Bone Grafting in Foot and Ankle Surgery

A Review of 300 Cases

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Three hundred foot and ankle bone grafts were reviewed in three separate series of 100 consecutive grafts from two institutions. The series represent a period from 1977 to 1990 and demonstrate treatment patterns that varied over time and between institutions in indications, graft material, and perioperative management. Over 42% of the 300 grafts were for calcaneal osteotomies; most were Evans calcaneal osteotomies. Over 72% of the grafts were allogeneic bone-bank bone, which performed well in calcaneal osteotomies and for packing of defects. Upon review of the incidence of bone complications, no significant differences were observed between surgical procedures that used autogenous *versus* allogeneic grafts. However, four out of six failures of first metatarsal repair were with allogeneic bone. There was a significant difference in complication rates for the major indications for bone-graft surgery. Nonunions and arthrodeses resulted in higher complication rates than expected, whereas calcaneal osteotomies resulted in a lower complication rate than expected. (J Am Podiatr Med Assoc 88(3): 109-118, 1998)

Bone grafting is an important aspect of foot and ankle surgery.[1] Despite the long history and widespread use of bone grafts and substitutes,[2] there have been few studies documenting patterns of utilization of bone grafting by podiatric surgeons. A survey on the use of bone grafts among orthopedists was reported in 1984 by Miller et al.[3] The present study was undertaken in order to determine patterns of utilization of bone grafts in foot and ankle surgery. In particular, this study was designed to demonstrate how indications for allogeneic bone and autogenous bone have changed and to examine the effectiveness of bone grafts for specific foot and ankle conditions.

Bone grafting can be used for many surgical procedures. Facilitation of fusion, repair of nonunions (Fig. 1),[4] and packing of cysts are all common reasons for bone-graft surgery. Reconstructive surgical procedures often require bone grafts (Fig. 2).[5] Lengthening procedures for repair of brachymetatarsia (Fig. 3)[6] and opening wedge procedures such as cuneiform osteotomies are other examples of procedures using bone grafts (Fig. 4).[7] Surgeons can choose from many different materials, although only a few are commonly used. An increasing number of choices are available to surgeons, including various forms of autogenous bone,[8] allogeneic bone,[9] and bone substitutes.[10] These choices obligate the surgeon to be familiar with the biology and biomechanics of these materials.

Bone grafts are classified by standard transplantation terminology.[11] Autogenous bone is procured

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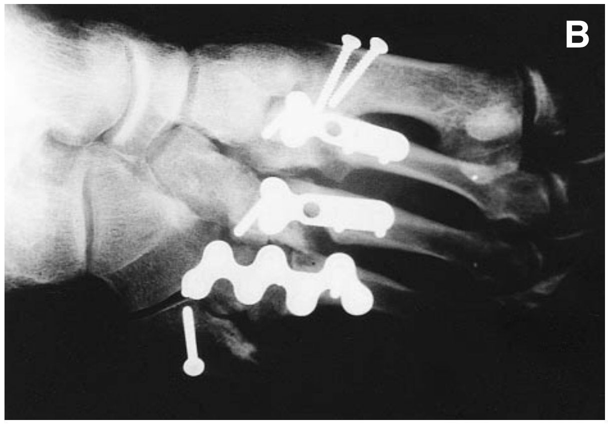
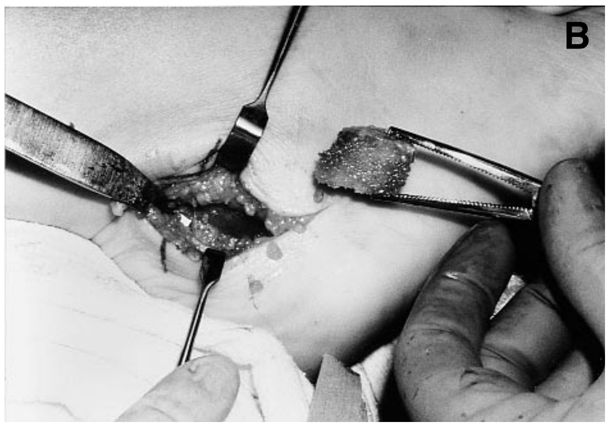


