



Complications of iliac crest graft and bone grafting alternatives in foot and ankle surgery

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Orthopaedic surgeons frequently perform operations that require bone grafting to augment bone healing and thus aid in the success of a particular procedure. The iliac crest has long been regarded as the primary source of autologous bone, but other sources of autologous bone, such as the metaphyseal ends of the tibia and the calcaneus, have been used. As the procedures to retrieve bone developed, the associated complications have become apparent. Bone grafting alternatives have become more popular as a way to avoid the morbidity that is associated with harvesting autologous bone. This article discusses the complications that are associated with obtaining autologous bone and reviews bone grafting alternatives and their associated problems.

Iliac crest bone graft

Thousands of procedures to obtain iliac crest bone graft are performed by orthopedic surgeons each year. Multiple techniques have been developed to retrieve this bone. As with any invasive procedure, a set of complications can arise that are specific to that operation. Iliac crest harvest has been associated with pain [1–5], nerve injury [2,5,6,], hemorrhage [1,7–13], fracture [9,11,14–18], hernia [2,19–23], and ureteral injury [24].

Pain

As with any surgical procedure, chronic, postoperative pain is a potential complication; many investigators regard this problem as the most common complication following iliac crest bone harvesting [16,19,25]. Fernyhough et al [3] reviewed 151 posterior bone graft harvests for spine surgery followed up at more than 1 year. They found a 29% incidence of chronic donor site pain in their

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retrospective study. The grafts were harvested through either a midline incision or lateral oblique incision; no difference in pain between the two techniques was seen. Goulet et al [25] noted in their review of iliac bone graft harvests that pain was the most common complaint during the first 6 months postoperatively; it was reported in 38% of patients. This percentage dropped to 18% at more than 2 years after surgery. All but one of the patients with chronic pain at more than 2 years had undergone spine surgery.

Pain can also be the result of a neurologic injury to the cluneal nerves or the lateral femoral cutaneous nerve [14,26]. Meralgia paresthetica describes symptoms that are associated with injury to the lateral femoral cutaneous nerve. Arrington et al [14] reported on six patients of more than 400 cases who developed meralgia paresthetica; three patients developed pain associated with injury to the superior cluneal nerves confirmed by exploration. Chronic pain is often a potential complication of surgery, but knowledge of the local anatomy should significantly decrease the incidence of pain related to nerve injury. Banwart et al [27] recommended a vertical incision close to the lateral border of the posterior superior iliac spine with two thirds of the incision inferior to the posterior spine to avoid the cluneal nerves. Similarly, Arrington et al [14] noted that venturing more than 8 cm from the posterior superior iliac spine correlated with cluneal nerve injury. For patients with anterior crest harvests, the lateral femoral cutaneous nerve, lateral cutaneous branch of the subcostal nerve XII, and lateral cutaneous branch of the iliohypogastric nerve can be at risk. When harvesting anterior iliac crest bone, Banwart et al [27] recommended an incision that starts just lateral to the anterior superior iliac spine below the iliac crest and extends no further than the area between the anterior one third and posterior two thirds of the iliac crest. Anatomic variations of the lateral femoral cutaneous nerve dictate the need to avoid making an incision closer than 1 to 2 cm from the anterior superior iliac spine [17,26–28].

Hemorrhage

Complications that are related to blood loss can present in two ways. Hematomas are seen with any type of surgery and iliac crest bone harvests are no different in that regard [5,14,16,17,19,26]. Arteriovenous fistula is an unusual complication of iliac crest bone harvest [8,24]. When harvesting bone from the posterior iliac crest, the superior gluteal artery is at risk as it exits the pelvis through the superior aspect of the greater sciatic notch. Injury to this vessel can result in heavy blood loss that requires more surgery to stop the bleeding. Kurz et al [26] reported on three cases of heavy blood loss from injury to the superior gluteal artery during iliac crest harvest. Similarly, Arrington et al [14] found three cases out of their large series where arterial injury occurred. The causes of injury to the superior gluteal artery included excessive retraction and placing sharp instruments into the greater sciatic notch. The vessel often retracts into the pelvis after injury and blood loss that requires transfusion is not uncommon. If injury to the vessel is encountered, the surgeon must be prepared to enlarge the approach and remove bone from the notch to help visualize the vessel so ligation is possible

