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Technical Corner

Technical Guide for Application of the Posterior Interosseous Bone Flap

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Background

The use of bone graft is a traditional treatment in orthopedic surgery (1). There are various indications for bone grafting, such as nonunion, bone defect after tumor resection, or arthrodesis (2-4). The vascularized bone graft should be used in particular circumstances like long structural bone graft, bone grafting in scar bed, an environment prone to infection (5, 6). Additionally, poor vascularity and low quality of the host bone (e.g., osteoporosis and a short remnant of the bone) make the union difficult and require a vascularized bone graft.

Posterior interosseous bone flap (PIBF) is a well-known fasciocutaneous flap in the forearm (7, 8). It could be applied as a composite flap containing bone. PIBF has been introduced as a retrograde flap for hand bone defects (9). Antegrade PIBF is a new method that has been used in the forearm and elbow (10, 11). This article presents the technique of PIBF harvesting as a vascularized bone graft for problems of the forearm and elbow.

Anatomy

After passing through the elbow, the brachial artery divides into two branches, the radial and the ulnar. After the ulnar artery passes under the pronator teres muscle, a branch called common interosseous artery originates from it, divided into anterior and posterior interosseous arteries. The anterior interosseous artery (AIA) runs distally on the anterior side of the interosseous membrane. The posterior interosseous artery (PIA) is thinner and moves posteriorly between the proximal edge and the oblique cord of the interosseous membrane. After giving off the recurrent interosseous branch, it continues distally in the posterior side of the interosseous membrane and between the muscles of the extensor carpi ulnaris (ECU) and extensor digiti minimi (EDM). It finally anastomoses with the AIA in the wrist area.

The PIA supplies extensor digitorum communis (EDC), extensor pollicis longus (EPL), extensor pollicis brevis (EPB), abductor pollicis longus (APL), ECU, the skin of the posterior forearm (fasciocutaneous branches), and the ulna (periosteal branches).

Rationale

The forearm and elbow nonunions and bone defects are uncommon, but they can be challenging for orthopedic surgeons (12, 13). Maintaining the proper length of the upper limb and the joints' range of motion (ROM) are the main therapeutic goals (13). Most forearm and elbow nonunion cases respond well to rigid fixation and the use of cancellous autograft (14-16). Intercalary nonvascularized grafts from the iliac crest and fibula are good options for filling the bone defects (17, 18).

Some factors can complicate the healing process and cause the failure of these methods. The presence of severe soft tissue damage, inadequate vascular supply, defects larger than 6 cm, and infection are some instances of such factors (19, 20). The low quality of the host bone in each end is another problem. It comes from poor vascularity, osteoporosis, or the small size of the host bone or contact area between the transferred bone and its host. The use of vascularized bone flaps such as fibular or iliac crest flaps plays an essential role in these situations (21-24). However, they require high technical skills and longer surgery duration.

Regional vascularized flaps require no microsurgical skills and have a shorter surgical time. Since the use of these flaps in the upper extremity is confined to one extremity, the regional blocks can be an appropriate anesthesia option. One of these regional flaps is the radial forearm bone flap that has shown promising results in treating forearm and elbow injuries. Its major drawback is sacrificing one of the forearm's main arteries, which may cause cold intolerance in the future (25, 26). Another type of regional vascularized bone flap in the upper extremity is PIBF (27-29).

In this method, both radial and ulnar arteries are preserved. Although this type of bone flap can be applied as a retrograde flap (30), this technical note is focused only on the antegrade type. It can be used as a partial ulnar flap from the dorsal half of the ulnar bone or a complete ulnar flap when sacrificing some ulnar bone length. As far as we know, the ulnar bone size that can be harvested has not been determined yet. We believe that the distal two-thirds of the ulna can be used in the flap, provided that the vascular pedicle has enough length to permit rotation and replacement in the recipient site.

Indications

The PIBF can reach throughout the radius and proximal two-thirds of the ulna and supracondylar area of the humerus. It can be used for nonunion or bone defect of the forearm or one of the distal humerus columns, and elbow arthrodesis. Moreover, it could be used for wrist arthrodesis when the distal radius is not salvageable. It is an alternative treatment for free fibular flap in radius congenital pseudoarthrosis or infected nonunion in children.