Figure 1. Bone-graft repair for multiple nonunions. A, Nonunion of the second, third, and fourth metatarsals. Intraoperative inspection revealed the second and third metatarsal nonunions to be stable, with the fourth metatarsal being unstable. B, Surgical repair with trephine plug removal of nonunion tissue, augmentation replacement with autogenous calcaneal trephine plug of bone, and T-plate for the second and third metatarsals. The fourth metatarsal was repaired with interpositional autogenous calcaneal graft and W-plate. C, Two years after nonunion repair, the plates were removed. The radiograph shows complete consolidation at all sites.



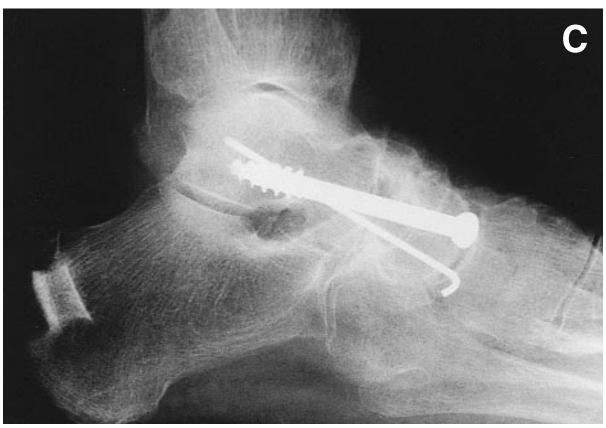


Figure 2. Bone-graft augmentation of talonavicular arthrodesis. A, Preoperative radiograph shows arthrosis of the talonavicular joint. B, Procurement of autogenous calcaneal graft through a lateral approach. C, Radiograph taken 1 month postoperatively shows consolidation of the graft in the arthrodesis site. Note that the calcaneal donor site has been packed with allogeneic iliac crest graft.

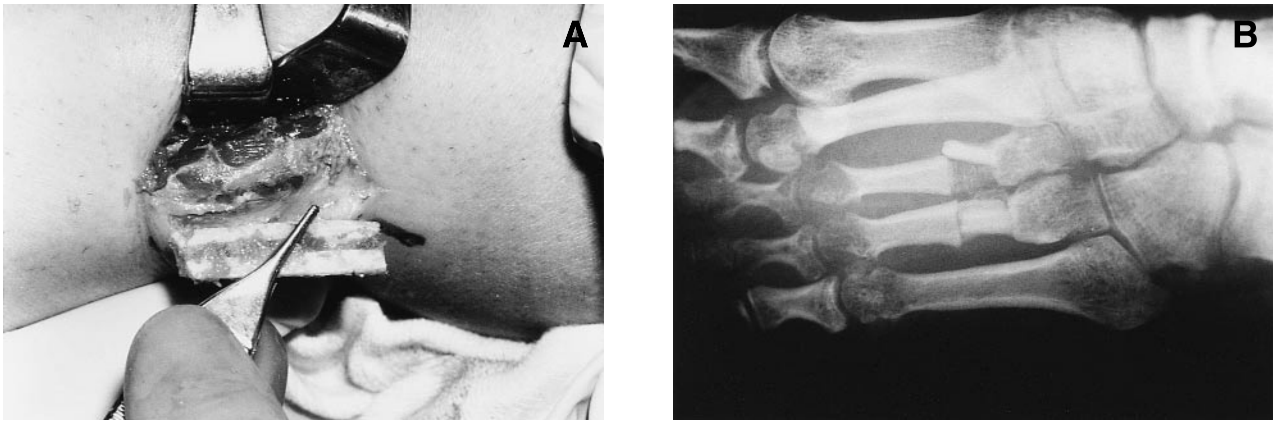


Figure 3. Fibular graft for multiple brachymetatarsia repair. A, Intraoperative photograph shows removal of a hemisection of the fibula. Note the significant thickness of the cortex. B, Radiograph taken 3 months postoperatively shows substantial but incomplete healing at the third and fourth metatarsal sites.

