BONE GRAFTS: AUTOGENOUS VS. ALLOGENEIC / CORTICAL VS. CANCELLOUS

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INTRODUCTION

Bone grafting techniques have been implemented by the faculty of the Podiatry Institute for several years. The primary uses have been as an adjunctive material to assist in obtaining surgical correction of deformity (i.e. Evans Calcaneal Osteotomy), repair of nonunion, and filling osseous gaps. Results have been gratifying and graft material has been incorporated without complications in the vast majority of cases.

According to Mahan, bone grafts serve three general functions: encouraging osteogenesis, enhanced immobilization or stability, and replacement of lost osseous tissue.[1] The specific function of the graft will be a primary factor in deciding the type of graft to be utilized. The successful incorporation of the graft is in a large part predicated upon this critical first step.

Autogenous and allogeneic grafts are the most common types of grafts which may be selected. Autogenous bone grafts are those harvested from the same individual, whereas allogeneic bone grafts are harvested from different individuals, but from the same species. In some instances, combinations of allogeneic and autogenous bone grafts can be used. Each has its own indications and pitfalls which will be discussed further in this text.

Another critical determination is whether one should use primarily cortical or cancellous bone in the graft. Traditionally, cortical grafts have been used in situations where structural stability is necessary. Cancellous bone grafts have been used when osteogenesis and provision of vascularity to the part is a primary consideration. A combination of cortical and cancellous bone grafts has been the mainstay of therapy to date. The determination of the relative ratio of cortical to cancellous bone is decided upon by the principal purpose of the graft and the graft site. The decision of whether to use autogenous vs. allogeneic bone grafts is also determined by similar parameters.

The purpose of this paper is to review the application of bone grafts in podiatric surgery and to provide the basic criteria for selecting the particular type of material needed to accomplish the desired result.

HISTORICAL PERSPECTIVE

Bone grafting techniques have been developed over the last few centuries. The first documented bone graft was an allograft and occurred in 1682 when Meekren was reported to have transplanted a dog cranium to a soldier's skull.[2] The earliest autograft experiments were reported by Merrem in 1810 who obtained autografts from skull trephination.[3] The use of allografts and autografts were reported throughout the nineteenth century. It was not until the early and mid 1900's that research was performed to further understand bone healing and to examine the physiology and biomechanics behind graft healing. Urist and others have performed extensive research in bone healing.[4,5] This has led to such breakthroughs as osteochondral and vascularized bone grafts.

BIOPHYSICAL PROPERTIES

Certain biophysical properties such as osteogenesis, osteoinduction, and osteoconduction, play a role in the incorporation of a bone into the graft site. There is also a relation between autogenous and allogeneic, and cortical and cancellous bone grafts, to these biophysical properties. Osteogenesis is the promotion of bone healing. This can be accomplished in two ways. The first being insertion of living osteoprogenitor cells. The living cells inherent in an autogenous bone graft have been shown to promote bone healing. The second being the promotion of bone healing via bone morphogenic protein (BMP). Bone healing which is stimulated via BMP is termed osteoinduction. Urist first described osteoinduction as the process of recruitment of mesenchymal-type cells into cartilage and bone under the diffusible BMP.[5] BMP is a glycoprotein which acts upon the undifferentiated perivascular mesenchymal cell. The protein is in higher concentrations in cortical bone than it is in cancellous bone. This plays a greater role in incorporation of the graft in allogeneic bone grafts since these grafts do not have the advantage of living cells.

Osteoconduction is another biophysical property used in describing bone graft incorporation and healing. It is the promotion of bone healing by the creation of a structural matrix. This structural matrix provides stability to the graft as well as providing a scaffolding for the ingrowth of capillaries. The property of osteoconduction is equally important in both allogeneic and autogenous bone graft healing.

ALLOGENEIC BONE GRAFTS

Allogeneic bone grafts are those grafts harvested from a different individual, but within the same species. At Northlake Regional Medical Center the allogeneic grafts most commonly used are freeze dried and kept in a sterile vacuum container. They can be stored for an indefinite period of time. Cortical-cancellous and cancellous grafts are available.

Allogeneic iliac bone crest provides an excellent combination of cortical and cancellous bone. The cortical shell supplies structural stability. Cancellous bone provides loosely placed trabeculations which better allows for the ingrowth of blood vessels. The iliac crest is the most common site for allogeneic bone used at our institution. It is presently being used for lesser metatarsal surgery and almost exclusively for the Evans Calcaneal Osteotomy. (Fig. 1)

The obvious advantage of allogeneic grafts is that a separate procedure does not need to be performed to harvest the material. The graft is easily stored and can be reconstituted quickly. The potential of increased antigenicity has been reduced due to the lyophilization or freeze drying process. This process has proven to reduce immunogenic rejection of the graft.

