a retrograde flow for bone loss within the hand.

However, this vascularized bone implantation did not provide an adequate response to extensive segment loss. It is indicated for limited, cavitary bone loss, although it can be associated with a conventional autologous graft for more

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<th>Table 1</th>
<th>Advantages and disadvantages of radius graft pedicled on the anterior interosseus artery with retrograde flow.</th>
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<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
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<tr>
<td>Locoregional anesthesia</td>
<td>Nonsegmental nonunion</td>
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<tr>
<td>Single operative site</td>
<td>Technically difficult</td>
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<tr>
<td>Low resorption</td>
<td>Unsightly scar</td>
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<td>Living osteogenic tissue (active participation in the biological bone union process)</td>
<td>Fracture at donor site</td>
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<td>Rapid healing</td>
<td>Theoretical risk of pronosupination impairment</td>
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<td>No need to sacrifice main artery</td>
<td></td>
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<tr>
<td>Reliability</td>
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<td>Composite flap</td>
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substantial defects. The size of the graft is limited in width because of the risk of fracture at the donor site. Dos Remedios and Schoofs [3] reported a case of fracture in a series of 15 cases following voluminous bone harvesting. The length of the graft can extend from the epiphysis to the lower part of the diaphysis, in this case preserving the distal posterior branch to ensure maximum vascularization of the graft. This graft can also be used in a composite form, particularly in cases of septic nonunion with unstable scars or osteocutaneous fistulae. The other disadvantages are the unsightly scar because it is located on the social side of the forearm, and a theoretical risk of pronosupination impairment because of having perforated the interosseous membrane. In addition, this technically difficult grafting procedure requires training in the anatomy laboratory (Table 1).

Conclusion

Determining the therapeutic strategy to implement in cases of recurrent nonunion is difficult. The good results found with vascularized pedicled bone implantation for hand reconstructions encouraged us to use this radius graft pedicled on the anterior interosseous artery with anterograde flow. In the end, this provided an ingenious solution to the problem of recurrent ulnar nonunion without the disadvantages of harvesting vascularized fibula.

The indications for this vascularized graft correspond to revision surgeries for nonunion, after conventional surgery, particularly in cases of long delay from the initial injury.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References