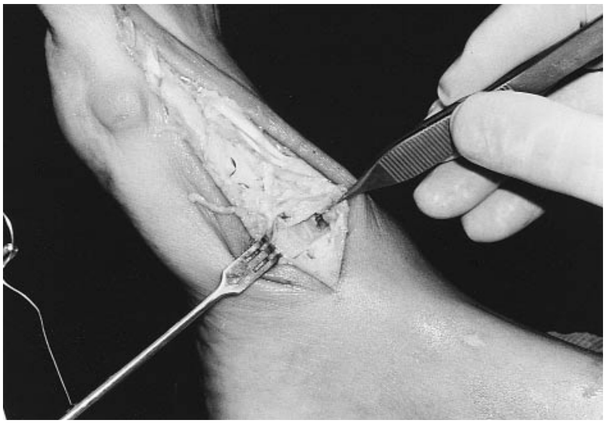


Figure 4. Intraoperative photograph shows use of allogeneic iliac crest graft as part of a repair of adolescent hallux valgus by means of an opening wedge cuneiform graft.

from the patient's own body. It is highly desirable material because it has the most favorable bone-healing characteristics.[12] Because of the transfer of living tissue, autogenous bone provides osteogenesis, osteoconduction, and osteoinduction. No other single material provides all three bone-healing characteristics. Because the bone is the patient's own, there is no difficulty with rejection phenomena or with disease transmission. These advantages have classically made autogenous bone the most preferred material for bone grafts.[13] These advantages come at a significant cost: Operating time and operative risks are substantially increased.[14] A separate surgical site for donor bone creates additional risks of infection, dehiscence, and nerve entrapment.[15] The donor site may also be functionally impaired by the procurement of the graft.[16] Vascularized grafts are autogenous grafts transferred with a blood supply that is anastamosed again at the host site: This is an effective way of managing large defects.[17]

Allogeneic bone is procured from other people. There are approximately 100 bone banks in the United States, of which approximately 40 belong to the American Association of Tissue Banks (AATB). The AATB has set standards for tissue banks and developed a voluntary accreditation process. Of the almost 150,000 musculoskeletal tissue grafts performed annually, there are approximately 30,000 freeze-dried bottled bone grafts and 10,000 long-bone segments.[18]

Most commonly, allogeneic bone is procured and then stored for later use.[19] In order to prevent disease transmission, the bone must come from individuals free of infectious diseases and malignancy. Bone banks have developed specific criteria for the selection of donors and for testing of their tissues.[20] These tests often include double tests for acquired immunodeficiency syndrome (AIDS) and hepatitis C (at the time of donation and 6 months after donation) for bone donations from living donors, such as femoral head donation after hip arthroplasty. Bone from cadavers is used only after an extensive history and physical examination and tests such as polymerase chain reaction (PCR) for AIDS, HIV-1 antigen, anti–HIV-1, hepatitis C, and anti–hepatitis C virus.[18] Once a donor has met the inclusion criteria, the bone must be removed and stored in such a way as to prevent infection. There are two principal methods of achieving this: Bone can be removed sterile and then stored frozen or freeze-dried, or it can be excised under clean conditions and sterilized later.[21] A particular concern is to ensure that human immunodeficiency virus (HIV) is not transferred with the bone.[22-25] Radiation sterilization is performed on some grafts, although this creates some changes in the mechanical properties of the bone.[26, 27] Lyophilized irradiated bone performed well in a large study, with the exception of avascular nonunions and postosteomyelitis gaps, as long as there was intimate contact between graft and host (Fig. 5).[28]

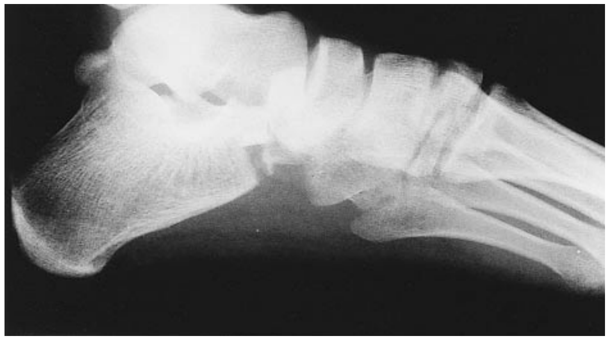


Figure 5. Lateral radiograph after allogeneic graft for Evans calcaneal osteotomy.

