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Particulated Juvenile Cartilage Allograft Transplantation for the Treatment of Osteochondral Lesions of the Talus

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Osteochondral lesions of the talus present a formidable treatment challenge to the orthopaedic surgeon. Although debridement with either microfracture, drilling, or curettage is often successful in relieving pain and growing fibrocartilage within a standard lesion, the option of implanting particulated juvenile cartilage allograft has become a promising treatment alternative for patients who have failed routine treatment or who have osteochondral lesions that are known to do poorly from the onset. Particulated juvenile cartilage allograft transplantation delivers 1 mm^3 of fresh juvenile cartilage, which contain live cells in their native extracellular matrix, that are secured into the osteochondral defect with the use of a fibrin adhesive. The current evidence, indications, and surgical technique for the use of particulated juvenile cartilage allograft transplantation in the management of osteochondral lesions of the talus have been reviewed.

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Introduction

The term osteochondral lesion of the talus (OLT) refers to any pathology of the talar articular cartilage and corresponding subchondral bone. Kappis[1] initially described this pathology as osteochondritis dissecans, suggesting spontaneous necrosis of bone as the primary etiology. However, contemporary data support trauma as the cause of most OLTs, with repetitive microtrauma, avascular necrosis, and congenital factors as the remaining etiologies.[2]

OLTs present a treatment challenge secondary to the innate inability of cartilage to heal. Ideally, OLTs could intrinsically heal from cell migration from the surrounding cartilage. However, although chondrocytes migrate and proliferate well in vitro, they have limited ability to replicate these actions in vivo. It is thought that in vivo chondrocyte migration is limited because of the rigidity of the extracellular matrix.[3-5] Therefore, modern options to treat OLTs typically employ methods to deliver autologous or allogenic cells. Even marrow stimulation (microfracture) attempts to deliver bone marrow cells by penetrating the subchondral plate. However, the fibrocartilage formed from this procedure has been shown to be biomechanically weaker than native hyaline cartilage.[6] Osteochondral autograft transplantation transfers viable chondrocytes with native extracellular matrix and subchondral bone from either minimal weight-bearing areas of patient's own femoral condyle or even the anterior aspect of the talus into the OLT. However, donor site morbidity, poor interface integration, need for perpendicular access via an osteotomy, and the idiosyncratic 3-dimensional geometry of talar shoulder OLTs limit the application of this technique.[7,8] Techniques such as autologous chondrocyte implantation (ACI) and matrix-induced ACI have been successful in forming hyaline-like cartilage at repair sites,[9] but their widespread use has been limited because of the technical and financial burden of chondrocyte expansion and the need for 2 procedures.[8] Bulk fresh osteochondral allografts have also demonstrated success in treating OLTs,[10] but this treatment option is limited by

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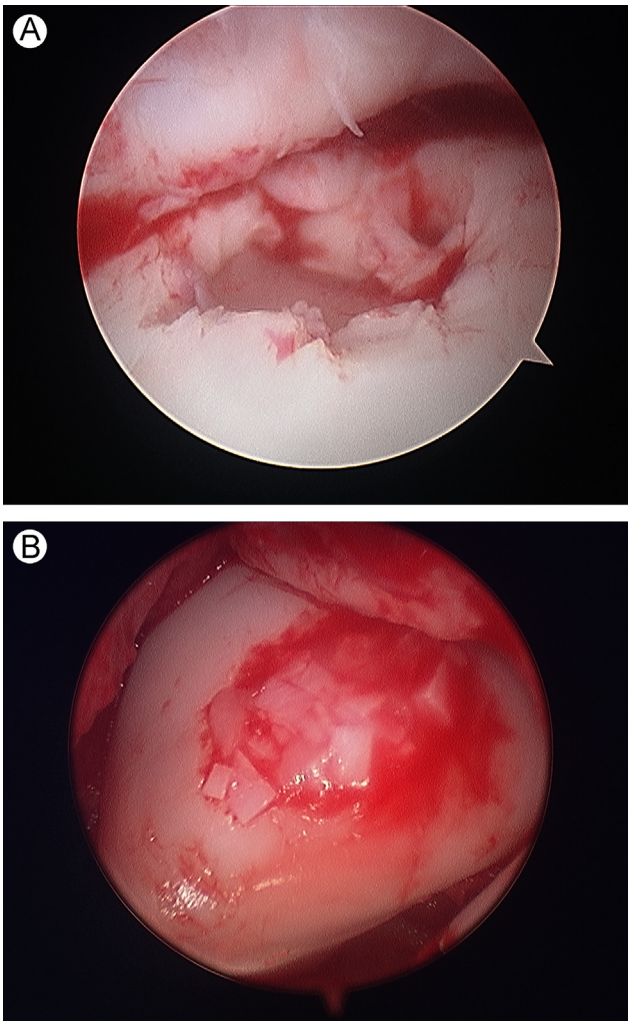

