CORTICAL STRUT ALLOGRAFTING
IN RECONSTRUCTIVE ORTHOPAEDIC SURGERY

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Abstract

Many approaches are used in the repair of skeletal defects in reconstructive orthopaedic surgery, and bone grafting is involved in virtually every procedure. Autografting remains the gold standard for replacing bone loss. However, the limited amount of bone that can be harvested and the morbidity associated with that procedure are major constraints to the clinical use of autografts. In contrast, bone allografts can be used in any kind of surgery, whether involving minor defects or major bone loss. Cortical strut allografts unite to host bone through callus formation, restoring bone stock and can be used as an onlay biological plate. These struts can be made from hemicylinders of tibia being fixed to host bone by circumferential metallic cables or by screws.

The purpose of this study was to analyze the radiographic outcomes of twelve cryopreserved cortical onlay strut allografts, used in a group of nine patients, for revision hip arthroplasty of the femoral side, to stabilize femoral periprosthetic fractures, to reinforce poor cortical bone and to treat one atrophic femoral nonunion. The average follow-up period was 4.3 years (range, 1.6 to 9 years).

No fractures, nonunions or progressive resorption of the bone allografts were observed. All struts were incorporated to the native femur with minimal resorption, within the first year after surgery. There was no failure of any of the allograft reconstructions.

The results obtained show that cortical onlay strut allografts, either alone or in conjunction with metallic plate or cancellous bone allografts, are a valuable adjunct for reconstructive surgery of the hip and to treat atrophic femoral nonunion.

Keywords: Cortical Strut Allografts; Reconstructive Surgery of the Hip; Radiographic Results.

Introduction

The orthopaedic surgeon can avail himself of a wide spectrum of surgical techniques for the treatment of musculoskeletal diseases. These techniques involve, among others, the use of bone allografts and synthetic bone substitutes. Bone allografts have long been used as a natural substitute to repair skeletal defects. They offer an attractive alternative to bone autograft because their supply is unlimited, they allow structural restoration of the skeleton, and their surfaces support bone formation. Approximately 1 million musculoskeletal allografts were distributed for use in the United States in 2004[1-3].

Different kinds of bone allograft are available to the surgeon, and the clinical applications for each type are dictated by the structure and biochemical properties of the allograft. Cancellous bone allograft and demineralized bone matrix (DBM) are used to fill cavitary defects, facilitate spinal arthrodesis, and repair nonunions. They can also be used as a cancellous autograft extender in these situations. Cortical bone allografts are used for bridging structural defects in long bones, spinal arthrodesis, buttress or strut grafts in limb salvage procedures, revision arthroplasty, and periprosthetic fractures. Advantages include vast supply and selection of bones to fit a specific need, and matching to better serve a given function[2,4,5].

The major concern regarding the use of allograft materials is the possibility of viral disease transmission, including hepatitis C and HIV. However, the risk of disease transmission will be remote if the

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protocols of the quality assurance are followed and the quarantine period is respected[6]. On the other hand, host response to bone allografts is still poorly understood. Experimental works have shown reduced immunogenicity when grafts were deep frozen and a marked decrease when freeze-dried. Clearly, the immune system plays an important role in bone graft incorporation, but the exact nature of this relationship is unknown[7].

Synthetic or engineered bone graft substitutes present the opportunity to provide materials that enhance bone regeneration without concerns of disease transmission or availability. However, these biomaterials are not appropriate for structural reconstruction because they are weak in terms of mechanical resistance. Synthetic graft substitutes consist of an osteoconductive matrix to which osteoinductive proteins and/or osteoprogenitor cells may be added[8].

Cortical strut allografts are diaphyseal segments of bone allograft. They are made from hemicylinders of tibia, femur or humerus or full circumferential segments of fibula[9,10]. In our institution, tibial struts are mainly used for revision arthroplasty of the hip on the femoral side, with the following indications: to restore bone stock for noncircumferential loss of cortical bone, to reinforce the repair of cortical windows, to bypass stress risers, and as a biological plate to stabilize periprosthetic fractures.

The clinical success of bone transplantation depends on many factors, some related to the host and others to the allograft and/or the donor, namely the site of transplantation, the quality of the bone bed from witch most of the revascularization arises, the host bed preparation, the preservation techniques used to store the allograft bone, systemic and local diseases, and mechanical stability of the host-graft interface. These factors are largely reliant on the surgeon and emphasize the importance of the surgical technique. The host bed must be prepared to leave bleeding bone. For optimal incorporation of the allograft, the host bed should either already contain enough pre-osteogenic or osteogenic cells, or must be enriched with a source of these cells, such as autograft or autogenous bone marrow[11,12].