[26,29]. The inability to control bleeding from this position requires finding the vessel from a retroperitoneal surgical approach [16,29]. Embolization of the bleeding vessel was reported in stable patients [7,10]. Shin et al [13] presented two cases of iliac crest harvest that were complicated by injury to the superior gluteal artery; they stopped bleeding by extending the incision and detaching the origin of the gluteus maximus to locate the bleeding vessel. Finally, beware of a postoperatively expanding hematoma in a patient who has undergone an iliac crest bone graft. This could be a sign of significant arterial injury [14,16,19]. Despite the possibility of arterial injury during iliac crest harvest, this complication is unusual. Banwart et al [27] reported no arterial injury in their review of 261 cases where iliac crest bone was harvested. Ahlmann et al [19] reviewed 106 cases and reported no major bleeding complications.

Fracture

Removing bone from the iliac crest creates a risk of fracture. Coventry and Tapper [9] reported on six cases of pelvic instability after iliac crest bone harvest. Four of the six patients underwent sacroiliac fusion to treat this instability. Banwart et al [27] found no fractures in their retrospective review of 261 patients who underwent iliac crest bone harvests. Porchet and Jaques [18] reported on two cases of iliac fracture following removal of tricortical iliac crest bone. Both cases were treated without surgery. To decrease the risk of this complication, they recommended the use of an oscillating bone saw and stopping a minimum of 3 cm from the anterior superior iliac spine. Arrington et al [14] found only two cases of iliac wing fracture out of 414 patients that they studied. They agreed with Porchet and Jaques and stated that straying too close to the anterior superior iliac spine puts the patient at higher risk for fracture. Kuhn and Moreland [30] noted that the pull of the sartorius and tensor fascia lata, combined with the stress riser of leaving a small spike of bone at the anterior superior iliac crest, can make fracture of the anterior superior iliac spine more likely. Other factors that may be correlated with fracture risk include quantity of bone harvested, age of the patient and post-operative activity level.

Hernia

If a sufficiently large, full thickness graft is taken from the ilium, the patient could be at risk for herniation of abdominal contents through the defect in the bone. The patient may notice a soft tissue mass in the area of the donor site with discomfort that gradually increases with a valsalva type of maneuver; auscultation of the mass may yield bowel sounds as well [21]. Lotem et al [22] reported a case of lumbar hernia through a bone graft donor site that occurred 11 years after a spine fusion procedure. The hernia became painful 3 years after the palpable mass became evident. At surgery, an incarcerated lumbar hernia was evident. Arrington et al [14] found two cases of lumbar herniation in their large review of patients who underwent bone graft surgeries. Both patients had undergone harvest of large

tricortical bone grafts. Treatment consisted of reduction of the hernia without closure of the defect. Other investigators, however, support closure of such a defect in the iliac crest following herniation of abdominal organs [16,20,21]. Cowley and Anderson [21] described surgical techniques to treat these unusual complications following iliac crest graft harvest.

Other complications

Infection is a complication that is seen in all surgeries at one time or another. Infections can be superficial and require only antibiotics or be more extensive and require surgery. Schulhofer and Oloff [12] presented a series of 40 patients who underwent iliac crest bone grafting and foot and ankle reconstructive surgery and described a hematoma/infection as their only complication. In their review of iliac crest bone graft cases, Arrington et al [14] found that less than 2% of patients had deep infection that required debridement. Goulet et al [25] reported an infection rate of between 2% and 3% in 119 patients who had bone taken from the iliac crest. In contrast, Ahlmann et al [19] reviewed 88 iliac crest grafts and found no infections. In reviewing the literature about this procedure, infection does not seem to be more or less frequent when compared with other orthopedic procedures [14,19,25,26].