Preoperative Workup

All signs of local infection must be explored and treated with suitable medication. Anteroposterior (AP), lateral, and oblique radiographs of the site should be taken. The joints' ROM (elbow, forearm, and wrist), fingers grip power, and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score should be measured precisely and documented to compare with postoperative values. The Allen test could be used to examine the competency of the radial and ulnar arteries. The requisite equipment is listed in table 1.

Table 1. Preoperative planning checklist

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An operating room bed with radiolucent hand table
Pneumatic tourniquet
C-Arm
Instruments:
Bipolar electrocautery
Freer elevator
Ruler
Oscillating saw
Fine osteotome
Power drill
Plate and screw instrument and set from 1.5 mm to 3.5 mm (DCP, LCP, & Reconstruction)

DCP: Dynamic compression plate; LCP: Locking compression plate

Surgical Steps for Forearm Defects

1. Position: The patient is placed on the bed in a supine position. The hand is placed on the hand table. The pneumatic tourniquet is fixed to the proximal region of the arm. For harvesting the bone flap, the forearm is in pronation, and the shoulder is in the abduction and internal rotation. If the shoulder or forearm rotation has made this position challenging, flexing the elbow and placing the hand palm on the patient's chest can be helpful.

2. *Preparation:* The preparation and drape are performed up to the upper elbow so that the flexion and extension movements of the elbow and the forearm's rotational movements are entirely free. The tourniquet is inflated at proper pressure after gentle exsanguination of the limb.

3. Skin Incision: With longitudinal incision between humeral lateral epicondyle and distal radioulnar joint in the posterior forearm, the skin and subcutaneous layers are opened, and the fascia of the forearm's posterior compartment is accessed (Figure 1).

Figure 1. Skin incision on the posterior side of the forearm between humeral lateral epicondyle and distal radioulnar joint

4. Fascial Incision: A longitudinal incision on the ECU muscle fascia and, another longitudinal incision parallel to the previous incision on the EDM muscle fascia is performed.

5. Finding the Vessels: Between the two fascial incisions, the muscle bellies of ECU and EDM are retracted and the septum fascia between these two muscles is meticulously exposed, and the PIA and its periosteal branches are seen (Figure 2). At the distal part of the incision, where we are looking for the vascular branches and the main artery of the flap, the septal fascia is at the radial side of the ECU and overlying EDM. The pedicle is better seen from the radial side of the septum. It is thin at a few centimeters of the distal part and almost superficial, and becomes slowly thicker, more visible, and deeper, proximally. In difficult cases or when the limb is exsanguinated, it may be simpler to find the pedicle a few centimeters proximal to the distal radioulnar joint. A loupe with 2.5x magnification can be used for better vision.

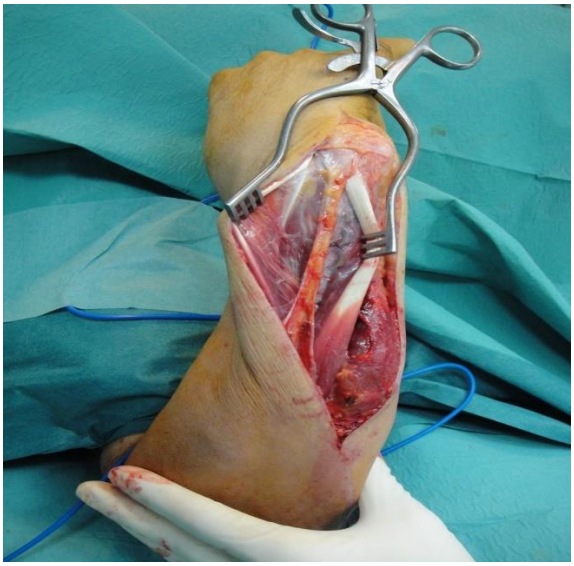

Figure 2. Septal fascia between extensor carpi ulnaris and extensor digiti minimi muscles holds the posterior interosseous artery (PIA) and its periosteal branches

6. Recipient Site Exposure: To prepare the recipient site in the ulnar bone, the same previous skin incision can be used. The same approach or a different volar approach to the radius bone can be used depending on the recipient site and internal fixation plan.

