CHAPTER **49**

AUTOGENOUS BONE GRAFTS

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Bone grafts, both autogenic and allogenic, have been used extensively in foot and ankle surgery. There are multiple factors involved in choosing the appropriate bone graft in order to properly address specific deformities. Considerations must be given to the size of the graft, the composition of the graft (cortical versus cancellous), and the morbidity of the donor site (if autogenic bone is required). Traditionally, autogenous bone transplantation has been the "gold standard" due to its immunocompatibility and its ability to incorporate. However, the use of allogenic bone implantation has become more prevalent with the advances made in decreasing the risk of disease transmission and increasing the availability through bone banks. The general guideline in deciding between autogenic and allogenic bone is often based on the amount of vascular supply at the receptor site. For instance, when working with highly vascular receptor sites such as the calcaneus (with Evan's or Dwyer osteotomy), it can be difficult to justify an additional surgical site (i.e. iliac crest) or requesting an orthopedic surgeon to harvest the bone. It has become more acceptable to use an allogenic tricortical iliac crest bone graft versus an autogenous graft when doing calcaneal flatfoot or cavus foot type reconstructions.

INDICATIONS

Although becoming less popular, autogenous bone transplantation still has its place in foot and ankle surgery. Common indications for autogenous bone transplantation of the lower extremity are management of nonunion or malunion, augmentation of bone defects after excision of benign neoplasms or osteomyelitic bone, reconstruction of shortened osseous structures (congenital and iatrogenic), and augmentation of arthrodesis sites. The common denominator in the above listed situations is having a less-than-ideal potential for revascularization and incorporation of a graft at the host site.

ADVANTAGES AND DISADVANTAGES

Advantages of autogenic as opposed to allogenic bone grafts are the osteogenic, osteoconductive, and osteioinductive properties. The ability to regenerate in addition to incorporate is crucial when the risk of viability at the host site is high (i.e. nonunion of the metatarsal shaft). The osteogenic autograft not only incorporates well, it also helps in production of new bone. Autografts have the capability to stimulate pluripotent mesenchymal cells of the host tissue to differentiate into osteogenic cells.[1] The disadvantages are having a secondary surgical site, structural compromise at the donor site, and inability to procure bone from certain areas of the body without the assistance of an orthopedic surgeon.

CHOICE OF DONOR SITE

Iliac crest offers not only a good construct of cortical and cancellous bone, but also a large volume of bone is available for grafting. As ideal as it may seem as an autogenous bone graft, it is not always necessary for foot and ankle repair. It has been noted that procurement of iliac crest bone is not without its own morbidity. Bone procurement from the hip often results in a tremendous amount of pain and discomfort. A study conducted by Laurie et al found that the average duration of pain localized to the iliac graft site was 6 weeks. At two years postoperative, 10% of the patients still had pain at the hip donor site.[2] Other complications affiliated with iliac crest grafts are lateral femoral cutaneous nerve entrapment, stress risers of the pelvis, and hernias through the defect. Unless a large volume of graft is necessary, procurement of autogenous bone from the tibia, fibula, and calcaneus, and other bones of the foot is more logical.

Another factor affecting proper donor site selection is the bone composition (cancellous or cortical). Deformities such as brachymetatarsal may require more cortical type bone for structural support. On the other hand, nonunion type deformities may benefit more from the rapid and complete revascularization properties from cancellous grafts. According to Burchardt et al there are three histologic differences between cancellous and cortical autografts: cancellous autografts are revascularized more rapidly and completely than cortical grafts; cancellous autografts undergo creeping substitution whereas cortical grafts undergo reverse creeping substitution; and cancellous autografts tend to repair completely with time, whereas cortical autografts remain a mixture of necrotic and viable bone. Cortical autografts undergo resorption up to 6 months, slowly leading to mechanical weakness. At one year postoperative, 40% of the original cortical necrotic bone still remains. For this reason, cortical bone is advantageous for structural integrity.[1,3]