Scarring can be problematic and should be included as a possible complication following iliac crest harvest. When large grafts are taken that change the usual contour of the crest anteriorly, patients may be at higher risk for cosmetic problems [26]. Several investigators described techniques to minimize cosmetic deformity [16,26,31].

Finally, Escalas and DeWald [24] reported on a case of ureteral injury and arteriovenous fistula developing after iliac crest harvest in a patient who underwent corrective scoliosis surgery. The patient was treated conservatively and recovered without incident. The surgeon should be aware of this type of problem in a patient who develops unexplained fever, vomiting, abdominal distension, and hematuria following surgery to remove bone from the iliac crest. If urine extravasation is present, then repair is indicated [24].

Summary

As discussed earlier, a certain morbidity exists when performing iliac crest graft harvests. Fortunately, several large series in the recent literature can help the surgeon understand the incidence and occurrence of various complications associated with iliac crest bone graft procedures [3,12,14,17,19,22,25,26]. Understanding the anatomy of nerves and vessels in the area of the procedure can minimize complications related to pain, neuropathy, and hemorrhage. Being aware of unusual complications, such as lumbar hernia and ureteral injury can help the surgeon treat them more quickly and effectively. Fracture risk can be minimized by avoiding harvesting excessive quantities of bone and by avoiding placement of the bone harvest too close to the anterior superior iliac spine.

Other autologous bone sources

The foot and ankle surgeon may encounter one or more of the previously discussed complications when obtaining iliac crest bone for bone grafting needs. Many complications will be more common with the harvest of larger quantities of bone, such as fracture, hernia, cosmetic deformity, and heavy blood loss. Other options for obtaining autologous bone in smaller quantities exist and have been used widely by foot and ankle surgeons. Horton [32] reviewed several of these sources in a recent edition of this journal.

Danziger et al [33] reviewed 40 cases of distal tibia bone graft harvest and noted no complications at an average follow-up of nearly 2 years. There was only one nonunion; two patients had a minor decrease in ankle motion at follow-up. They did not measure the amount of bone that was obtained in these patients, but in 11 subsequent patients, an average of 9.1 grams of bone was obtained from the distal tibia. The bone was used in a variety of cases including triple arthrodeses, ankle fractures, and midfoot fusions. A description of the harvest technique was presented in their review. Donley and Richardson [34] described a technique for the harvest of distal tibia bone graft and Brown [35] described the use of a bone graft harvest system from Acumed (Acumed, Inc., Hillsboro, OR) for obtaining distal tibia bone graft. Potential complications from harvesting bone from the distal tibia include fracture, infection, wound healing problems, pain, and chronic swelling. O'Malley and Conti [36] reported one stress fracture of the distal tibia out of 100 patients surveyed. The patient was treated with nonweightbearing for 4 weeks in a cast and the fracture healed uneventfully. They stated that osteopenia and peripheral neuropathy were relative contraindications for using distal tibial bone graft. In addition, if cortical bone is needed for structural support, the distal tibia is not an appropriate choice unless it is used to augment other bone graft sources. The distal fibula is commonly used as a graft source for ankle and tibiototalcalcaneal arthrodeses. Raikin and Myerson [37] described the use of an acetabular reamer as a way to obtain morselized bone from the distal fibula.

The calcaneus is also a source of bone graft that can be used in foot and ankle surgery. Mahan [38] reported on 25 calcaneal grafts and noted two complications. One patient developed peroneal tendinitis that resolved after 2 weeks following symptomatic care which included a cortisone injection. The other patient developed a neuritis of a branch of the sural nerve that resolved over a 2-month period. Biddinger et al [39] reviewed the cases of 17 patients who had undergone calcaneal bone graft harvests and were followed up at an average of 2 years. Mild incisional discomfort was reported in five patients. One of these patients required shoewear modifications. Plantar fasciitis developed in three patients. It was unclear whether the donor site had any relationship to the development of the medial heel pain in these three patients. No fractures or loss of subtalar motion developed in any patient. Potential complications of harvesting bone from the calcaneus include infection, hematoma, chronic pain, fracture, wound problems, and nerve injury. A possible disadvantage of this procedure is the need to consider

nonweightbearing ambulation for several weeks to minimize the risk of calcaneal fracture [1,38].