Materials and Methods

Problem Statement

There are no consistent reports in the literature concerning the number and type of bone complications arising from foot and ankle surgical bone-graft procedures. It is unclear if the complication rate differs on the basis of indication or use of allogeneic *versus* autogenous bone graft. Two questions were posed: 1) Is there a difference in the incidence of bone complications between surgical procedures that use autogenous *versus* allogeneic grafts? 2) Is there a difference in the bone complication rate based on the indications for the bone-graft surgery? To answer these questions, the following null hypotheses were formulated:

> H1: If the incidence of bone complications is reviewed retrospectively, then no significant differences will be seen between surgical procedures that use autogenous *versus* allogeneic grafts.
>
> H2: If the complication rate is assessed for the major indications for bone-graft surgery, then no significant differences will be seen.

Experimental Protocol

Three individual series of 100 consecutive foot and ankle bone-graft cases were reviewed, for a total of 300 grafts. The first series (Series 1) was 100 consecutive grafts performed between 1977 and 1982 at Doctors Hospital (now Northlake Regional Medical Center) in Tucker, Georgia. The second series (Series 2) consisted of 100 consecutive grafts performed at the same hospital from 1987 to 1989. The third series (Series 3) was 100 consecutive grafts performed by surgeons from the Foot and Ankle Institute of the Pennsylvania College of Podiatric Medicine (PCPM) at various hospitals in the Philadelphia area between 1985 and 1990.

Each series consisted of consecutive grafts that met the following criteria for inclusion in the study: adequate documentation of the preoperative graft and host area, the surgical procedures, perioperative management, the postoperative course and outcome, and at least 6 months of follow-up. This required the hospital record or the operative report and discharge summary, office records, and radiographic records representing the preoperative, intraoperative, and postoperative periods. Some information was supplemented by personal interviews with operating surgeons and those physicians providing postoperative care. In order for the graft to be included in the study, there needed to be adequate information regarding the outcome of the graft, and sufficient information to determine whether the surgical procedure was successful. Evaluation was performed on the radiographic outcome of the graft in the host area and the donor site, with the exception of the iliac crest graft donor sites, which were evaluated radiographically at the host site only.

The parameters that were recorded included the following: the indication for the procedure requiring the graft, the type of graft (autogenous or allogeneic, and the donor site for autogenous grafts), perioperative antibiotics (flush and/or intravenous), fixation, complications (infection, delayed union or nonunion, and soft-tissue problems), and graft outcome (success or failure); age and gender of the patient, surgeon, date of surgery, and associated medical history were also recorded. Surgeries were performed by multiple surgeons at both institutions. The senior author (K.T.M.) was involved with the majority of Series 1 surgeries as a resident and with the majority of surgeries in Series 3 as an attending physician.

Data Analysis

The resulting proportions (ie, observed frequencies) of bone complications and bone-graft type were summarized. Contingency tables were formed such as the pooled data shown in Table 1. The expected frequencies for each cell are then calculated as follows:

$$(1) \qquad E = \frac{(N_{row})(N_{col})}{(N_{total})}$$

where N_{row}, N_{col}, and N_{total} are the row, column, and frequency totals, respectively. The expected frequencies for the pooled bone complication data are shown in Table 2. To test for the equality of proportions, the chi-square statistic is used.[29, 30] To apply the chi-square statistic, the structure or complexity of the problem, commonly referred to as the degrees of freedom, must be determined. For degrees of freedom (*df*) larger than 1:

$$(2) \quad \chi^2 = \Sigma \frac{(\text{Observed Frequencies} - \text{Expected Frequencies})^2}{\text{Expected Frequencies}}$$

The degrees of freedom are defined as:

$$(3) \quad df = (\text{Number of Rows} - 1)(\text{Number of Columns} - 1)$$

or

$$(4) \quad df = \text{Number of Cells} - 1$$

Note that equation (4) is used when the contingency table has only a single column (or row).