PROCUREMENT TECHNIQUE AND GRAFT HANDLING

One important concept in procurement of autogenous grafts is minimizing the potential of violating donor site integrity. With hard cortical bone, stress fractures through a rectangular or square window poses more of a potential complication, whereas a circular or an oval window has a lower risk of a stress fracture.[4] It is recommended that Kirschner-wire (K-wire) drilling be used for rounding off corners of the angular grafts or to circumscribe a more rounded shaped graft in order to decrease stress fractures. It is also important to use an osteotome versus a power instrument to prevent thermal necrosis of valuable osteogenic cells. After the graft is harvested, it is optimal to transplant the autograft immediately for preservation of cell viability. Gray and Elvis have shown that autograft should not be stored in air for more than 3 hours. They recommend wrapping the graft in blood-soaked sponge (versus saline or antibiotic solution, both of which can be toxic to cells) if the graft can not be transplanted immediately after procurement.[5] If the autograft harvested creates a large defect, it is beneficial to pack the defect with allogenic bone for structural stability and prevention of hematoma formation. Another factor to consider is the weight-bearing status for protection of not only the recipient site, but also the donor site.

Tibia

The best donor site for high quality graft is at the distal metaphyseal region just proximal to the flare. Brown suggests staying 2-3 cm proximal to the tibial plafond in order to make sure the ankle joint is protected.[6] If the desired graft is mainly cancellous, procurement is via a hinged window leaving the periosteum intact over the window of cortical bone that will then be replaced. Yunger suggests that the cortical bone be cut in an oval shape (versus rectangular or square) to prevent stress fractures. The dimension should be 2 cm by 1.5 cm elliptical shape, with a distal hinge maintained. A one-quarter curved osteotome is useful after drilling the circumferencial cortical bone with K-wire. Avoid cutting or drilling into the cancellous bone with the power saw (thermal necrosis). Curette the cancellous bone from the window as desired.[4] Using this technique of tibial procurement, protection from weight bearing is not required. However, protected weight bearing or non-weight bearing is often dictated by the recipient site of the primary procedure.

CASE PRESENTATION ONE

Following is a case presentation of a failed oblique closing base wedge that was originally fixated with screws. The initial fixation failed and the second procedure using multiple threaded K-wires also failed. The patient presented with symptomatic displaced nonunion confirmed with bone scans, computed tomography (CT) scans, and radiographs. The medial cortex was still intact, acting as a strut after resection of the fibrous nonunion site. The chosen donor site was the distal tibia. The graft was taken at the metaphyseal region being aware of the ankle joint relationship to the graft site. The cortical bone was drilled with a 0.062 inch smooth K-wire in an oval shape (to prevent stress fractures at the corners). An osteotome was used to procure the underlying cancellous bone with the cortical bone. A central K-wire was used to help manipulate the graft as a whole piece. Additional cancellous bone was curetted from the tibia and packed into the medullary canal of the first metatarsal. The graft was then placed and fixated with a 2.7 cm screw (Figures 1-9).

Figure 1. Preoperative radiograph with nonunion site at the first metatarsal osteotomy site fixated with multiple threaded K-wires after first failed attempt using screw fixation.

Figure 2. Computed tomography scan indicating an intact cortex medically and atrophic nonunion laterally.

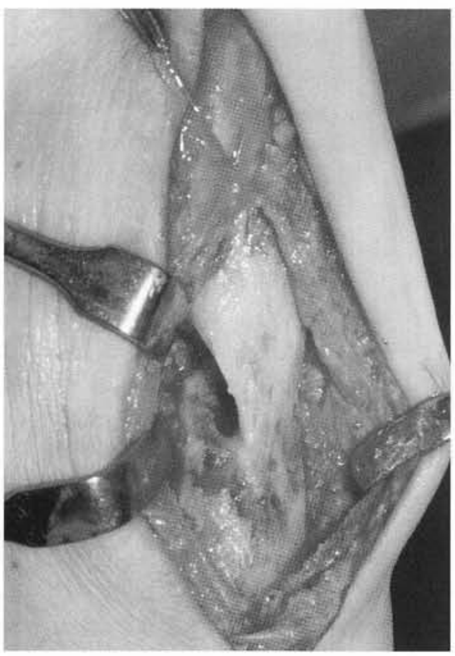

Figure 3. Defect at the first metatarsal after resection of nonunion site and removal of K-wires. Medial cortex is intact.

