

# SURGICAL TECHNIQUE FOR ARTICULAR CARTILAGE TRANSPLANTATION TO FULL-THICKNESS CARTILAGE DEFECTS IN THE KNEE JOINT

KEVIN R. STONE, MD and ANN WALGENBACH, RNNP

Focal arthritic defects in the knee lead to pain, swelling, and dysfunction. Treatment of the defects has included drilling, abrasion, and grafting. This report describes our surgical technique of autogenous articular cartilage grafting of arthritic and traumatic articular cartilage lesions. Articular cartilage grafting can be performed as a single arthroscopic outpatient procedure. The mixture of articular cartilage and cancellous bone appears to provide a supportive matrix for cartilage formation. Pain relief is excellent if careful surgical technique and a defined rehabilitation program is followed. Further collagen typing data and additional biopsies will reveal more about the durability of the newly formed cartilage.

**KEY WORDS:** articular cartilage transplantation, cartilage, knee

Treatment of articular cartilage defects by autogenous cell cultured grafting, periosteal flaps, microfracturing, and drilling has been evaluated in many previous models.<sup>1-19</sup> Success of the treatments has generally diminished over time because of the development of fibrocartilage at the grafted lesion site and breakdown of the margins between the grafts and the surrounding normal articular cartilage.<sup>20</sup> Our own experience with microfracturing arthritic lesions has frequently led to symptomatic pain relief. However, biopsy of those lesions has yielded fibrocartilage (Figs 1-3). Our experience with chondral drilling has similarly yielded a predominantly fibrocartilage cap at the site of the drilling (Figs 4-6). Recent reports of grafting of articular cartilage cells grown outside the body and placed into articular cartilage defects have reported good gross appearances but without histological or collagen typing evaluations.<sup>4</sup> Johnson verbally reported promising results from cancellous bone grafting of traumatic articular cartilage defects alone (L. Johnson, personal communication, Bay Area Knee Society, San Francisco, CA, May 1992). No investigators have reported successful regeneration of predominantly type II hyaline articular cartilage in the human knee. To treat full thickness cartilage defects, we developed a technique to harvest a mixture of articular cartilage and cancellous bone with the belief that the pluripotential cells found in the cancellous bone combined with the presence of the extracellular matrix found in the articular cartilage and the growth factors found in the associated blood clot would be sufficient to stimulate the regeneration of hyaline-like cartilage if treated with continu-

ous passive motion and non-weight-bearing. Additionally, we had noted that the intercondylar notch regenerated hyaline-like cartilage after notchplasty was performed during anterior cruciate ligament (ACL) surgery. We hypothesized that if the cartilage could regrow in that location, it could possibly regrow if transferred to an articular cartilage defect. The following report describes our technique for performing this procedure.

## MATERIALS AND METHODS

Since 1992, 60 patients have undergone articular cartilage grafting by our technique. The patients ranged in age from 23 to 63 (average age was 42), with 38 men and 22 women. The average time from initial injury to surgery was 8 years. Thirty-five patients had undergone previous surgical procedures to the affected knee including abrasion arthroplasties in 3 instances, microfracture in 5, chondroplasty in 20, and meniscectomy in 20. ACL reconstructions had been performed in 10 patients. Preoperative symptoms varied but usually included pain (average of 2.3 on a point scale of 0-3; 3 being severe), swelling (average of 1 on a scale of 0-3; 3 being severe), giving way (average of 1.1 on a scale of 0-2, with 0 being none, 1 being sensation, 2 being actual), locking (average of 0.5 on a scale of 0-2, with 0 being none, 1 being sensation, 2 being actual), and difficulty with ascending and descending stairs (average of 0.8 on a scale of 0-2, 0 being normal, 1 being with difficulty, 2 being cannot do).

The preoperative radiographs obtained on all patients were a standing anterior-posterior (AP) view, a 45° postero-anterior (PA) flexion view, a skyline view, and a lateral view. These radiographs revealed five patients with bone-on-bone radiographic changes and five others with significant narrowing. Varus alignment was noted in ten patients, two of which were as much as 7° and 12°. Significant valgus was noted in one patient with bone-on-bone lateral joint changes.

---

From The Stone Clinic, San Francisco, CA.

