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THE EFFECT OF GRAFT SIZING ON OSTEOCHONDRAL TRANSPLANTATION

Takeshi Makino, Hiroyuki Fujioka, Mitsunobu Terukina,

Shinichi Yoshiya, Nobuzo Matsui, Masahiro Kurosaka

Department of Orthopaedic Surgery,

Kobe University Graduate School of Medicine, Kobe, Japan

Corresponding Author: Hiroyuki Fujioka

Address: 7-5-1 Kusunoki-cho, Chuo-ku, Kobe, Japan

Zip code: 650-0017

TEL: 81-78-382-5985 FAX: 81-78-351-6944

e-mail: hfujioka@med.kobe-u.ac.jp

ABSTRACT

Purpose: The goal of this study is to analyze the effect of the graft sizing on the histological property of articular cartilage in autologous osteochondral transplantation.

Type of study: Histological analysis using an animal model.

Materials and Methods: Eighteen skeletally mature female Japanese white rabbits were used in this study and divided into two groups based on the surgical procedure. **Group I:** A cylindrical fragment (7 mm in diameter and 5 mm in depth) was harvested at the femoral condyle using the Osteochondral Autograft Transfer System (Arthrex, Florida, U.S.A.), then precisely returned to the defect from which the fragment was originally harvested. This surgical model supposes that the articular surface geometry of the osteochondral graft exactly match that of the cartilage lesion; however, the osteochondral graft is not the same size as the defect in this model because of the surrounding gap which corresponds to the blade thickness of the chisel used to take the graft. **Group II:** A 1 mm larger osteochondral fragment (8 mm in diameter and 5 mm in depth)

taken from the contralateral femoral condyle was transplanted to the osteochondral defect made as in Group I achieving a tight fit. Specimens were stained with Safranin-O fast green and analyzed microscopically at 4, 12 and 24 weeks after surgery.

Results: In Group I, histological examination revealed an increase in cartilage thickness and cell density during the implantation period. Round and polygonal hypertrophic clusters of chondrocytes with cytoplasmic vacuoles were observed. By contrast, in Group II, thickness of the articular cartilage was almost the same as that of the normal adjacent cartilage with no significant change being observed.

Conclusions: It is suggested that sizing of the implanted osteochondral fragment play an important role in preserving the histological properties of cartilage.

Key words: Cartilage repair, Autologous osteochondral transplantaion, Graft sizing, Histology

INTRODUCTION

Articular cartilage defects associated with traumatic chondral injury, osteochondritis dissecans, and osteonecrosis may be repaired by a number of surgical procedures such as subchondral drilling, abrasion arthroplasty, osteochondral grafts, periosteal or perichondrial grafts, chondrocyte transplantation with collagen gel, and autologous osteochondral transplantation.[1-9]

Autologous osteochondral transplantation system is commercially available to clinics, however, histological findings regarding the implanted cartilage remain controversial.[9-15] Previous reports of both post-transplantation biopsies and animal experiments reveal maintainance of cell viability without significant remodeling on gross and light microscopic examination of the transplanted cartilage.[9-12] It is understood that chondrocytes survive after osteochondral transplantation via diffusion of joint fluid without requiring a blood supply for nutrition.

In contrast, hypercellularity or partial degenerative changes of the transplanted cartilage have also been reported after autologous

osteochondral transplantation.[13,14] In a previous report, we have described histological changes occurring in the implanted cartilage, in the case of an osteochondral graft taken from the femoral condyle and returned to its original site.[15] The surgical model in that study was selected so that the surface geometry of the graft exactly matched the surface of the lesion. However, the osteochondral graft was not the same size as the defect in that model because of the blade thickness of the chisel used to take the graft, resulting in an undersized graft compared to the defect.

We thus hypothesized that graft sizing may effect histological changes in articular cartilage in osteochondral transplantation. The purpose of this study is to analyze the effect of graft sizing on the histological changes of the implanted cartilage.

MATERIALS AND METHODS

The Animal Research Committee of the Kobe University Graduate School of Medicine reviewed the study protocol and approved this investigation. Eighteen skeletally mature female Japanese white rabbits (Kitayama

Labes, Nagano, Japan) with a mean weight of 3.2 kg (range, 2.7 to 4.0 kg) were used in this study. At surgery, general anesthesia was administered using an intravenous pentobarbital sodium solution (30 mg/kg body weight). The rabbits were placed in the supine position and the surgery was performed on the left knee. In each rabbit, the left limb was disinfected, and 5 ml of 1 % lidocaine was injected subcutaneously into the medial parapatellar region, where the incision was to be made. A medial parapatellar approach was used to expose the knee joint. The region of the trochlear of the femoral condyle, which is in contact with the patella when the knee is flexed at 90 degrees, was selected as the site for the osteochondral defect. The rabbits were divided into two groups depending on the mode of surgical procedure for cartilage repair, with each group composing 9 rabbits (Figure 1).