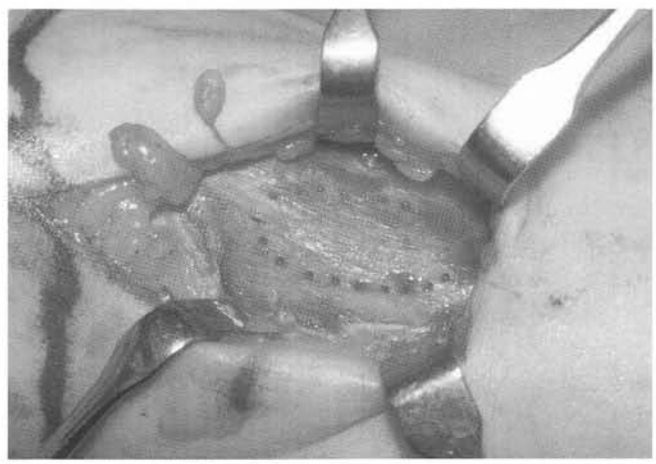

Figure 4. Marking the ankle joint and procuring tibial bone at 3-4cm proximal to the joint to avoid violation of the joint.

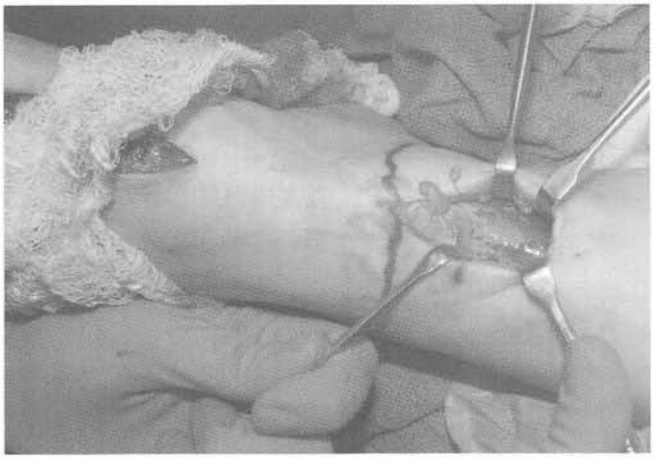

Figure 5. Distal tibial donor graft site drilled with 0.062 inch K-wire in an oval shape.

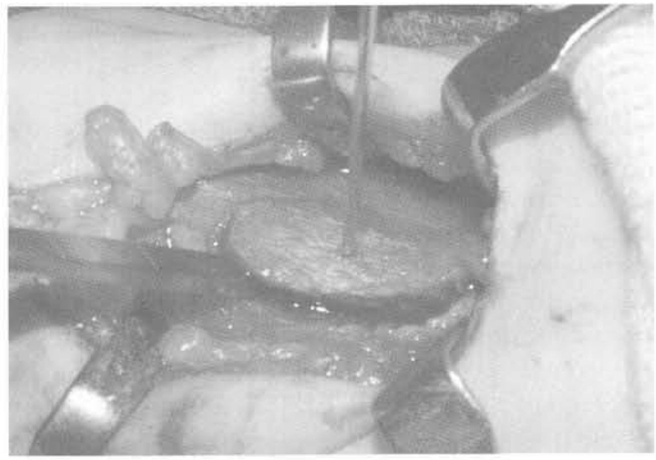

Figure 6. Using a central K-wire to manipulate the graft and an osteotome to remove a strut of corticocancellous bone. The osteotome should be angled in a convergent fashion.

Figure 7. Autogenous graft from distal tibia transplanted to the first metatarsal and fixated with a 2.7mm screw.

