CURRENT CONCEPTS

Bone Graft Options in Upper-Extremity Surgery

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Bone grafting in the upper extremity is an important consideration in patients with injuries or conditions resulting in missing bone stock. A variety of indications can necessitate bone grafting in the upper extremity, including fractures with acute bone loss, nonunions, malunions, bony lesions, and bone loss after osteomyelitis. Selecting the appropriate bone graft option for the specific consideration is important to ensure optimal patient outcomes. Considerations such as donor site morbidity and the amount and characteristics of bone graft needed all weigh in the decision making regarding which type of bone graft to use. This article reviews the options available for bone grafting in the upper extremity. *(J Hand Surg Am. 2018;■(■):■−■. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Bone grafting, bone morphogenic protein, scaphoid nonunion, upper extremity, vascularized.

Bone grafting in the upper extremity is a complex concept because of the many graft options and applications. Understanding the properties of osteoconductivity, osteogenicity, and osteoinductivity guides treatment options. Factors such as donor site morbidity, the amount of bone graft, and the characteristics of bone graft influence decision making. Options include autograft, allograft, and bone graft substitutes.

OSTEOCONDUCTIVE, OSTEOINDUCTIVE, AND OSTEOGENIC GRAFTS

When comparing the effectiveness of graft options, materials are judged based according to 3 elements: osteoconductivity, osteoinductivity, and osteogenicity. An osteoconductive graft is a bioactive matrix that offers a structural lattice to provide a scaffold promoting growth of new bone and neovascularization functioning primarily as a structural support. The matrix facilitates fibrovascular ingrowth, host progenitor cell migration into the scaffold, osteoblast attachment, and the manufacture of new bone. The ability to form new bone depends on direct contact with exposed bony surfaces. An osteoinductive graft stimulates the production of new bone via the release of cytokines of the transforming growth factor-β family, inducing mesenchymal stem cell differentiation to osteoprogenitor cells.[1] An osteogenic bone graft refers to grafts that include osteoprogenitor cells, such as osteoblasts and osteocytes, which can directly form new bone in the grafted area.[1,2]

BONE GRAFT OPTIONS

Important characteristics need to be considered when analyzing graft options. They are the structural integrity and osteointegrative ability of the graft. Structural integrity refers to the strength of the grafted material in compressive strength and the resistance to torsion and shear. Osteointegrative ability is the

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Received for publication January 18, 2017; accepted in revised form March 30, 2018.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/18/■ ■-0001$36.00/0
https://doi.org/10.1016/j.jhsa.2018.03.055

capacity of the graft to incorporate into the host bone. The amount of graft needed and host characteristics such as vascular supply also should be considered.[1,2]

Although autografts such as iliac crest and distal radius are the reference standard, a limited supply of autograft is available in any given patient. In addition, the risk for donor site morbidity exists when harvesting autograft. Other bone graft options available to surgeons, including allografts and bone graft substitutes, are numerous and often confusing, with differing amounts of literature supporting their use.

Autograft

Autogenous bone graft is considered the reference standard owing to its histocompatibility, osteogenicity, osteoinductivity, and osteoconductivity.[2,3] Multiple types of autogenous bone grafts exist, including cortical, cancellous, corticocancellous, and vascularized.[4] Autologous bone graft sources for upper-extremity surgery are numerous and include iliac crest, distal radius, proximal ulna, toe phalanx, metacarpal, distal femur, scapula, and fibula. The most common sources include the iliac crest and distal radius.

Cortical bone grafts provide mostly osteoconductive properties, with minimal osteoinductive and osteogenic properties.[5] Cortical bone grafts are most appropriate when immediate mechanical stability is needed.[4] Because of its dense mineralization, cortical bone grafts are slow to revascularize and incorporate.[5] Because resorption must take place before cortical bone graft is properly incorporated into existing bone, these bone grafts become weaker during the first 6 months before regaining structural integrity at 12 months. This process is known as creeping substitution.[6]

Cancellous autografts are the most commonly used autogenous bone grafts because of their strong osteoinductive and osteogenic properties.[4,7] Although cancellous autografts possess osteoconductive properties via large surface areas that allow for rapid remodeling and incorporation into existing bone, they have little to no structural integrity and are not appropriate in situations that necessitate immediate mechanical strength.[4] Cancellous autograft's osteogenicity and osteoinductivity are primarily explained by the fact that the trabeculae of cancellous bone are lined with functional osteoclasts. When exposed to local cytokines, they are able to promote mesenchymal cell recruitment.[7] Cancellous bone graft's properties make it an excellent choice for arthrodesis and treatment of nonunions.[4]

Corticocancellous bone graft offers the benefits of both cortical and cancellous bone graft. The cortical portion provides structural support and immediate mechanical strength whereas the cancellous portion of the graft provides osteoconductivity, osteoinductivity, and osteogenicity. Typically, corticocancellous bone graft is obtained from the iliac crest for larger defects, but small bony defects can be filled with a distal radius corticocancellous graft.[8]

Vascularized bone graft is a cortical or corticocancellous autograft that is harvested with a vascular pedicle to improve graft incorporation and healing. Vascularized bone grafts can be obtained from the fibula from branches of the peroneal artery, iliac crest from branches of the deep circumflex iliac artery, the distal radius from the supraretinacular artery, the ribs from branches of the posterior intercostal artery, and the medial femoral condyle from branches of the descending geniculate artery. Harvest and use of vascularized bone graft are technically demanding and are indicated for larger bone defects or with established avascular necrosis.[9]

Nonvascularized autograft

The standard autograft source in the treatment of conditions necessitating bone graft is iliac crest, largely because of the possibility of obtaining large volumes of osteoprogenitor-rich corticocancellous graft.[1] Iliac crest bone graft can be harvested anteriorly or posteriorly, depending on the positioning of the patient and the surgeon's comfort. The volume of bone graft needed may factor into the approach used, because anterior iliac crest autograft can yield approximately 13 to 27 cm^3 whereas posterior iliac crest autograft can yield approximately 30 cm^3.[4] Situations requiring larger volumes can use a combined anterior and posterior iliac crest harvest. Morbidity associated with iliac crest harvest remains a concern; there is a complication rate of 2.8% to 37.9%.[2] Possible complications include persistent donor site pain, superficial sensory nerve damage, hematoma, infection, incisional hernias, donor site fracture, and vascular injury.[4] Precautions such as elevating a cap of iliac crest subtended on the external oblique, followed by harvesting the outer table, and finally replacing the iliac crest cap to restore bone contour and repairing the periosteum and fascia may minimize donor site morbidity. (Fig. 1).

Another commonly used cancellous autograft source, particularly for upper-extremity surgery, is the distal radius. The distal radius can be harvested to obtain up to 3 cm^3 of bone graft.[10] Drawbacks of distal radius autograft include a more limited quantity