A radiographic study was performed on twelve cryopreserved cortical strut allografts, which were used in reconstructive surgery of the hip and in proximal femoral fractures, with an average follow-up period of 4.3 years.

Materials and Methods

Nine patients were treated with cortical strut allografts: one man and eight women with an average age of sixty-one years at the time of surgery (range 38 to 74 years old). The etiology of the preoperative condition was as follows: periprosthetic proximal femoral fracture (n=4); aseptic loosening of total hip prosthesis – femoral component – (n=3); primary total hip prosthesis in congenital hip dislocation in adult (n=1) and atrophic nonunion of the femur (n=1).
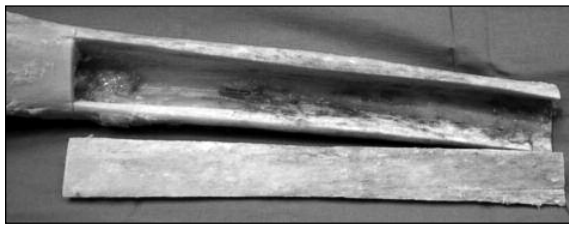
Twelve cortical strut allografts were used to restore femoral bone stock, reinforce the repair of cortical windows, bypass stress risers, and as a biological plate to stabilize bone fractures and femoral osteotomy. X rays were taken at 6 weeks and 3, 6, and 12 months after surgery and yearly thereafter.

Cortical strut allografts of the tibia were processed (debridement, cleaning and treatment in 70% ethanol and 30% hydrogen peroxide solutions), aseptically preserved in liquid nitrogen, and further prepared according to the HUC Tissue Banking protocol (Figure 1) which is in agreement with internationally accepted standards[13,14].

The struts were fashioned to fit the femur. Excessive debridement of soft tissue was avoided to preserve the periosteal circulation, and care was taken to ensure adequate surface area between the graft and the cortical layer of the femur without interposition of soft tissue. The endosteal surface of the allograft strut is contoured to match the outer diameter of the host femur, and the interfaces are augmented with allograft cancellous bone graft. To apply the strut allografts, the vastus lateralis was dissected of the linea aspera of the femur and stripped it from the femur and retracted it anteriorly.

The struts were fixed by metallic cables or by the screws of the metallic plates, and most of them were placed laterally to restore noncircumferential bone loss (Figure 2). The average length of the struts was 125 mm (range, 90 to 180 mm). In five cases metallic plates were used in conjunction with one or two cortical struts. Four patients were treated with cortical onlay strut allografts alone. In the case of the atrophic nonunion, a metallic plate in conjunction with cortical strut and cancellous bone allograft were used. The cortical allograft was fixed to the host femur with the screws of the metallic plate.

Study of serial postoperative radiographs pro-

Figure 1. Preparation of a tibial cortical strut allografting.

Figure 2 a) and b). Surgical treatment of an aseptic loosening of a total prosthesis using a cementless femoral stem revision and a cortical onlay strut allografting (arrows), with 5 years of follow-up. Reconstruction of the acetabulum with a metallic cage and particulate cancellous bone allograft.

duced a cortical strut categorization as follow: (1) round off, (2) scalloping; (3) partial bridging, (4) complete bridging, (5) cancellization, and (6) resorption. A strut could have none, one, or any number of these conditions. This information was analyzed to determine the average time to union, the percentage of struts that had united, and the allograft resorption. Each strut was treated individually, despite some patients having more than one strut. The radiographic criterion of union of strut graft to host bone was defined as trabecular bridging between any part of the graft and the host femur[9,15].

Results

The mean duration of follow-up was 4.3 years (range, 1.6 to 9 years). Union was achieved along the entire length of the cortical struts. All bone allografts were incorporated as demonstrated by radiography. A layer of new appositional bone was observed in the interface graft-host bone, in an average postoperative follow-up period of 8 months (range, 6 to 12 months). No cases of nonunion were noted. A consistent callus formation was observed at 8 months of the postoperative period in the clinical situation of nonunion of the femur. There was no failure of any of the allograft reconstructions.

Progressive resorption of the allografts was not observed. The minor localized resorption was usually seen at the sites of cables but no other resorption could be measured. There was a slight loss of length of strut grafts by the remodeling process at the ends of the allograft. No cases of strut fractures were noted.