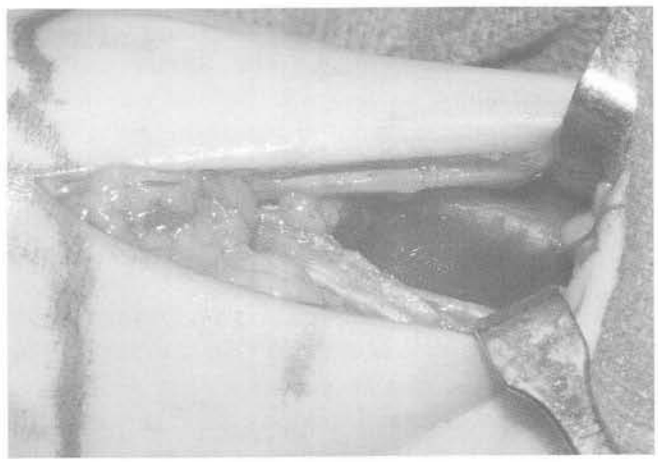

Figure 8. Defect at the distal tibia after procurement of both cortical and cancellous bone.

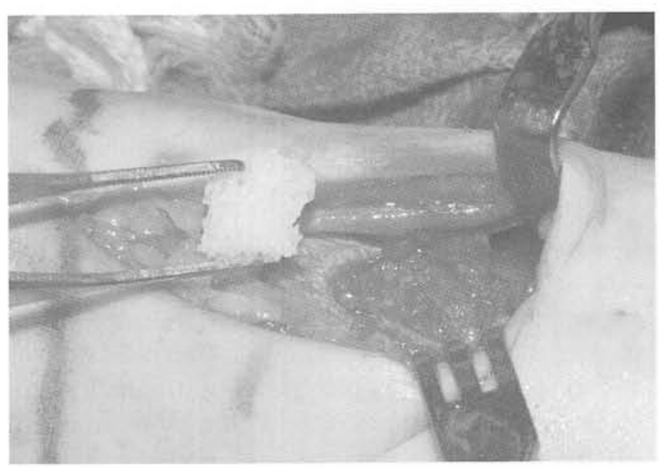

Figure 9. Filling the defect at the donor site with allogenic cancellous bone chips to avoid hematoma and structural weakening.

Fibula

Fibular grafts are mostly cortical in composition. Fibular grafts are usually indicated as a strut in situations where structural stability is necessary. Direct lateral incision approach over the fibula is recommended. The middle third section poses to be the desirable harvest site. Options are to either completely transect the fibula or to keep the medial cortex intact as a strut for host regeneration. The crucial factor in regeneration of bone at the host site is maintaining the periosteum envelope. An important concept in fibular bone procurement (just like in the distal tibia) is staying proximal to the ankle joint complex. Mendicino recommends staying at least 8 cm from the distal tip of the fibula.[7]

Fibular cut-downs are often performed during ankle arthrodesis procedures. This makes autogenous bone readily available for the purpose of arthrodesis enhancement. The fibula can be hemisected after the cut-down. One half can be used as the on-lay graft to stabilize the lateral aspect of the ankle fusion. The remainder section can be prepared for packing/enhancement at the arthrodesis site.

Calcaneus

The calcaneus is generally approached from a lateral incision for the ease of access. Vital structures to be aware of are the small saphenous vein, sural nerve and branches, peroneal tendons, subtalar joint, and Achilles insertion. The calcaneus serves as a good source of both cancellous graft (trephine) and corticocancellous autograft (segmental). When procuring cancellous graft via trephine, place the instrument perpendicular to the lateral wall and rotate until the desired depth is achieved, usually 1-2 cm. Then rock back and forth until the plug of bone loosens. This can be repeated via the same cortical window created by the initial trephine, but aimed at different angles.

When a segmental piece of corticocancellous autograft is needed, a vertical incision between the subtalar joint region and Achilles insertion site is recommended (Haglund's type incision). The superior margin of the calcaneus is then available for procurement. A rectangular graft is commonly used. The rectangle can be directed vertically or horizontally as long as the subtalar joint and the Achilles insertion are avoided. This is often a bicortical graft since the medial wall should be maintained intact to avoid complications of inadvertent calcaneal fractures or medial neurovascular damage. Once again, drilling the corners with the K-wire helps to prevent propagation of stress risers. Because the calcaneus is a very vascular bone, it is a good idea to fill the defect with allogenic bone or bone wax and use a suction drain to prevent hematoma.[8]

CASE PRESENTATION TWO

The following is a case where a 1.3 cm x 1.3 cm segmental calcaneal autograft was procured for the use of displaced malunion of a fifth metatarsal following a Tailor's bunion procedure. Note that the incision is vertically placed between the subtalar joint and the Achilles insertion posteriorly. The graft is bicortical with cancellous bone attached. The malunion site was reosteotomized and the graft placed and secured with a plate and screws (Figures 10-13).

