Osseous Healing in Foot and Ankle Surgery with Autograft, Allograft, and Other Orthobiologics

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KEYWORDS

• Bone • Autograft • Allograft • Orthobiologic • Nonunion • Foot • Ankle

KEY POINTS

- In the surgical treatment of foot and ankle abnormality, many problems require bone grafting for successful osseous union.
- Nonunion, reconstruction, and arthrodesis procedures pose specific challenges due to bony defects secondary to trauma, malunions, or previous surgery.
- Nonunion in foot and ankle arthrodesis is a significant risk and is well documented in recent literature.
- This article is a review of the recent literature regarding the use of bone graft and orthobiologics in foot and ankle surgery.

Bone grafting is a common component of foot and ankle surgery that requires successful osseous union. Nonunion, reconstruction, and arthrodesis procedures may pose specific challenges, including bony defects secondary to trauma, malunions, or previous surgery. The average nonunion rate is 10% for ankle arthrodesis[1] and 16% for subtalar joint arthrodesis.[2] Nonunion rates in foot and ankle arthrodesis literature range from 0% to 47%[3] in complex and revision procedures.

In primary arthrodesis of the ankle and hindfoot, the following have been found to increase the risk of nonunion and other noninfectious complications:

- Positive smoking history[2,3]
- Previous attempted fusion[2]
- Presence of avascular bone[2]
- Diabetes mellitus[3]
- Previous solid organ transplantation[3]
- Poor preoperative serum glucose control (>200 mg/dL)[3]

In revision arthrodesis, neuropathy and prior revision attempts have been identified as statistically significant risk factors for nonunion.[4]

Autologous bone grafting (ABG) is the gold standard because of its osteoconductive, osteoinductive, and osteogenic properties. The disadvantages of autograft include limitations in quantity, donor site morbidity, and infections and complications from donor site harvest. For example, one study quoted that 8.8% of patients undergoing autograft procedures have more clinically significant donor site pain (≥20 mm on the visual analogue scale [VAS]) 1 year postoperatively.[5] A recent survey of orthopedic surgeons showed when considering graft for foot and ankle arthrodesis procedures, the strongest factors supporting the use of ABG were clinical or radiographic nonunion, avascular necrosis, smoking history, and evidence of potential for incongruous apposition of bone.[6]

In foot and ankle surgery, many of these clinical scenarios are common, and the surgeon must weigh the advantages and disadvantages

This author has no commercial or financial conflicts or disclosures.
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Orthop Clin N Am 48 (2017) 359–369
http://dx.doi.org/10.1016/j.ocl.2017.03.009

when choosing autograft, allograft, and/or orthobiologic bone graft substitute. Orthobiologic bone graft substitutes include cellular bone allograft with mesenchymal stem cells (CBA with MSCs), platelet-derived growth factor (PDGF), platelet-rich plasma (PRP), bone morphogenetic proteins (BMPs), and fetal tissues. This article reviews the various bone grafting and bone substitute options and presents available and recent evidence supporting their use in procedures requiring osseous healing in foot and ankle surgery.

AUTOLOGOUS BONE GRAFTING

ABG continues to be the gold standard because of its osteoinductive, osteoconductive, and osteogenic properties. Harvest from the calcaneus or distal tibial metaphysis can provide small amounts of autograft with minimal complexity added to the procedure. Ipsilateral iliac crest bone graft (ICBG), when harvested as a tricortical wedge, has the added benefit of improved osteoconduction or mechanical support, especially in the setting of an opening wedge osteotomy or large bony defects.

A recent logistic regression analysis of 159 foot and ankle studies from 1959 to 2012 concluded that there is a trend toward higher healing rates when using cancellous and structural ABG in foot and ankle surgery compared with allograft, but this was not statistically significant.[7] However, 153 of 159 studies included in this analysis were retrospective case series. Retrospective case series have inherent methodological limitations and have potential for selection bias. In these retrospective case series, surgeons could have elected the use of their preferred graft for procedures they deemed more complex, or those that had an anticipated lower rate of union. By introducing this variable, the results in these studies may not give an accurate picture of treatment efficacy.

Surgeons may choose to use the reamer-irrigator-aspirator (RIA, DePuy Synthes, West Chester, PN, USA) to collect cancellous ABG from the patient's femoral shaft. Although there is strong evidence supporting RIA use in the orthopedic trauma literature, there is a paucity of data supporting its use in foot and ankle surgery. In 2014, a retrospective study was performed comparing clinical and radiographic outcomes in patients undergoing tibiotalar arthrodesis.[8] When compared with ICBG, use of the RIA showed significantly lower nonunion rates. Furthermore, no patient undergoing RIA had chronic pain at the harvest site compared with 2 in the ICBG group. Length of stay and radiographic fusion were similar in both groups. The RIA may be a viable alternative to ICBG, especially in terms of reducing nonunion rates and donor site morbidity.

ALLOGRAFT

Allogenic bone grafts (allografts) are harvested from cadavers, avoiding the complications associated with ABG donor site harvest. Although allograft can have osteoconductive properties as does ABG, processing cadaver allograft tissue takes its toll. Although gamma-irradiation and heat sterilization processing are necessary to allow successful transfer of tissue from donor to host, these processes kill live bone cells and cause allograft to lose a significant amount of its osteogenic properties.[9] Processing the graft limits cell viability, which increases osteoblast apoptosis. Graft Processing also destroys other cells that produce cytokines, bone morphogenic proteins, which decreases the osteogenic and osteoinductive properties of the graft. Demineralized bone matrix (DBM) is a form of allograft prepared by acid extraction so it retains BMPs and bone collagens. Therefore, DBM has improved osteoinductive capacity compared with traditional allograft, because it retains more bone morphogenic proteins and bone collagens.[10]

CELLULAR BONE ALLOGRAFT CONTAINING MESENCHYMAL STEM CELLS

CBA containing MSCs is a biologic allograft alternative to traditional ABG and other bone graft substitutes. Like ABG, cadaveric CBA with MSCs have osteoconduction, osteoinduction, and osteogenesis properties. Human undifferentiated MSCs and MSCs differentiated into bone, cartilage, and adipose escape a host's immune system because they express HLA class I, and not HLA class II.[11] Therefore, MSCs from an allogenic or cadaveric source avoids the host's cell-mediated immune response by avoiding the T cells and lymphocyte cell response.[11] Allograft tissue is harvested to preserve living MSCs or osteoprogenitor cells. Processing and specifications of different CBA with MSCs products vary by company and product.

Jones and colleagues[12] conducted a prospective, multicenter trial of cryopreserved CBA with MSCs (Trinity Evolution; Orthofix, Inc, Lewisville, TX, USA) in patients undergoing ankle and/or hindfoot arthrodesis. Trinity Evolution describes a screening process whereby only 3% of cadaveric donors are used and cryopreserves tissue