One of the principal disadvantages of allogenic material is the "healing potential" of the graft. Obviously, allogeneic bone does not possess living cells. Therefore, the graft is dependent upon osteoinduction and osteoconduction principles to be incorporated at the surgical site. In our experience over the past five years, this has not appeared to be a problem if used in the appropriate situations. Cortical-cancellous bone grafts have, for the most part, been incorporated when placed in loosely packed cancellous bone with a good blood supply. There have been a few instances where allogeneic bone placed in a largely cortical bone site did not take, and resulted in a nonunion. However, in both of these cases the graft was of a rather large size and this size could have been a determining factor.

Cases have been reported in the literature where cracks have occurred during the freeze drying process resulting in stress risers within the cortical bone. Obviously, this would present a problem when using internal fixation and stabilization of the graft. However, this problem has only rarely been encountered by the faculty of our Institution.

AUTOGENOUS BONE GRAFTS

Autogenous bone grafts are the most commonly preferred graft material. This preference is largely due to the living cells and the immunological compatibility of the graft with the host cells. Autogenous bone grafts are preferred in those situations where direct osteogenesis is needed, and the vascularity to the bone is poor i.e. avascular nonunion, cortical bone.

Cortical and cancellous grafts are harvested depending on what the specific situation dictates (Fig. 2). In graft sites which contain good vascular supply, the ratio of cortical to cancellous bone can be greater. This has been observed

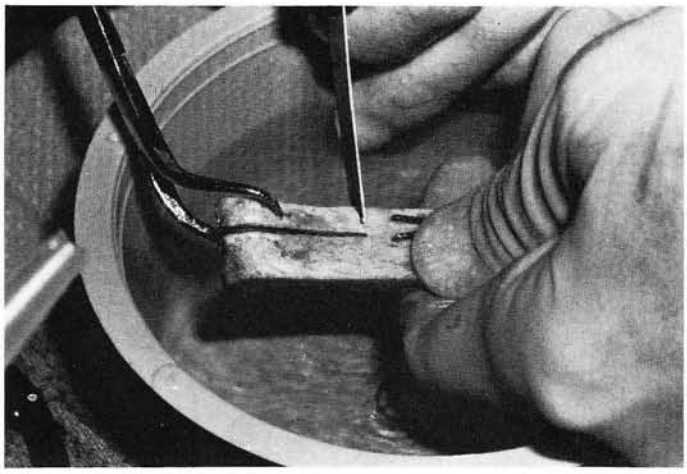

Fig. 1. Allogeneic iliac crest bone graft. The graft shown is being shaped for use in the Evan's calcaneal osteotomy.

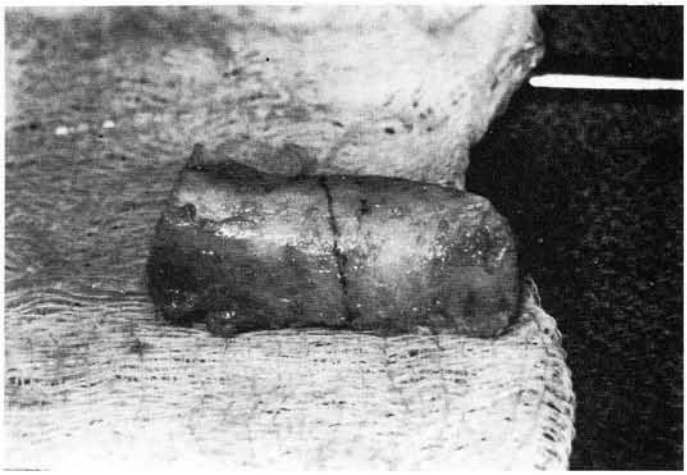

Fig. 2. Autogenous cortical-cancellous iliac crest bone graft previously harvested. Graft shown was used to repair a resected non-union of the first metatarsal.

when performing the Evans calcaneal osteotomy. The calcaneus is a largely cancellous bone which is richly vascularized. The iliac crest bone graft contains a good percentage of cortical bone, and postoperative follow-up has indicated good uptake of the graft into the calcaneus.