7. Recipient Site Preparation: Debridement of the recipient site is performed until it reaches the normal bone. A 1-cm-long section from half of the bone diameter should be removed on each side to create an appropriate place to accommodate the flap.

8. Provisional Fixation: To restore the injured bone's proper length, a provisional fixation is performed with a plate holding bone clamps. Rotational movements and C-Arm imaging can be used during surgery for reduction assessment. The plate can be fixed by inserting two screws on each side.

9. Flap Pedicle Preparation: To calculate the appropriate length for pedicle release, we consider the total length of the required graft and length of the pedicle rotated and placed in the recipient site. We coagulate all the muscular and fasciocutaneous branches of the PIA, preserving only the periosteal branches. After etermining the bone flap's

length (next step), the pedicle is explored further by protecting the fascia's continuity to the pedicle, incised a few millimeters deeper, and the redundant periosteal branches are coagulated. This can be continued until the appropriate length for a safe rotation of the flap is reached. However, the pedicle can be extended as far as the posterior interosseous vessels' entry point to the posterior compartment. At the proximal half of the way, the pedicle is very close to posterior interosseous nerve muscular branches, which should be dissected and preserved.

10. Flap Length Determination: At the distance of 1 cm from the distal radioulnar joint, the osteotomy boundaries are determined in the ulna's dorsal half on the sagittal plane. The bone flap's appropriate length should be equal to or slightly larger than the length of the recipient site's defect.

11. Donor Site Osteotomy: The PIA is ligated distal to the osteotomy site and cut. Osteotomy is performed by multiple drilling with a 1-mm pin and a thin osteotome or a fine oscillating saw. Two ends of the osteotomy site are beveled to reduce the chance of fracture at the donor site. In case of uncertainty about the donor site's strength, a reconstruction plate can be used to reinforce and prevent pathologic fracture.

12. Flap Harvesting: The bone flap is completely detached from its bed, and the pedicle with a suitable length is completely freed in an antegrade manner (Figure 3).

Figure 3. Bone flap and its vascular pedicle is freed with appropriate length

13. Flap's Vascularity Evaluation: After proper washing, the tourniquet is deflated, and the blood flow to the flap is carefully controlled.

14. Flap Transfer: For the ulna, the flap can be transferred via the same dorsal exposure beneath or above the ECU muscle. For the radius, it can be transmitted radially through a subcutaneous or submuscular route beneath or above the EDC muscle. Special care must be taken in order not to overstretch the vascular pedicle.

15. Definitive Fixation: The flap is placed in the recipient location. There are different types of fixation of the flap in the recipient site. It may be placed under the main plate or placed at the opposite side of the main plate and fixed to the host bone with screws or another plate. The main plate can be definitely fixed with the insertion of additional screws. If the recipient site is on the ulna, the main plate should pass the donor site with at least one screw, or it must be stopped far enough from the donor site to prevent a stress rising area between the plate and the donor site. Figure 4 illustrates the summary of PIBF surgery.

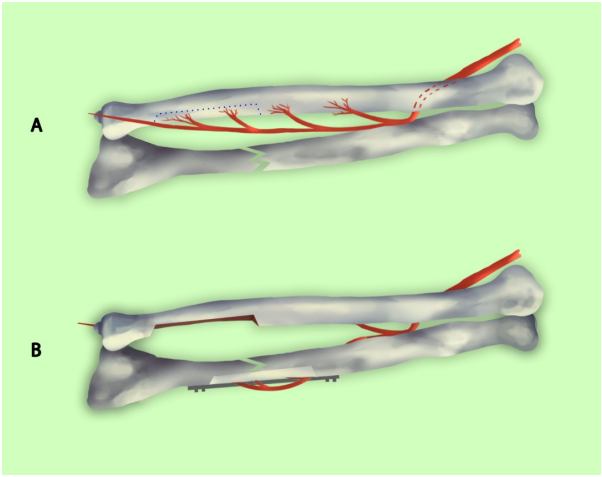

Figure 4. Schematic view of the posterior interosseous bone flap (PIBF) surgery procedure: A) osteotomy boundaries are depicted with dotted line, B) the harvested bone flap is transferred to its new place on nonunion site, C) the flap is finally fixed with suitable device.