Krause and Perry [40] studied the harvest of bone from the distal femur for bone grafting purposes. The clinical aspect of the prospective study involved 30 patients who needed bone grafting for acute trauma (13 patients) and reconstructive procedures (17 patients), such as fracture nonunion and arthrodeses. Follow-up averaged 10 months and all fractures healed. Eleven of the 12 nonunions healed and two of three arthrodeses fused. The other two cases involved tibial defects and one of these did not fill in appropriately. No infection or wound problems were reported; two patients had mild pain with the donor site scar which resolved over time. One patient subsequent to this series did, however, develop a supracondylar femur fracture through the bone graft site after a fall; it was treated with flexible intramedullary fixation.

The proximal tibia has also been used as a source of autologous bone. Alt et al [41] reported on 54 patients who had bone taken from the proximal tibia to augment treatment of acute fractures and nonunions. The patients were allowed to bear weight immediately after surgery. They described a complication in only one patient who had a local hematoma. Pain at the harvest site usually lasted only a few days. O’Keeffe et al [42] presented a retrospective review of 230 cases of proximal tibia bone graft harvest in 206 patients. The cases involved primarily acute fractures with a smaller number of nonunion cases. The patients were nonweightbearing for at least 6 weeks and follow-up averaged almost 2 years. Only three complications were reported. One patient developed a nondisplaced fracture of the tibial eminence that healed with appropriate nonoperative care. The other two developed wound complications that resolved with nonoperative care. The article described their technique for harvesting the bone graft.

Bone graft alternatives

The use of autologous bone graft to aid in the success of orthopedic surgery is a widely-practiced principle. As discussed earlier, however, harvesting autologous bone presents an element of potential morbidity to the patient. Procuring bone from another location in the body away from the surgical site also adds time to the operation, especially when the surgeon is operating without qualified assistants. Many options have been developed that can be used as alternatives to autologous bone.

When considering bone grafting alternatives, the surgeon ideally needs a material that provides osteogenic cells, osteoinductive factors, and an osteoconductive matrix [43,44]. Osteogenic cells differentiate into cells that are capable of producing bone. The osteoinductive factors produce elements that induce bone formation. Finally, the osteoconductive aspect provides a scaffold that supports bone growth. Autogenous bone has all three of these components, and the goal of alternative graft sources is to have as many of these components as possible.

Allograft bone

Allograft bone is a commonly-used alternative to autogenous bone. Allograft describes tissue that is donated to a genetically different individual of the same species. Allografts are advantageous because they are readily available and are present in large quantities. An allograft serves primarily only as an osteoconductive medium as it lacks living cells and has limited osteoinductive capacity [43,45]. Three options exist for the surgeon in choosing this type of bone graft. Fresh specimens are limited in their usefulness because they must be used fairly quickly and the time to check for disease is short. The most common indication for using a fresh allograft occurs with joint resurfacing procedures that rely on maintaining living chondrocytes in the donor specimen [43]. More commonly, allografts that are preserved by freezing or freeze-drying are used by orthopedic surgeons. Freezing an allograft involves storing the specimen at approximately -60° to -70°C [43,46]. Freeze-drying removes at least 95% of the water content from the tissue that has been frozen.