Given the *df* and level of significance ($\alpha = 0.05$), one may obtain the critical value of the chi-square statistic from a chi-square table. If the calculated chi-square value for the data is greater than or equal to the critical value, then the null hypothesis is rejected (ie, there is a significant difference).

Table 1. Pooled Bone Complication Statistics

Complication	Autogenous	Allogeneic	Total
Nonunion	5	9	14
Delayed union	2	8	10
No complications	78	198	276
Total	85	215	300

Results

Indications

Table 3 summarizes the indications for grafts in the aggregate and for each of the series. There were 24 arthrodeses in the PCPM series, and 16 and 15 in each of the Doctors Hospital series. There were fewer calcaneal osteotomies in the PCPM series (35) than in the two Doctors Hospital series (42 and 51). In the aggregate, calcaneal osteotomies represented over 42% of indications, arthrodeses over 18%, nonunions over 9%, and opening wedge osteotomies (mostly Cotton-type cuneiform osteotomies) over 8%.

Graft Materials

Just as the indications for the grafts varied among the three series, so did the material selection. In the aggregate, 72.33% of the grafts were allogeneic bone-bank bone and 27.67% were autogenous bone (Table 4). The allogeneic grafts came from a variety of bone banks. All of the grafts were freeze-dried, with the exception of one fresh-frozen graft. Some grafts, particularly in the later series, were sterilized (ethylene oxide or radiation, depending on the bone bank); most of the grafts were procured sterile without any additional treatment. The PCPM series was 41% autogenous bone; the two Doctors Hospital series were 13% and 29% autogenous bone. The more recent the series, the more autogenous bone that was used, with the exception of the calcaneal osteotomy indication. The PCPM series had 24 calcaneal autogenous grafts (out of 41 autogenous grafts). The remainder of the autogenous grafts came from a variety of sources in the foot, the fibula, the tibia, and the iliac crest (Table 5).

Table 2. Pooled Bone Complication Expected Frequencies

Complication	Autogenous	Allogeneic	Total
Nonunion	[14(85)/300] = 3.97	[14(215)/300] = 10.03	14
Delayed union	[10(85)/300] = 2.83	[10(215)/300] = 7.17	10
No complications	[276(85)/300] = 78.20	[276(215)/300] = 197.80	276
Total	85	215	300

Table 3. Bone-Graft Indications

Indication	Series 1 (N = 100)	Series 2 (N = 100)	Series 3 (N = 100)	Total (N = 300)
Arthrodesis	16	15	24	55 (18.33%)
Nonunion	8	9	11	28 (9.33%)
Calcaneal osteotomy	42	51	35	128 (42.67%)
Cyst	9	3	2	14 (4.67%)
Opening wedge	8	5	12	25 (8.33%)
Metatarsal lengthening	6	3	6	15 (5.00%)
Trauma	5	5	5	15 (5.00%)
Miscellaneous	6	9	5	20 (6.67%)

Table 4. Bone-Graft Materials

Material	Series 1 (N = 100)	Series 2 (N = 100)	Series 3 (N = 100)	Total (N = 300)
Allogeneic bone	87	71	59	217 (72.33%)
Autogenous bone	13	29	41	83 (27.67%)

Table 5. Autogenous Bone Graft Donor Sites

Site	Series 1 (N = 100)	Series 2 (N = 100)	Series 3 (N = 100)
Metatarsal	2	3	1
Fibula	2	4	4
Calcaneus	3	5	24
Navicular	–	1	3
Tibia	4	4	2
Iliac crest	2	9	6
Miscellaneous	–	3	1
Total	13	29	41