16. Wound Closure and Splinting: After placing the suction drain, the wound is sutured layer by layer. There is no need for immobilization after surgery. However, a removable splint can be applied for a few weeks, especially for children and osteoporotic bones.

Table 2 declares the common pitfalls of the PIBF harvest procedure.

Table 2. Common pitfalls of posterior interosseous bone flap (PIBF) surgery

Pitfall	Preventions
Vascular pedicle damage	Gentle fascial dissection Use of a magnifying loupe
Malreduction	Provisional fixation of recipient site by plate Intraoperative fluoroscopy Intraoperative examination of ROM
Donor site fracture	Beveled osteotomy of donor site boundaries Application of a plate for donor site reinforcing if necessary
Vascular pedicle overstretch	Release of pedicle proximally by proper length

ROM: Range of motion

Postoperative Care

Patients are advised to do hand and elbow movements but are prohibited from strenuous activity for up to 6 weeks. Periodic visits are performed every six weeks until the radiological and clinical union are confirmed. At the final follow-up visit, the joints' ROM (elbow, forearm, and wrist), fingers grip power, and QuickDASH are measured and compared with preoperative levels.

Advantages and Disadvantages

PIBF does not sacrifice any of the limb's main arteries compared with the radial forearm bone flap, which is crucial in the elderly or when the forearm's vascularity has already been damaged. Compared to the free bone flaps, the surgery is limited to a single limb, and all operations can be conducted under regional anesthesia. Besides, it does not need complicated microsurgical skills.

The drawbacks include the limited volume of the bone graft compared to the radial forearm and free bone flaps, vulnerability of the donor site to pathological fractures, and requisite of meticulous dissection and thorough anatomical knowledge.

Technical Points in Other Conditions

Whole Diameter Harvest of the Ulna in PIBF: When the distal part of the ulnar bone can be sacrificed, the ulna's whole diameter can be harvested as a vascularized bone flap with the same technique. When a Darrach-like procedure could be planned, the ulna's whole distal part can be removed. When a procedure like Sauve-Kapandji is

considered, the distal portion of the osteotomy is 1 cm proximal to the distal ulna.

Distal Humerus Bone Graft: The position should change to semi lateral. The flap should be harvested from the most distal part. The pedicle should be released as proximal as possible.

Elbow Arthrodesis: When there is bone loss, and the elbow arthrodesis is planned with a structural PIBF, the bone is harvested with the complete diameter. In this case, the bone should be shaped concerning the angle of the arthrodesis. The osteotomy of the bone flap should be performed to save the periosteal supply of the bone flap. For PIBF with a partial ulna diameter, the harvesting and insertion principle is the same as the supracondylar recipient version.

Distal Radius: Due to the arc of rotation, the flap's distal point reaches the distal segment of the radius 1 cm proximal to the distal point of the donor site on the ulna. This flap does not work for a too short distal radius segment unless the ulna's distal part is removed. In this case, after removing a part of the ulna by the Darrach procedure or the Sauve-Kapandji procedure, the radius would be shortened, and the flap could reach the distal segment of the radius without a problem.

Wrist Arthrodesis: When the distal radius is damaged and lost, the wrist arthrodesis could be planned considering two current options. The first one is the Ulnocarpal arthrodesis, which makes the limited forearm rotation. The second one is the accommodation of nonvascularized structural bone graft between radius and carpus with an unpredictable union chance. An alternative option is transferring the whole distal ulna to the distal radius, between the radius stump and carpal bones. A vascularized bone can reconstruct the proximal carpal bones with high union potential while preserving the forearm's rotation function.

PIBF in Children: There are some special notes in the PIBF harvest in children. The ulna's distal physis should be protected, and the distal part of the flap should be a few millimeters far from the physis. Because of the ulna's thin diameter in children, the donor site is more prone to fracture. So, prophylactic insertion of an intramedullary pin in the ulna before completing the osteotomy is advisable. Postoperative immobilization of the forearm is also recommended. The whole diameter harvest of the ulna is forbidden because of the iatrogenic ulnar club hand. Fixation of the bone flap to the recipient's bone is also more complicated than adults or free fibular flap.

Conflict of Interest

The authors declare no conflict of interest in this study.

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