Today the greatest concern in using allograft is the transmission of an infectious disease to the patient who receives the graft. The American Association of Tissue Banks and the Food and Drug Administration have developed guidelines for reducing the incidence of disease transmission [47,48]. A detailed donor history is performed along with a thorough autopsy including serologic testing. The tissue is then processed by combinations of physical irrigation and debridement, chemical treatments, freezing or freeze-drying, and terminal sterilization [44]. Terminal sterilization is performed with either ethylene oxide or irradiation [43,44,49,50]. With current technology and screening practices the risk of viral or bacterial disease transmission to the graft recipient is low. Human immunodeficiency virus, hepatitis B, and hepatitis C viruses cause the most concern in terms of transmitting infection by way of a graft to a patient. If the graft undergoes appropriate screening, testing, and processing, then the risk of HIV transmission is reported to be 1 in 1.6 million [46,49]. Although disease transmission is rare, it can occur [44,50–52]. Conrad et al [51] reported that bone, ligament, and tendon allografts could transmit the hepatitis C virus; they indicated that their results suggested that gamma radiation may deactivate the virus. Several cases of HIV transmission were reported with the use of frozen allografts [50,52]. Freeze-dried bone allografts have not been reported to transmit the HIV virus [44,50,52]. Although viral infection with the use of an allograft is the most common infectious concern, bacterial infections with allografts were recently reported in several knee surgeries [53].

Infection can occur as a complication of the surgical procedure and not as a result of the graft itself. Tomford et al [54] reviewed the use of more than 300 frozen allografts and found that the use of femoral heads and small bone allografts resulted in no postoperative infections. The use of large allografts was associated with an infection rate of 5% in bone tumor cases and an infection rate of 4% in revision surgery of hip arthroplasties. They concluded that factors, such as long operating times, large dissection, heavy blood loss, and introducing large

avascular organic material into the wound, might contribute to the development of infection. The investigators also noted that none of the grafts underwent secondary sterilization; contaminating organisms on the allograft may not have been detected.

Nonunion of the allograft to the host bone is another potential complication in the use of this bone graft alternative. Mahan and Hillstrom [55] reviewed 300 bone grafts used in foot and ankle cases; almost three quarters of the cases involved allograft bone. They noted that healing problems at arthrodeses sites and nonunion repair sites were disproportionately represented in the complications that were reported using allograft. Important factors in optimizing success with an allograft include the presence of a stable construct and appropriate contact between the host bone and the allograft [44]. Incorporation of the graft may also depend on the immunogenic response of the host to the allograft. Resorption of a graft or early mechanical failure could indicate rejection of the graft by the host [44]. When implanted, the allograft will incite an immune response; this response will slow activities that are needed for graft incorporation such as vascularization and appropriate cellular activity [44,46,50,56]. Graft processing and freeze-drying significantly reduce the immunogenicity of the allograft, but this also reduces its mechanical strength and osteoinductive capabilities [46,49,50,57]. Other factors that may influence graft incorporation include the general health of the patient, postoperative rehabilitation protocols, and the condition of the host bed [44].

Allografts may fail by fracturing. This complication is seen with structural allografts that are needed to provide support. Berrey et al [58] reported on their experience with large structural allografts that were used to treat bone tumors; they found a 16% incidence of fracture in their review of more than 200 patients. Surgical treatment of the fractures was required in all but 4 of the 43 cases that fractured.

Demineralized bone matrix (DBM) is a form of allograft in which the mineral has been removed from the bone tissue. In 1965, Urist [59] described the formation of ectopic bone in rodents following the implantation of demineralized bone matrix into muscle. Following appropriate processing, the once-mineralized bone tissue contains only bone growth factors, collagen, and other proteins [43,60]. The material lacks structural strength, but does possess osteoinductive properties because of the presence of bone morphogenic proteins (BMP) [43,44,46]. The bone morphogenic proteins are a group of 15 growth factors that stimulate mesenchymal cells to differentiate into musculoskeletal tissue [43,56,61]. Of this group, BMP-2 through BMP-6 and BMP-7 through BMP-9 have shown osteoinductivity [62]. DBM has been used widely in spinal fusion surgery, filling osseous defects, craniofacial reconstruction, and treatment of nonunions [63,64]. Michelson and Curl [65] published a prospective study that compared the use of iliac crest autograft and demineralized bone matrix in hindfoot arthrodeses; they found that the two groups healed the arthrodeses in similar fashion. No difference in time to healing was noted between the two groups. Blood loss, however, differed significantly between the two procedures. The only complication was nonunion of the arthrodesis site in one patient. Scranton [66] had success with