Table 6. Perioperative Management

Antibiotic Pattern	Series 1 (N = 100)	Series 2 (N = 100)	Series 3 (N = 100)	Total (N = 300)
Antibiotic flush	76	25	32	133 (44.33%)
Antibiotic prophylaxis	72	92	65	229 (76.33%)

Table 7. Complications

Complication	Series 1 (N = 100)	Series 2 (N = 100)	Series 3 (N = 100)	Total (N = 300)
Delayed union	2	4	4	10 (3.33%)
Nonunion	6	4	4	14 (4.67%)
Infection	0	0	2	2 (0.67%)
Dehiscence	0	0	1	1 (0.33%)

Perioperative Management

The perioperative antibiotic pattern varied. Antibiotic flush was commonly used (76%) in the first Doctors Hospital series, but was used much less frequently in the second Doctors Hospital series (25%) and the PCPM series (32%) (Table 6). Antibiotic prophylaxis was used in over 76% of the cases. The regimen for prophylaxis varied but was usually a first-generation cephalosporin with one dose administered immediately preoperatively and additional doses administered no more than 24 hours postoperatively.

Complications

The complications in the series were mostly related to bone. Bone complications occurred in 8% of the cases (Table 7). Delayed union (using a definition of failure to heal by 5 months) occurred in 3.33% of the cases; nonunion (cessation of healing after 6 months) occurred in 4.67% (Fig. 6). Seventeen of the 24 bone complications occurred with allogeneic grafts. The rates of complications for autogenous and allogeneic bone grafts were comparable to their proportions of the total number of grafts. Autogenous grafts represented 27.67% of the grafts and 29.17% of the bone complications. Allogeneic grafts represented 72.33% of the grafts and 70.83% of the bone complications. There was no statistically significant difference between the complication rates in the two groups. Only one of the allogeneic bone complications occurred with a calcaneal osteotomy (a delayed union that responded to electrical stimulation). There were 128 calcaneal osteotomies (127 allogeneic grafts, 1 auto-

Figure 6. Dorsoplantar radiograph showing nonunion of attempted composite graft (allogeneic rib, autogenous calcaneal cancellous bone) repair of metatarsal collectomy.

genous graft) representing 42.67% of all the grafts, yet only one (0.78%) of those grafts resulted in a complication. Most of the complications occurred with repair of nonunions (37.5% of the bone complications) or arthrodesis (25%). Both of these procedures were disproportionately represented in the complications. Nonunions made up 9.33% of the grafts, but 37.5% of the bone complications. The complication rate among the nonunion repairs was 32.14% (9 of 28). Arthrodeses made up 18.33% of the grafts, but 25% of the bone complications, with a complication rate of 10.91% (6 of 55). The clearest association was between the use of allogeneic bone for arthrodeses and nonunion repair and the occurrence of delayed union or nonunion of the graft. Allogeneic grafts for first metatarsal osteotomy nonunion repair were generally unsuccessful: Four of the six first metatarsal nonunion repairs that failed were with allogeneic bone. Of the two failed autogenous grafts used for nonunion repair of the first metatarsal, one was poorly fixated, and the second was a sliding inlay graft of poor-quality bone that was also inadequately stabilized. Allogeneic grafts used to facilitate fusion in talonavicular, ankle, and other arthrodeses were less successful than autogenous grafts.

Observed bone complications for each of the three 100-patient series are shown in Table 8. The corresponding expected frequencies are depicted in Table 9. Note that the pooled data are summarized in Tables 1 and 2. The observed and expected bone complication rates for each indication for surgery requiring a bone graft are shown in Table 10. Note that the expected complication rate (ie, 8.00%) is the number of observed complications ($n_c = 24$) divided by the total number of pooled cases ($n = 300$) and is used as a theoretical value to test the null hypothesis of no expected difference. As shown in Table 11, there was no statistically significant difference in overall bone complications (ie, nonunion or delayed union) for allogeneic *versus* autogenous grafts for any of the 100-patient series or pooled series of subjects. Hypothesis 1 was therefore accepted. There was a statistically significant difference in bone complication rates across indications for bone-graft surgery (Table 11). Hypothesis 2 was therefore rejected. It was concluded from statistical tables and inference that calcaneal osteotomies were the least risky and nonunion and arthrodesis procedures were the most risky with regard to bone complications.