Group I: A full-thickness cylindrical defect (7 mm in diameter and 5 mm in depth) was created using the Osteochondral Autograft Transfer System (Arthrex, Inc., Naples, Florida, U.S.A.). The osteochondral fragment was removed and precisely returned to its original site. This surgical model is

that the surface geometry of the graft exactly matches the surface of the cartilage lesion, however the transplanted graft is undersized compared with the lesion because of the surrounding gap which corresponds to the blade thickness of the chisel used to take the graft.

Group II: A full-thickness cylindrical defect (7 mm in diameter and 5 mm in depth) was grafted with a 1 mm oversized osteochondral donor graft (8 mm in diameter and 5 mm in depth) harvested from the contralateral femoral condyle. In this model the oversized graft is transplanted to the cartilage lesion.

At 4, 12, and 24 weeks postoperatively, three rabbits from each group were euthanized with an intravenous injection of a fatal dose of pentobarbital sodium and the femoral condyle was taken from the knee, then prepared for macroscopic and histologic evaluation.

For the histological study, the specimens were fixed in 10 % neutral buffered formalin for seven days, decalcified with 0.25 M ethylenediaminetetraacetic acid in phosphate buffered saline at pH 7.5, dehydrated in 70, 80, 90 and 100 % alcohol, and embedded in paraffin wax.

Sagittal sections (7 μ m thick) were stained with safranin-O fast green, and examined by light microscopy.

RESULTS

All the rabbits moved freely in their cages by the second postoperative day. No evidence of postoperative infection at the wound site was observed, and all the wounds healed uneventfully.

On macroscopic findings, four weeks after surgery, a gap around the implanted osteochondral fragment was clearly identified in both groups. At 12 and 24 weeks after surgery, the gap around the graft had filled, the boundary line of the graft had become unclear, and the articular surface between the implanted osteochondral fragment and the host cartilage was smooth and continuous in both groups.

In Group I, histological examination at 4 weeks revealed that the transplanted graft had united at the subchondral bone area, however, the osteochondral fragment had sunk and fibrous tissue covered the fragment at the proximal and articular site of the transplanted fragment. The layer

of the grafted cartilage was thicker than that of the normal host cartilage. At high magnification, cell density was higher and chondrocytes with intracellular cytoplasmic vacuoles were observed. These histological changes of increase in cartilage thickness and cell density as well as chondrocytes with intracellular cytoplasmic vacuoles continued to be observed at 8 and 24 weeks after surgery (Figure 2A and 2B).

In Group II, the transplanted graft had united at the subchondral bone area and no sinking of the osteochondral fragment was observed when examined at 4 weeks. Although a cleft around the osteochondral fragment was detected, histological changes in the grafted articular cartilage were not observed throughout the entire postoperative period when compared with the host cartilage. Thickness, cell density, and morphology of the transplanted cartilage appeared to be normal (Figure 2C and 2D).

DISCUSSION

In Group I, cartilage thickness increase and fibrous tissue covered the graft at the proximal site. By contrast, in Group II, no significant change

was observed in the transplanted graft. It is suggested that fibrous tissue have covered the transplanted graft because the transplanted osteochondral fragment sunk at the cartilage defect in Group I.

The remodeling process of the osteochondral graft in autologous osteochondral transplantation has not been well clarified. Since healing and incorporation of the graft are influenced by various factors, results reported have varied depending on the respective biological and biomechanical environments.[9-15]

The repair and regeneration process of nonvascularlized autologous cancellous bone graft is similar to the repair and regeneration process in osteonecrosis of cancellous bone.[16] In this process vascular ingrowth and progenitor mesenchymal cell invades after cell death, an osteoblastic appositional new bone forms onto the dead trabeculae, and remodeling of the trabeculae to mature pattern occurs.[16]

Although long bone fracture typically exhibits endochondral bone formation and membranous bone formation during healing, fractures with rigid compression plating and external fixation heal without a visible

callus by direct haversian remodeling, called primary bone healing.[16] Because the oversized osteochondral graft was transplanted in Group II, increased graft stability may be obtained in Group II compared with Group I. Therefore, the repair process of the transplanted osteochondral fragment in Group II is considered to be different to that of Group I.