In the case of the congenital hip dislocation, a dislocation of the total hip prosthesis and a superficial infection (cellulite) were noted and successfully treated with antibiotics without significant repercussion on the clinical and radiographic results.
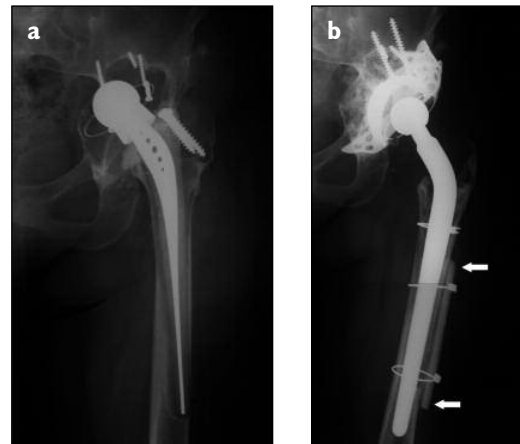
Discussion

The treatment of periprosthetic femoral fractures, aseptic loosening of total hip prostheses, congenital hip dislocation in adults and nonunion of the femur remains challenging. These clinical situations can be effectively treated with metallic implants in conjunction with some forms of bone grafting. Segmental loss of cortical bone from the proximal femur is common in revision surgery. Bone allografting is becoming a common procedure in the orthopaedic operating room. Cortical onlay strut allografts are used as biological bone plate, with or without a metallic plate fixation, and they are an extremely versatile resource for the reconstructive surgery of osteoarticular prostheses replacement and also in orthopaedic trauma surgery. Appropriate placement of the graft is critical[8,16-19].

In our study twelve cryopreserved cortical onlay strut allografts were radiographically analyzed, demonstrating satisfactory mechanical results. In fact, evidence of strut-to-host bridging was seen in all of the patients, and no cases of progressive graft resorption or graft fracture were noted (Figure 3). There was no failure of any of the allograft reconstructions. They were consistently united to bone and restored bone stock. These grafts performed

Figure 3. Incorporation of a cortical onlay strut allografting (arrows), with 8 years of follow-up, used to bridging a femoral structural defect in a revision hip arthroplasty.

better when stabilized with metallic cables in close proximity to vascularized host bone.

Cancellous bone allografts were placed between the ends of the struts and the host bone, because they promote the bone healing process and enhance strut-to-host bone union[17,20,21]. Strut union was seen within the first year after surgery. Studies of retrieved specimens have shown a close correlation between radiographic evidence of union and histologic observations[22]. Gradual callus formation occurs at the junction site, extending from the periosteal surface of the native bone to the outer surface of the cortical bone allograft. There is some degree of creeping substitution at the allograft host junction, but the bulk of the cortical strut remains dead but structurally intact. On the external surface of the allograft, mesenchymal proliferation from the adjacent host cells leads to a thin layer of bone formation that becomes incorporated into the allograft cortex. In fact, the initial host response to the allograft bone strut is rapid mobilization of mesenchymal tissue, initiating intense osteogenesis. The healing process of cortical allograft to host bone is prolonged, following the steps of hematoma formation, inflammatory process, resorption of graft bone and revascularization, and finally replacement of graft with new host bone. Nevertheless, the graft is never entirely replaced with new host bone[4,5].

Processed and preserved bone allografts are favoured in clinical practice. Processing involves the removal of antigenic cells and proteins; preservation techniques include deep-freezing or freeze-drying. Deep frozen cortical struts retain their mechanical properties and may be implanted after thawing, however, freeze-dried cortical struts are vulnerable in torsion and bending, because freeze-drying may alter the mechanical properties of the bone[23-25]. We therefore used struts stored in liquid nitrogen (cryopreserved) in order to achieve immediate structural support.

In the case of treatment of the atrophic nonunion two very important requisites for successful bone formation were achieved: vascularity and mechanical stability. These factors are largely surgeon-dependent and emphasise the importance of the surgical approach and the preparation of the site to be grafted.

Conclusion

Cryopreserved cortical onlay strut allografts act as biological bone plates, serving both a mechanical and a biological function. The results obtained in the present study show that the use of cortical struts, either alone or in conjunction with a metallic plate or with cancellous bone allografts, is a useful adjunct for revision hip arthroplasty of the femoral side, stabilization of femoral periprosthetic fractures, reinforcement of poor cortical bone and for the treatment of femoral nonunion.

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