As shown in Table 7, soft-tissue complications occurred in only 1% of the cases: Infection occurred in 0.67% of the cases and dehiscence occurred in 0.33% of the cases.

Discussion

Allogeneic *versus* Autogenous Bone

The availability of freeze-dried bone-graft material has been a tremendous benefit to foot and ankle surgery. In the late 1970s, allogeneic bone was used at Doctors Hospital for a wide variety of indications. The bone at that time came from the University of Miami bone bank, where it was procured in sterile fashion from selected donors. Bone from the Miami bank made up the majority of the Series 1 grafts. The

Table 8. Bone Complications

Complication	Series 1			Series 2			Series 3		
	Autogenous	Allogeneic	Total	Autogenous	Allogeneic	Total	Autogenous	Allogeneic	Total
Nonunion	3	3	6	1	3	4	1	3	4
Delayed union	0	2	2	1	3	4	1	3	4
No complications	16	76	92	23	69	92	39	53	92
Total	19	81	100	25	75	100	41	59	100

Table 9. Bone Complication Expected Frequencies

Complication	Series 1			Series 2			Series 3		
	Autogenous	Allogeneic	Total	Autogenous	Allogeneic	Total	Autogenous	Allogeneic	Total
Nonunion	1.14	4.86	6	1	3	4	1.64	2.36	4
Delayed union	0.38	1.62	2	1	3	4	1.64	2.36	4
No complications	17.48	74.52	92	23	69	92	37.72	54.28	92
Total	19	81	100	25	75	100	41	59	100

Table 10. Bone Complication Rates for Each Indication of Bone-Graft Surgery				
Indication	Observed		Expected	
	Number	%	Number	%
Nonunion	9/28	32.14	2.24/28	8.00
Arthrodesis	6/55	10.91	4.40/55	8.00
Calcaneal osteotomy	1/128	0.78	10.24/128	8.00
Other indications	8/89	8.99	7.12/89	8.00

Note: The expected complication rate (ie, 8.00%) is the number of observed complications (n_c = 24) divided by the total number of pooled cases (n = 300) and is used as a theoretical value to test the null hypothesis of no expected difference.

Table 11. Chi-Square Statistics (α = 0.05)							
Data Set	Tables	χ^2	*df*	Critical Value χ^2	*P* Value	Statistical Significance	Hypotheses
1	8, 9	4.370	2	5.991	.1125	No	Accept H1
2	8, 9	0.000	2	5.991	1.000	No	Accept H1
3	8, 9	0.920	2	5.991	.8312	No	Accept H1
Pooled	1, 2	0.718	2	5.991	.6983	No	Accept H1
Complication rates	10	80.54	3	7.815	<.0001	Yes	Reject H2

Series 2 grafts consisted mostly of Miami bone and also a few ethylene-oxide sterilized bone grafts from a California bone bank.[31] Series 3 grafts consisted mostly of sterilized bone (primarily radiation-sterilized bone) and bone that was removed sterile and freeze-dried (Miami bone).

This study clearly documents that allogeneic bone performs quite well for calcaneal osteotomies. Calcaneal osteotomies (127 out of 128 were allogeneic) had a very low complication rate (0.78%), and the use of allogeneic bone reduces operating time and the risk of donor-site morbidity.