DBM mixed with a local slurry of bone in performing arthroscopic subtalar arthrodeses in five patients. The processing of DBM into its final product can affect the osteoinductive properties of the finished product. Several steps are required to produce DBM from bone; these include the use of demineralizing agents, organic solvents for fat removal, freeze-drying, and terminal sterilization [49,63]. When choosing one of these options, the surgeon should look for scientific evidence of bone formation in applications that are similar to the intended purpose of the chosen product. Several DBM-containing products are on the market including Grafton[®] (Osteotech, Eatontown, NJ), DynaGraft[®] (GenSci OrthoBiologics, Irvine, CA), AlloMatrix[™] (Wright Medical Technology, Arlington, TN), Opteform[®] (Exactech, Inc., Gainesville, FL), Osteofil[®] (Medtronic Sofamor Danek, Memphis, TN), DBX[®] (Synthes, West Chester, PA), and OrthoBlast[™] (GenSci OrthoBiologics, Irvine, CA). They are available in various forms such as gel, paste, freeze-dried powder, granules, and putty. At present, DBM is believed to be most successfully used as a bone graft supplement to autograft or allograft rather than as substitute for these graft choices in spinal fusions [64]. To promote safety and the efficacy of DBM, the Food and Drug Administration and the American Association of Tissue Banks require that each batch of DBM comes from a single human donor [63]. Although these requirements are in place, DBM is not required to meet high levels of proof of effectiveness because of its classification as a minimally-manipulated tissue [67]. The risk of infection with HIV is a concern when using any allograft material. Current data suggest that transmission of the HIV virus following the use of DBM is extremely unlikely [63]. Decalcification of bone seems to deactivate the virus [68].

Ceramics

Synthetic options exist to use as bone grafting alternatives. Subjecting naturally-occurring mineral salts to high temperatures is referred to as sintering; the crystalline materials produced are called ceramics [62]. For these materials to be successful in becoming a bone graft substitute, they must have physical properties that allow the adherence of osteoblasts and be structured so that vascular ingrowth is optimal [69]. The use of these materials carry several advantages that include no risk of disease transmission, no need for a second surgical site, and availability in large supply. Disadvantages include a lack of osteoinductive and osteogenic properties and poor initial structural support. In addition, the cost of the product could be considered a disadvantage, depending on the material chosen. Ceramics are used primarily as scaffolds upon which host bone can build new bone. Several factors are important in determining the suitability of a ceramic as a bone graft substitute. The material needs to be biocompatible, biodegradable, and appropriately structured to optimize bone ingrowth and remodeling [70,71]. Porous implants remodel much more quickly than denser materials, but faster resorption is associated with less mechanical strength [72]. Ceramics that are used most commonly in orthopedics include hydroxyapatite, tricalcium phosphate, and coralline hydroxyapatite.

Pro Osteon[®] (Interpore Cross International, Irvine, CA) is a commercially-available coralline hydroxyapatite that is produced from sea coral; calcium carbonate is converted to hydroxyapatite by using a hydrothermal exchange reaction [69]. The compressive strength of this material is close to that of cancellous bone and with progressive bony ingrowth and apposition, the material gains strength [73]. Indications for its use include filling bony cavities such as metaphyseal fracture defects; rigid internal fixation should be used if structural support is needed [73–75]. Bucholz [74] noted, however, that interporous hydroxyapatite was used in other applications, including spinal fusion, bone healing problems, and revision arthroplasties. Rahimi et al [76] presented several cases in which coralline hydroxyapatite was used successfully in foot and ankle surgery.

Vitoss[™] (Orthovita, Inc., Malvern, PA) is a beta-tricalcium phosphate that was approved by the Food and Drug Administration in 2000 to fill bony defects [74]. As with the coralline hydroxyapatite, this structure is not intended to bear loads; supplemental internal fixation may be required if using this material. Clinical trials are underway to test the efficacy of this ceramic as a bone graft substitute.