Miscellaneous

The tibia, fibula, and calcaneus are the more frequently used donor sites for autogenous bone procurement. Other less frequently used places are the ancillary prominence, resected bone from deformities being corrected, and "splitting and swabbing" bones between relatively long and short structures. Following are two examples of more creative ways of bone procurement.

The first case is an older patient with a moderate to severe bunion deformity with a chronic ulceration over the dorsomedial prominence. The first surgery included debridement in preparation for the second surgery. The second surgery will be to correct the deformity depending on the results of the bone cultures. After the laboratory studies were confirmed amiable for surgery, a second surgery took place that consisted of a Keller bunionectomy. This procedure was selected because of the large defect in the head of the first metatarsal. The healthy bone resected from the base of the proximal phalanx was used as the autograft for packing the defect at the metatarsal head. (Figures 14-17)

The second case is a patient with an extremely short third digit as a result of previous overaggressive PIPJ arthroplasty. The patient presented with the complaint of a hammer toe deformity at the second digit and a short unstable third digit. The procedure performed here is resection of the head of the second proximal phalanx and hemisecting it. Half of the hemisected bone was used as a lengthening graft in the third toe and the other maintained in the second digit. The result is relatively equal length second and third digits with improved stability (Figures 18-21).

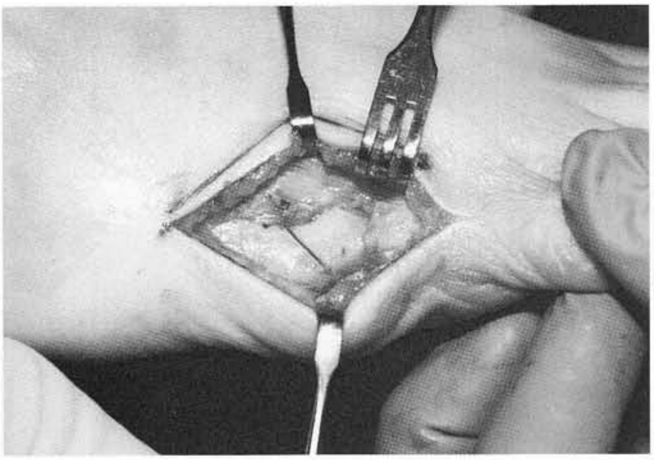

Figure 10. Displaced malunion at the fifth metatarsal after tailor's bunion procedure.

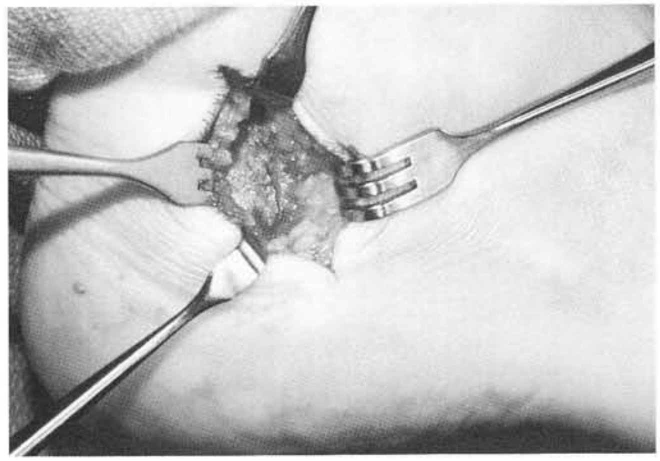

Figure 11. Vertical incision made between the posterior facet of the subtalar joint and the Achilles insertion. Rectangular shaped graft from the superior aspect of the calacaneus.