Autologous osteochondral transplantation is clinically a useful surgical treatment for articular cartilage lesions of the femoral condyle.[5,8,9] Several autologous osteochondral transplantation systems are commercially available. Most of these systems recommend that a slightly oversized osteochondral fragment should be transplanted to achieve the tight fit of the fragment. The present study suggests that sizing of the implanted osteochondral fragment influences its healing process and plays an important role in preserving the histological properties of cartilage.

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LEGENDS

Figure 1. Surgical procedures. (**A**) Group I: Full-thickness cylindrical defect (7 mm in diameter and 5 mm in depth) was made and the osteochondral fragment was removed and precisely returned to its original site. (**B**) Group II: Osteochondral graft (8 mm in diameter and 5 mm in depth) was taken from the contralateral femoral condyle and transplanted to the defect (7 mm in diameter and 5 mm in depth).

Figure 2. Histological findings of saggital sesction of the femoral condyle at postoperative 24 weeks stained with Safranin-O fast green. (**A**) Group I: The layer of the grafted cartilage was thicker compared with the layer of the normal host cartilage. Arrows indicate the margins of the graft. (original magnification × 30). (**B**) Group I: An increase in the numbers of chondrocytes and intracytoplasmic vacuoles was observed in chondrocytes. (original magnification ×300). (**C**) Group II: Thickness of cartilage, cell density, and morphology of the transplanted cartilage appear similar to the normal host cartilage. Arrows indicate the margins of the graft.

(original magnification ×30). (**D**) Group II: Thickness of cartilage, cell density, and morphology of the transplanted cartilage appear well preserved. (original magnification ×300).