Collagraft[™] (Zimmer Corporation, Warsaw, IN) is composed of bovine-derived collagen and porous calcium phosphate. Autogenous bone marrow aspirate is added to the product to provide an osteogenic component to the substance [72,74]. The material does not provide structural strength, so internal fixation is required if the construct has any element of instability. Chapman et al [77] demonstrated the effectiveness of Collagraft[™] in treating bony defects that are associated with acute fractures.

Calcium phosphate cements have been developed to enhance stabilization of fractures. The cements become hard without excess heat dissipation, provide compressive strength, and slowly remodel as a result of their bioactive components [78]. Skeletal Repair System (SRS[®], Norian Corp., Cupertino, CA), BoneSource[®] (Howmedica-Osteonics, Rutherford, NJ), and Alpha-BSM[®] (ETEX Corp., Cambridge, MA) are currently available as calcium phosphate cements. Schildhauer et al [79] augmented calcaneal fracture internal fixation with Norian SRS[®] in 36 joint depression calcaneal fractures. They found that early weightbearing, as soon as 3 weeks following fracture fixation, could be allowed. The complications that occurred included four infections. Thordarson et al [80] performed a cadaver study that demonstrated improved compressive strength and stability of the fixation of experimentally-created calcaneal fractures when the construct was augmented with Norian SRS[®]. The Norian product has also been used to aid in the treatment of hip fractures, distal radius fractures, and tibial plateau fractures [78].

Calcium sulfate, also more familiarly known as plaster of Paris, may be the oldest osteoconductive material that is currently in use [62]. Its rapid resorption rate may make it less reliable than other osteoconductive materials. Osteoset[®] (Wright Medical Technology, Arlington, TN) and BonePlast[™] (Interpore Cross International, Irvine, CA) are available as commercially-prepared, surgical grade, calcium sulfate products. Indications for calcium sulfate include spine fusion, revision arthroplasty, and filling bony defects [74]. Kelly et al [81] used Osteoset[®] alone or in combination with demineralized bone matrix, autograft, or bone

marrow aspirate in 109 patients with bone defects caused by tumor (42%), trauma (36%), and other causes (22%), such as periprosthetic bone loss and fusion augmentation. They found that patients who were treated with Osteoset[®] alone had a greater amount of bone ingrowth than those who were treated with a mixture of Osteoset[®] and other substances. Four patients developed serous wound drainage which was believed to be related to the calcium sulfate product. The Osteoset[®] was used to fill defects and not to provide structural support. This product seems to be best suited as a space filler and bone graft extender [74]. AlloMatrix[™] (Wright Medical Technology, Inc., Arlington, TN) is a composite graft material that consists of 86% demineralized bone matrix by volume and surgical grade calcium sulfate. The graft material provides osteoconductive and osteoinductive properties.

Summary

The ability to harvest iliac crest bone is a well-established skill in the surgical armamentarium of the orthopedic surgeon. As with any surgical procedure, this operation has its own set of complications. The surgeon must be aware of these potential problems in an effort to avoid them when possible. Other autologous sites for bone harvest are available to the surgeon, and s/he should be aware of these in terms of location, limitations of use, harvest technique, and potential pitfalls. The foot and ankle surgeon almost always needs less bone graft than our colleagues in spine surgery or joint revision surgery, so these other sites may be more suitable than the iliac crest for obtaining bone graft.

Nonautogenous alternatives are becoming increasingly available to the orthopedist as a way to decrease morbidity and operating times. Scranton [82] recently published an article about his success with several different bone substitute products that are used in foot and ankle reconstructive cases. As these options become more varied, it becomes more difficult to know which product to select. Understanding the biology of bone grafting with respect to osteoconduction, osteoinduction, and osteogenesis provides the surgeon with the knowledge that is needed to make an informed choice when selecting a bone grafting option. Before choosing an alternative graft material, the surgeon should also investigate how the graft material has performed in cases similar to his or her patient's needs. In the future, with continued research, the fields of tissue engineering and gene therapy will provide even better options for nonautogenous bone graft material.

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