The iliac crest and the fibula are excellent sites for cortical bone struts. Iliac bone crest provides the option of one to three cortices with a varied amount of cancellous bone. The fibula provides primarily a cortical strut graft, but if harvested distally near the lateral malleolus, can supply cancellous bone. Common sites for cancellous bone are the tibial tuberosity, the calcaneus, and the cancellous bone within the iliac bone crest. If small amounts of cancellous bone are desired, the calcaneus is an excellent site due to its easy availability and low complication rate.[1]

Osteochondral grafts and vascularized grafts are the more advanced forms of bone grafting techniques currently being performed. At our Institution, two osteochondral bonegrafts have been performed. E. D. McGlamry, D.P.M. placed a fresh frozen calcaneal allograft in a 34 year old female with a previous history of hematogenous osteomyelitis. This procedure was complicated by a hematoma located at the wound site resulting in subsequent pseudomonal infection. Consequently, aggressive debridement of the graft was necessary.[6] Dr. McGlamry also used a osteochondral graft (a second metatarsal head and neck) to repair an iatrogenic absence of a second ray. This particular patient is two and-a-half years postoperative with a complete incorporation of the graft and relief of symptoms.

With the advent of microsurgical techniques, vascularized bone grafts have been reported in the literature during the past decade. Salibian reported on sixteen patients, with large segmental defects in the extremities. A transfer of large vascularized iliac bone graft was performed with the average osseous union occurring in 8.8 months.[7] The primary use of this technique would be for avascular nonunion or large defects as was performed in this study.

Advantages to the autogenous grafts include the fact that osteogenesis is accomplished with living cells. There is also no risk of rejection because of immunological incompatibility. The principal disadvantage is the disability received at the donor site due to the second procedure.

COMPLICATIONS

The primary complication with bone grafting is nonunion. The literature reports an incidence of 15 to 20 percent nonunion following bone grafting procedures. Prevention of this complication can be achieved by adherence to compressive fixation techniques and selection of the appropriate type of graft for the given situation.[1] Other than nonunion, very few complications have been seen with the allogeneic bone grafts. Hyperantigenicity has been reported in the literature with the result being reported as a nonunion.

To date, no infections directly related to the bone graft material have been reported at our institution. Other complications related to bone grafts in general which have been reported are hematoma, resorption of the donor material, and various wound complications.

POSTOPERATIVE FOLLOW-UP

Traditionally, patients who have undergone procedures with bone grafts to the metatarsal, midfoot, rearfoot, and ankle region are kept non-weight bearing for four to six months. Premature weight bearing before adequate consolidation will encourage failure of the graft and/or a nonunion.

The surgical sites are most commonly evaluated by conventional radiographical techniques. Observance of consolidation of the bone graft is noted when trabeculations cross the graft/recipient interface. This must be observed before the patient is allowed to bear weight.

Other methods of evaluation of the bone graft are tomograms, computerized tomography, magnetic resonance imaging, and bone scans. However, evaluation of bone grafts in the foot is particularly difficult due to the small size of the bone and the difficulty in producing a good image of the graft-host site.[1]

DISCUSSION

Experience has shown that successful bone graft incorporation has been observed in both allogeneic and autogenous bone grafts. In situations where there is poor vascularity, as in an avascular nonunion, autogenous bone grafts have primarily been implemented because of the advantage of living cells to aid in the healing and incorporation of the graft. The use of autogenous grafts are also hypothesized to be important when the graft site is primarily cortical, and the size of the graft desired is greater than 0.5 cm.. In podiatric surgery, the cortical graft site which is commonly encountered is the metatarsals. Several surgical procedures were performed in the past five years at our Institution, where cortical-cancellous bone grafts, both autogenous and allogeneic, were used for metatarsal surgery. The purpose of the surgical procedures included non-union repair, and lengthening osteotomies of the metatarsal to alleviate various forefoot pathology. The success of these grafts are currently being evaluated and will be presented at the Atlanta 1990 seminar.

Determination of the relative ratio of cortical to cancellous bone in the grafts involves certain important factors. The function of the graft must be assessed. If the graft is being primarily used to promote bone healing (osteogenesis), cancellous bone is preferred because it is loosely packed and serves as an excellent matrix for the ingrowth of capillaries. However, if structural stability is needed, a higher percentage of cortical bone is desired. This occurs in situations where there has been cortical bone loss, increased biomechanical stresses, or areas where the cortical bone has been weakened due to an osteotomy. However, in some situations the type of fixation used can add in the structural stability. An example of this would be the use of a plate to neutralize bending and torsional forces at the graft site. In most situations where a plate is used for fixation of the bone graft, a high percentage of cortical bone may not be as important.

SUMMARY

Bone grafting techniques have been briefly reviewed. Autogenous and allogeneic grafts have both proven to be successful and will continue to be used in the future. It is essential to understand the indications and the pitfalls of both types as well as to determine the relative ratio of cortical to cancellous graft needed.

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