Figure 1 (A) Medial talar shoulder OLT accessed through an anteromedial arthrotomy with plafondplasty. (B) The lesion underwent PJCAT. Notice the mechanically minced pieces in the surrounding fibrin glue. (Color version of figure is available online.)

donor availability, geometric contour discrepancies, and the uncertainty of delivering truly viable chondrocytes after allograft processing and impacting into place.

Particulated juvenile cartilage allograft transplantation (PJCAT) is a new technique of transplantation of multiple fresh juvenile cartilage allograft tissue pieces, containing live cells within their native extracellular matrix, with fibrin adhesive securing the tissue pieces firmly inside the lesion (Fig. 1). This technique is in many ways similar to the osteochondral autograft transfer with the following differences: transplantation of particulated cartilage pieces instead of osteochondral plugs, the use of juvenile cartilage instead of adult cartilage, and graft fixation with fibrin adhesive instead of bony press-fit. Currently, the only graft material available for this procedure is DeNovo NT Natural Tissue Graft (Zimmer, Inc, Warsaw, IN). The cartilage pieces of this product are obtained, in compliance with Good Tissue Practice, from donors ranging in age from newborn to 13 years old; however, it is typically obtained from neomorts younger than 2 years.[11] No stillborn or fetal tissue is used. Standard disease screening is performed on each lot (one lot of tissue comes from a single donor). The first clinical implantation of DeNovo NT Graft was performed in May 2007 for a patella lesion.[12]

The advantages of this technique are that it is a surgically simple procedure without the need for graft press-fitting or contouring (as needed for osteochondral autograft or allograft transplantation), it does not require osteotomy in most cases (as is often needed for osteochondral autograft transfer or allograft transplantation), it is a single-stage procedure, there is no donor site morbidity, and there is a minimal chance for immunologic reaction (cartilage is considered immune privileged). The disadvantages of this technique are the fact that it is a relatively new procedure with limited patient data, there is a limited supply of juvenile donor cartilage, it is a relatively expensive treatment option compared with other techniques, and as with any allograft tissue, disease transmission concerns exist.

Basic Science Evidence

The concept of hyaline cartilage repair using particulate articular cartilage was first proposed in 1983 by Albrecht et al.[13] The authors created full-thickness articular defects down to subchondral bone in adult rabbit patellae. The lesions were treated with nothing, collagen foam, collagen foam plus fibrin glue, autologous mechanically minced cartilage plus fibrin glue, or autologous mechanically minced cartilage plus collagen foam. None of the defects in the groups without minced cartilage demonstrated hyaline cartilage. On the contrary, 61% of the defects treated with minced cartilage demonstrated filling consistent with hyaline cartilage at 16 weeks. The authors reported an increase in the number of implanted chondrocytes and a change in morphology similar to juvenile chondrocytes. They speculated that the transformation of the chondrocytes to this quasi-"juvenile" status was because of the opening of the subchondral vessels, which provided an abundant supply of oxygen and nutrients resembling the physiological state before the end of skeletal maturity. Subsequently, Lu et al[8] demonstrated, in a mouse subcutaneous pouch model, that chondrocytes from minced cartilage pieces were able to outgrow into polyglycolide-polylactide and polyglycolide-polycaprolactone scaffolds. The outgrowth was uniform by 6 weeks and the cells were surrounded by newly deposited extracellular matrix. Interestingly, the authors found an inverse relationship with minced cartilage piece size and efficiency of the outgrowth. In this same study, the authors filled goat trochlear defects with autologous minced cartilage pieces. At 6 months, hyalinelike cartilage with complete integration to the surrounding cartilage and subchondral bone was found. These data indicate that viable chondrocytes found in particulated cartilage grafts can migrate, multiply, and form a new hyalinelike cartilage tissue matrix within the host tissue. Adkisson et al[14] compared the chondrogenic activity of human juvenile and adult chondrocytes. Chondrocytes from juvenile (< 10 years) donors showed significantly greater extracellular matrix synthesis (sulfated glycosaminoglycan; S-GAG) than chondrocytes from mature donors. Moreover, the rate of