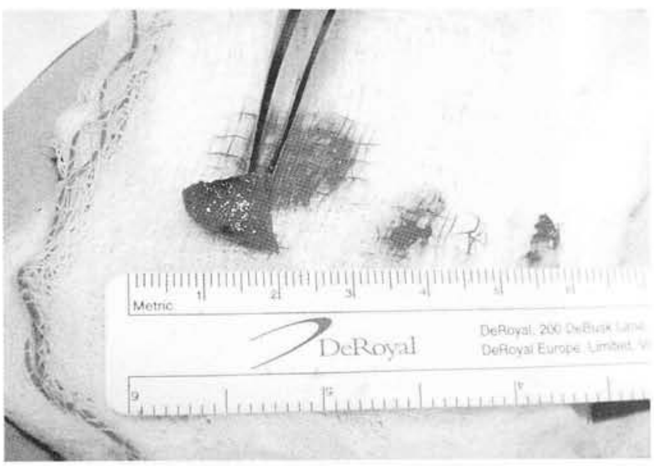

Figure 12. Corticocancellous graft procured from the calcaneus.

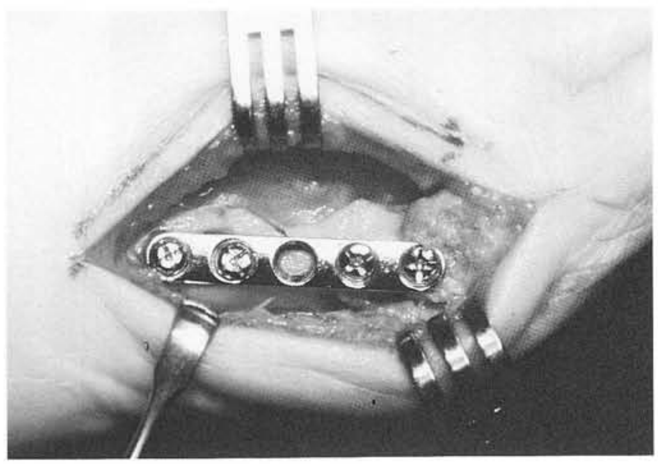

Figure 13. Graft inserted into the reosteotomized fifth metatarsal using plate and screw fixation.

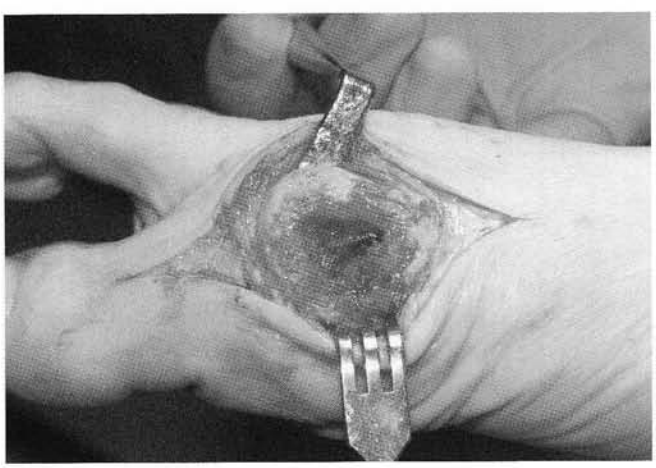

Figure 14. Defect at the first metatarsal head after debridement.

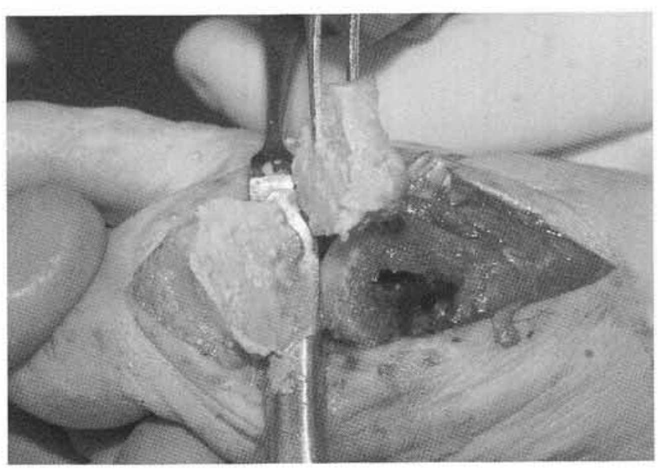

Figure 15. Healthy bone taken from the base of the proximal phalanx (Keller bunionectomy).