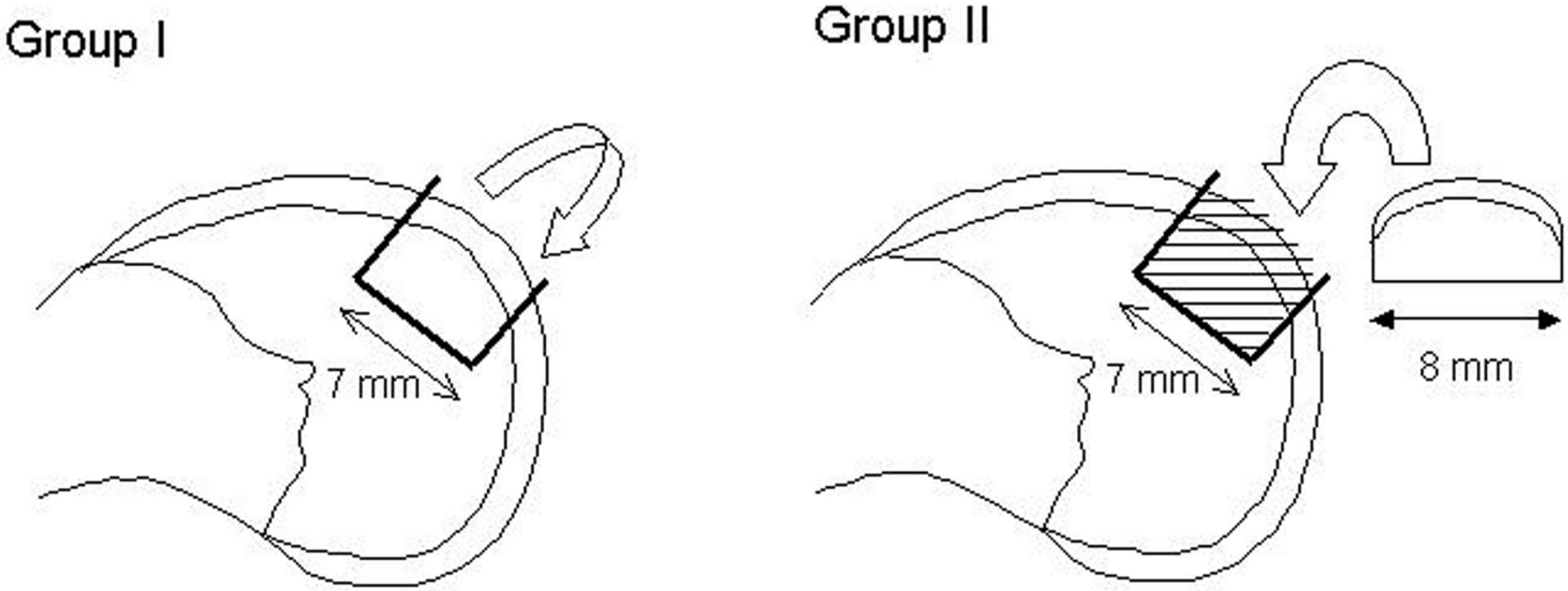

Figure 1

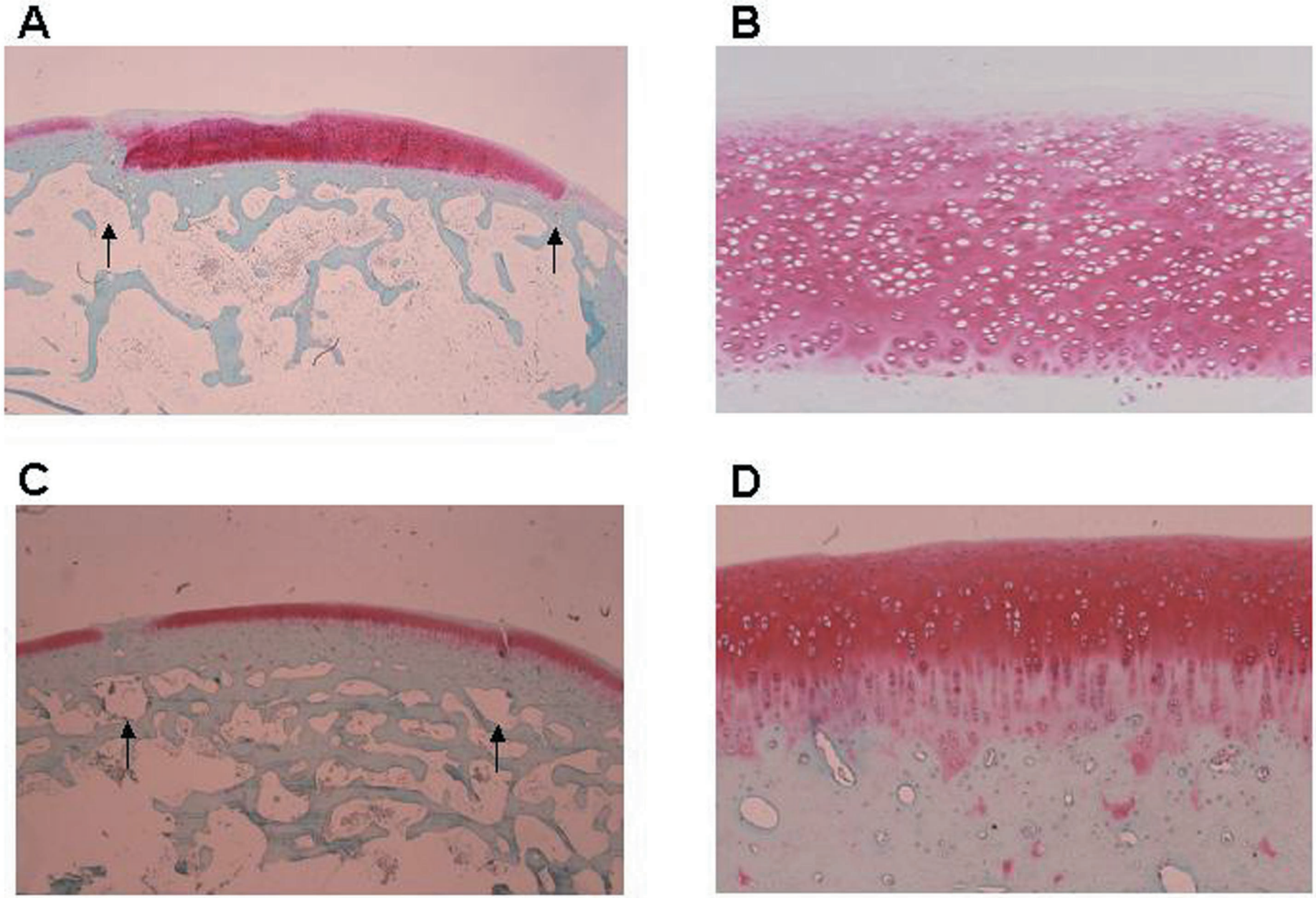

Figure 2