The Use of Bone Grafts and Substitutes in the Treatment of Distal Radius Fractures

Kagan Ozer, MD[a,*], Kevin C. Chung, MD, MS[b]

KEYWORDS

• Autogenous • Bone graft • Distal radius • Fracture
• Malunion

The interest in developing biomaterials to augment fracture healing continues to grow. This trend is in part fueled by the high market value of these products, but also associated with an increased incidence of fractures related to aging and osteoporosis. New products coming to the market promise early return to function with minimal morbidity; however, indications to use these products, particularly in the treatment of distal radius fractures, remain unclear.

An ideal bone graft material stimulates bone healing and provides structural stability while being biocompatible, bioresorbable, easy to use, and cost-effective. Commercially available products offer various combinations of those features, but not all. Moreover, it is important to understand that different anatomic locations have varying levels of bone forming activity and stability. Therefore, a single study validating the use of a bone graft material in 1 location may not predict its performance in another anatomic site. In distal radius fractures, the risk of nonunion is minimal. Consequently, bone graft substitutes are primarily used to provide structural stability and perhaps early return to function. Structural stability is directly affected by the method of fixation, with each fixation technique providing a different level of structural support. Although minimally invasive methods of fixation (pins and external fixation) could effectively be supplemented with bone graft substitutes for added stability, advances in plate design and technology, such as locking plates, make bone graft substitutes perhaps not as essential. This article reviews the biology of bone grafts and the clinical evidence in the use of bone graft substitutes for the treatment of distal radius fractures.

BONE GRAFT PROPERTIES

There are 4 essential elements for bone healing: (1) osteogenic cells (eg, osteoblasts or progenitor cells); (2) osteoinductive signals provided by growth factors; (3) an osteoconductive matrix; and (4) adequate blood and nutrient supply.[1] Bone graft materials are described on the basis of osteogenicity (presence of bone forming cells), osteoconductivity (ability to function as a scaffold) and osteoinductivity (ability to stimulate bone formation). Following trauma, the resultant fracture hematoma provides a source of hematopoietic cells that produce

Supported in part by grants from the National Institute on Aging and National Institute of Arthritis and Musculoskeletal and Skin Diseases (R01 AR062066) and from the National Institute of Arthritis and Musculoskeletal and Skin Diseases (2R01 AR047328-06) and a Midcareer Investigator Award in Patient-Oriented Research (K24 AR053120) (to Kevin C. Chung, MD).

[a] Department of Orthopaedic Surgery, University of Michigan Health System, 2098 South Main Street, Ann Arbor, MI 48103, USA
[b] Section of Plastic Surgery, Department of Surgery, The University of Michigan Health System, 2130 Taubman Center, 1500 East Medical Center Drive, Ann Arbor, MI 48109, USA
* Corresponding author.
E-mail address: kozer@umich.edu

Hand Clin 28 (2012) 217–223
doi:10.1016/j.hcl.2012.02.004
0749-0712/12/$ – see front matter

secreting growth factors (eg, bone morphogenic proteins [BMP], transforming growth factor [TGF]-β, insulinlike growth factor [IGF]-II, platelet-derived growth factor [PDGF]) that stimulate osteoblasts and differentiation of progenitor cells.[2] This results inmetaplasia of mesenchymal cells to produce collagen and proteoglycans and cartilage matrix and differentiate into osteoblasts. Every step of this process is regulated by a number of signaling pathways.

TYPES OF BONE GRAFTS

Based on their biologic and physical properties, bone grafts can be divided into 3 main categories (**Table 1**).[3]

Autograft

Autogenous bone grafts are considered the standard material, because they offer complete histocompatibility and provide the best osteoconductive, osteogenic, and osteoinductive properties.[2–4] Autografts usually contain osteogenic cells (viable up to 2 hours in normal saline) and bone matrix proteins. They offer structural support (if harvested with its cortical part) and are incorporated into surrounding bone through creeping substitution.[4] They also suffer from resorption and limited availability and viability. The most common source of these grafts is the iliac crest, but they can also be obtained in limited amounts from the tibial crest and olecranon. The iliac crest has frequently been used in the treatment of distal radius fractures[5–13] and for corrective osteotomies.[14–17] Although the outcomes based on radiographic parameters and wrist function are satisfactory, iliac crest bone graft harvesting is associated with a number of complications, including donor site pain, hematoma, neuroma formation, chronic unexplained thigh pain, and local infection.[18–22] Depending on the series and the amount of bone harvested, the prevalence of 1 or more of these complications is reported to range from 9% to 49% in various series.[23–33] In addition, the procedure itself adds an average of 30 minutes to the operative time. Although iliac crest bone grafting was initially thought to be cost-effective, the direct and indirect costs (postoperative rehabilitation, cost of pain management, and time off work) were found to be substantially high.[34–37] Due to the high morbidity, increased operative time, and cost, surgeons are seeking alternative materials that can substitute for autogenous bone grafts.

Allograft

Allograft bone is osteoconductive and osteoinductive, but lacks the osteogenic properties of the autograft. Its major advantages include availability in various shapes and sizes and no donor site morbidity. However, it only partially retains the structural strength of the autograft. Although a few studies have shown disease transmission through allografts, recent advances in processing have likely made that a historical and theoretical concern.[38–41]

Allogenic bone is available in the form of demineralized bone matrix, morselized and cancellous chips, corticocancellous and cortical grafts, and osteochondral and whole-bone segments. Despite its low cost, there are only a few studies to date that

Table 1
Modification of Laurencin's classification

Bone Grafts and Substitutes			OG	OI	OC	SS	Cost
Autograft			+	+	+	+[a]	+++/++++[b]
Allograft			-	+	+	+[a]	+/++
Substitutes	Biologic	Coral	-	+	+	-	++/+++
		Collagen type 1	-	+	+[c]	-	(No studies on DRFx)
		Demineralized bone matrix	-	±	+	-	+/++
	Synthetic	Factor-based (TGF-β, PDGF, FGF, BMP)	-	+	±	-	+++/++++[d]
		Cell-based (mesenchymal stem cells)	+	-	+[c]	-	(No studies on DRFx)
		Ceramic-based (calcium HA, tricalcium phosphate, calcium phosphate cement)	-	-	+	+	+/++
		Polymer-based	-	-	+	-	(No studies on DRFx)

Abbreviations: BMP, bone morphogenic proteins; DRF, distal radius fracture; FGF, fibroblast growth factor; HA, hydroxyapetite; OC, osteoconductive; OG, osteogenic; OI, osteoinductive; SS, structural support; TGF, transforming growth factor.
[a] If the graft includes cortical bone.
[b] Including direct and indirect costs, data based on studies of spinal fusion and tibial nonunions.
[c] If used with a carrier.
[d] Only Rh-BMP is tested on distal radius fractures.