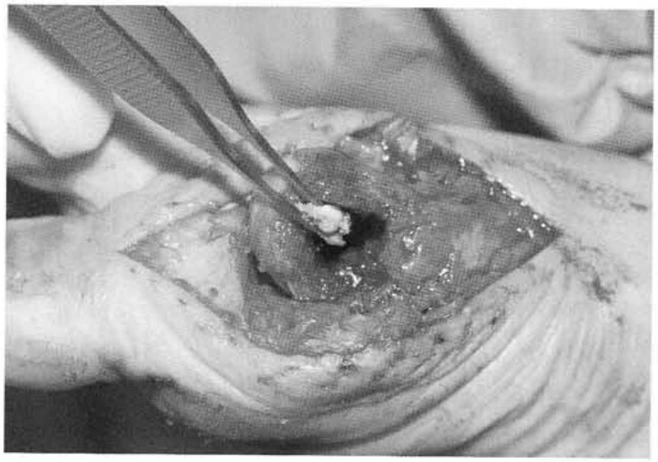

Figure 16. Autogenous bone graft from the base of the proximal phalanx being packed into the defect.

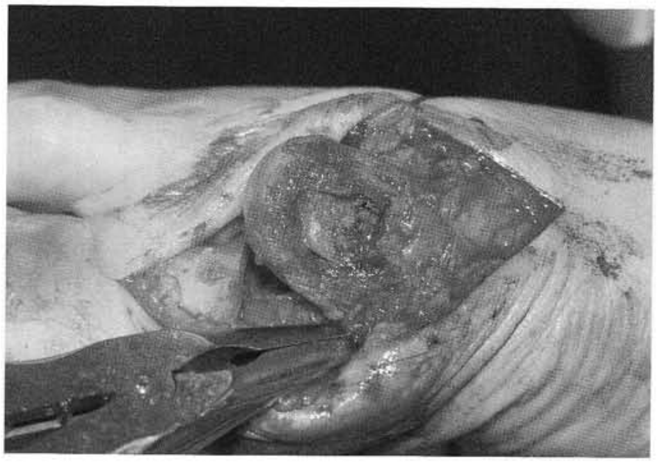

Figure 17. The defect at the 1st metatarsal head packed with autogenous bone.

Figure 18. Preoperative AP radiograph of shortened third digit after previous PIPJ arthroplasty.

Figure 19. Preoperative oblique radiograph showing short third digit.

Figure 20. Postoperative AP radiograph after the head of the proximal phalanx has been hemisected to provide as a graft for the third digit.

Figure 21. Postoperative oblique radiograph after "split and swab" autogenous graft from the second to third digit for lengthening.

SUMMARY

Autogenous bone grafting for use in foot and ankle surgery can often be achieved effectively without requesting iliac crest procurement from an orthopedic surgeon. There are multiple ways of harvesting bone from the tibia, fibula, and the calcaneus which are all easily accessible. The general principles for procurement and handling remain relatively constant. With a good understanding of bone healing properties and differences in different types of grafts, bone grafting can become less intimidating.

REFERENCES

1. Burchardt H. The biology of bone graft repair. *Clin Orthop* 1983:174:28-42.
2. Laurie S, Kaban,L, Mulliken J, Murray J. Donor site morbidity after harvesting rib and iliac bone. *J Plast Reconstr Surg* 1984;73:933-8.
3. Cypher TJ, Grossman JG. Biological principles of bone graft healing. *J Foot Ankle Surg* 1996;35:413-7.
4. Yunger EW, Chapman MW. Morbidity at bone graft donor sites. *J Orthop Trauma.* 1989;3:192-5.
5. Gray JC, Elvis MW. Early osteogenesis in compact bone isografts: a quantitative study of the contributions of the different graft cells. *Calcif Tissue Int* 1979;29:225.
6. Brown CH. A technique for distal tibial bone graft for arthrodesis of the foot and ankle. *Foot Ankle Intern* 2000;21:780-1.
7. Mendicino RW, Leonheart E, Shromoff P. Techniques for harvesting autogenous bone grafts of the lower extremity. *J Foot Ankle Surg* 1996;35:428-35.
8. Mahan KT. Calcaneal donor bone grafts. *J Am Podiatry Med Assoc* 1994;84:1-9.