Autogenous bone is the preferred material for nonunions and arthrodeses. The cells transferred with the graft provide almost all of the new bone activity during the first 8 weeks of graft healing. At 14 weeks, still only 20% of the bone activity is derived from host bone.[32] Gray and Elves[33] have demonstrated that the majority of new cells are provided by the periosteum and endosteum. The calcaneus provides rich corticocancellous bone that can be used in many situations in foot and ankle surgery.[34]

Thoren et al[35] compared talonavicular fusions with defatted cancellous grafts *versus* autogenous grafts. Using a dowel technique, they concluded that talonavicular fusions should be done only with autogenous grafts. Canine studies have demonstrated that autogenous bone is superior to allogeneic bone (frozen, demineralized, bone matrix gelatin) for overall healing.[36, 37]

Burwell[38] has proposed a theory of medullary osteogenesis that requires both an inducing system composed of growth factors present in normal bone and a reacting system of principally marrow cells with osteogenic precursors. This is the current theory used to understand clinical performance of bone grafts and substitutes.

Perioperative Management

Antibiotic flush is no longer used by the senior author (K.T.M.) as part of the intraoperative management of bone grafts. Antibiotic prophylaxis is routinely used by the author for bone-graft surgeries, although it is not entirely clear that this is essential. The use of allogeneic freeze-dried bone constitutes the insertion of an implant, and it may be advisable to use antibiotic prophylaxis in those situations.[39]

Bohr et al[40] have demonstrated that fresh autografts have greater osteogenic potential than autografts exposed to air for an hour or kept in saline for 3 hours. Maximizing the viability of autogenous cells prior to transfer is an important element of early bone-graft activity.

Bone-Graft Substitutes

Bone substitutes were not evaluated in this study. The use of bone substitutes has become increasingly popular, particularly for the packing of defects.

There are three widely distributed products: Collagraft®[1, 41], Pro-osteon®[2, 42], and Grafton®[3]. Pro-osteon is available in 200- and 500-μm pore sizes. The material is hydroxyapatite derived from South Pacific coral and processed through heating to form the final product. The 200-μm pore size corresponds to cortical-bone density, whereas the 500-μm pore size corresponds to cancellous-bone density. The 500-μm pore size is commonly used for packing of defects. Some caution must be exercised when using this material in areas of unprotected stresses. It is unclear to what degree the coral-derived implant biodegrades. This is a particularly important factor in areas that require remodeling to prevent late refracture. Bucholz[42] has suggested that 10-year studies will be necessary to identify the significance of this question. A second issue is the mechanical properties of the material. Bucholz[43] has indicated that the use of internal fixation is necessary to prevent cyclical loading of the graft, stating: "Its use in the absence of internal fixation has been uniformly unfavorable." More work must be done before bone substitutes can play a greater role in foot and ankle surgery.

Recommendations

Allogeneic bone is effective when placed in the proper environment. The calcaneus (as in an Evans calcaneal osteotomy) is a highly orthotopic site and provides a very acceptable host site for allogeneic bone. The vascular supply is rich, and the graft is placed in a stable environment inherent in lengthening procedures. Lengthening creates compression on the graft, which stabilizes the graft-host junctions. The success of a bone graft depends not only on the graft but also on the host bed. An allogeneic graft can be highly successful if the host bed is sufficiently vascular and the graft is placed in a stable environment.

Autogenous bone is the most desirable material for areas of difficult healing. This study demonstrates that nonunions have a higher incidence of complications than calcaneal osteotomies. The analysis of the first metatarsal nonunions showed difficulty with allogeneic grafts in this situation. Nonunions represent failed fracture or osteotomy healing. The use of autogenous bone grafts for this indication is clearly preferred because of their greater healing potential. Creation of a vascular and stable environment is key to the ultimate success of the graft. Success, according to Phemister,[44] depends on asepsis, coaptation, and hemostasis.

®[1] Zimmer, Inc, Warsaw, IN.
®[2] Interpore International, Irvine, CA.
®[3] Osteotech, Inc, NJ.

The future for bone replacement looks promising. New ceramics and other bone substitutes, augmented with human bone morphogenetic protein or iliac crest marrow, may prove to be useful in many bone-graft situations.[45]

Summary

Three hundred bone grafts were reviewed in this study. There was no difference in overall success rates between allogeneic and autogenous bone grafts. Calcaneal osteotomies had the best results, and allogeneic bone was highly effective. Nonunion and arthrodesis repair had a higher incidence of complications than would be expected. These may be indications for autogenous graft repair.

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