Vascularized Small-Bone Transfers for Fracture Nonunion and Bony Defects

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KEYWORDS

• Vascularized bone grafting • Fracture nonunion • Scaphoid • Lunate • Kienbock disease • Medial femoral condyle • Pedicled distal radial grafting • Osteoperiosteal or corticoperiosteal flaps

KEY POINTS

- Vascularized small-bone grafting is an efficient and often necessary surgical approach for nonunion or necrosis of several bones in particular sites of the body, including scaphoid, lunate, distal ulna, and clavicle.
- The medial femoral condyle is an excellent graft source that can be used in treating scaphoid, ulna, clavicle, or lower-extremity bone defects, including nonunion.
- Vascularized bone grafting to the small bones, particularly involving reconstruction of damaged cartilage surfaces, should enhance subchondral vascular supply and help prevent cartilage regeneration.
- Pedicle distal radial bone grafting is still a viable option as a technically easier way to treat scaphoid nonunion or revascularization of Kienböck disease.
- Vascularized osteoperiosteal and corticoperiosteal flaps are useful for treating nonunion of long bones.

INTRODUCTION

Vascularized bone grafting has frequently been used in reconstruction of long-bone defects, because vascular supply to the graft will ensure better healing to the defect size. Vascularized bone grafting for small-bone defects or nonunion is necessary only in some special clinical conditions, such as nonunion of scaphoid fractures, or defects in small bones such as clavicles, radius or ulna, facial bones, and tarsal bones in the foot.[1–5]

The sources of such bone grafts vary. Typically, vascularized iliac bone grafting has been used as a free transfer to many parts of the body, and pedicled bone chips taken from the distal radius have been used in the hand and wrist.[1,2,6,7] The medial femoral condyle (MFC) has emerged more recently as one of the most versatile donor sites in the treatment of challenging bone reconstruction. This graft donor site, described by Sakai and colleagues[8] in 1991, has recently gained popularity thanks to the work of Burger, Higgins, and others.[9–13] The current application of small-bone grafting in 3 units in 3 countries, China, Italy, and Austria, are summarized in later discussion. The indications and applications of small-bone grafting in the 3 units are summarized in **Table 1**.

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Table 1
The current application of vascularized small-bone grafting in 3 units in China, Italy, and Austria

	Nantong, China	Florence, Italy	Innsbruck, Austria
Free MFC graft	Scaphoid Ulna Clavicle Lunate (advanced Kienböck)	Scaphoid Ulna Clavicle Navicular bone	Scaphoid Tibia Metacarpal —
Free iliac bone graft	— —	— —	Scaphoid Lunate (advanced Kienböck)
Distal radial graft[a]	Scaphoid Lunate (Kienbock)	— —	— —

[a] A graft based on a pedicle of the 1,2 or 2,3 intercompartmental arteries (ICSRAs) for nonunion of the scaphoid or the fourth and fifth ICSRA for Kienbock disease.

MEDIAL FEMORAL CONDYLE AS A GRAFT DONOR IN RECONSTRUCTION OF SMALL-BONE DEFECTS

Originally described as a periosteal or corticoperiosteal flap based on the descending genicular artery (DGA), this flap has evolved into a more structural graft including a variable amount of cancellous bone and finally into an osteochondral graft, including a small amount of the articular cartilage of the MFC.[9,10] From a structural point of view, this graft belongs to the family of flat bone flaps, such as the scapula and, more importantly, the iliac crest, and is therefore indicated in reconstructions of small defects that for some reason require vascularized bone.

Maxillofacial surgery and hand surgery are the 2 main fields of application of the procedure to a variety of conditions; nonunions, tumors, and infections are the most common abnormalities that benefit from an MFC graft. This flap provides a very well-vascularized bone block and a thick periosteum that may be significantly larger than the bone flap in order to overlap the junction with the host bone, improving the blood supply and the ability to heal. In addition, in the case of intraoral location of the flap, the periosteum is quickly colonized by the neighboring mucosa, providing optimal and fast integration with the surrounding tissues.

In the upper limbs, recalcitrant nonunion of the forearm bones and clavicle, scaphoid nonunion, necrosis of the proximal pole of the scaphoid, and Kienböck disease have been the pathologic conditions most frequently treated by an MFC graft. More recently, this graft has been successfully used in metacarpal and phalangeal reconstruction as well as tarsal reconstruction.

An MFC graft is actually a very versatile graft. In addition, the donor site morbidity is inconspicuous,[14] and the harvesting technique is relatively straightforward.

Surgical Anatomy and Harvesting Technique

The surgical anatomy and the harvesting technique have been described in detail by several authors, who progressively refined the anatomic knowledge of the region and added many technical details to the procedure.

This flap is based on the DGA system. The DGA rises from the superficial femoral artery and runs distally, deep and posterior to the vastus medialis muscle. Usually it bifurcates 0.7 cm distal to its origin in 2 branches: the saphenous artery, which supplies the skin of the medial aspect of the knee, and a terminal, periosteal branch that supplies a rich periosteal network on the medial condyle. In this typical vascular configuration, the pedicle of a medial condyle flap may be up to 8 cm long. However, in about 30% of cases, the periosteal branch of the DGA is extremely small or even absent.[15] In those circumstances, the superior medial genicular artery, a short vessel that arises directly from the popliteal artery, is the main contributor to the periosteal network and the pedicle of such a flap.

The patient is placed supine with hips extrarotated and abducted, and the knee flexed at 80°. A sterile tourniquet is suggested but not mandatory. A longitudinal incision is placed over the projection of the posterior margin of the vastus medialis muscle and extended over the MFC. The DGA may be visualized close to the femur and to the posteromedial aspect of the vastus medialis muscle. After dedicating some branches to the muscle and its tendon, the artery supplies a rich periosteal plexus on the MFC together with the superior medial genicular artery (**Fig. 1**). The flap may be tailored in a variety of forms according to the specific need of the recipient area. It may be constituted only of periosteum and a thin layer of cortex, but it can be also a vascularized corticocancellous bone graft if a block of cancellous