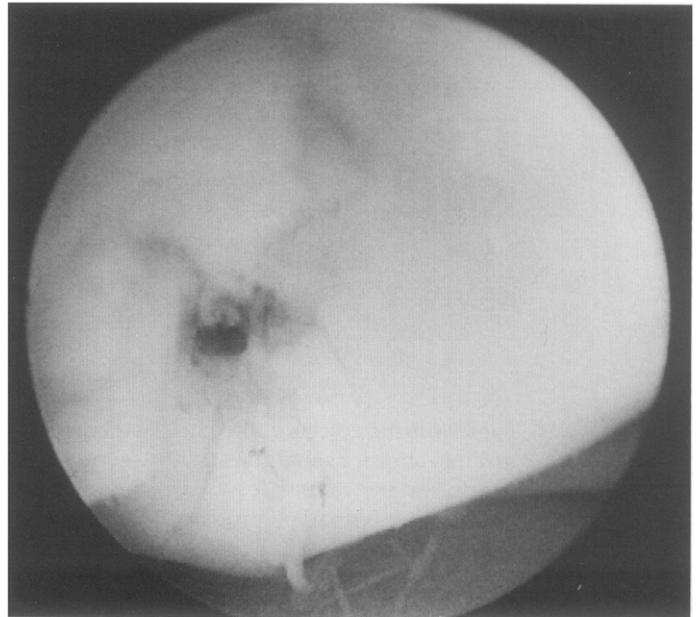
This research is supported by The Stone Foundation for Sports Medicine and Arthritis Research.

Address reprint requests to Kevin R. Stone, MD, The Stone Clinic, 3727 Buchanan St, San Francisco, CA 94123.

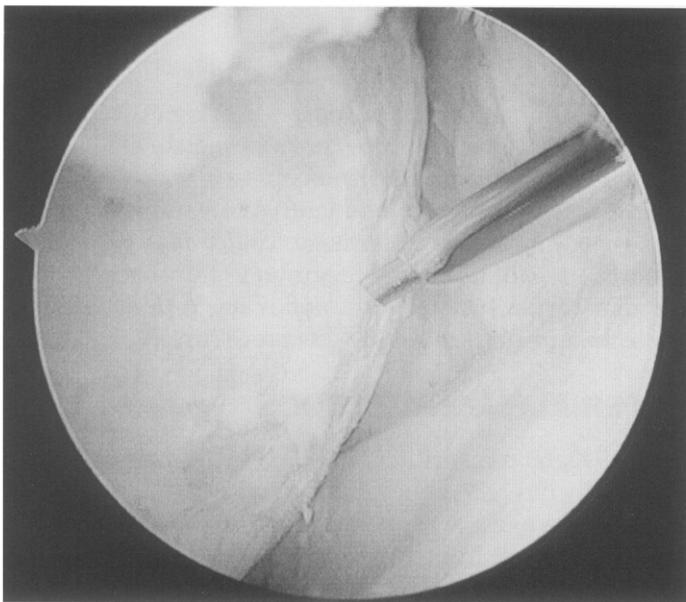
Copyright © 1997 by W.B. Saunders Company  
1048-6666/97/0704-0007\$05.00/0



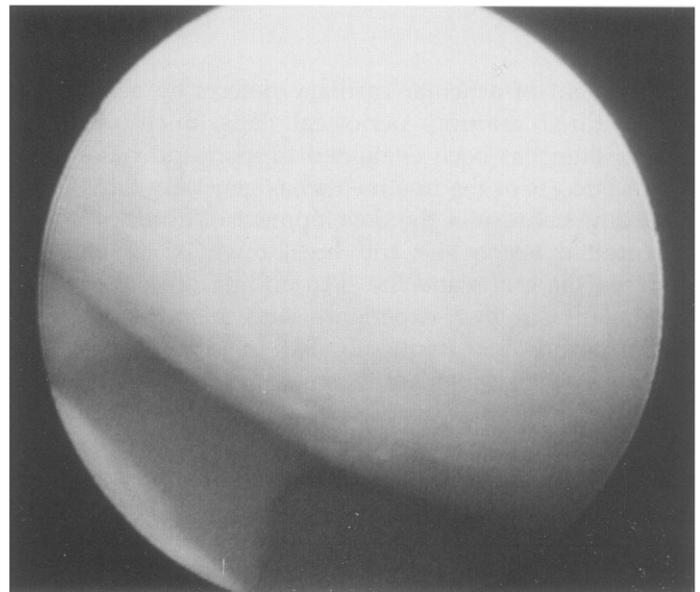
**Fig 1. Eburnated bone medial femoral condyle perforated during microfracture technique.**



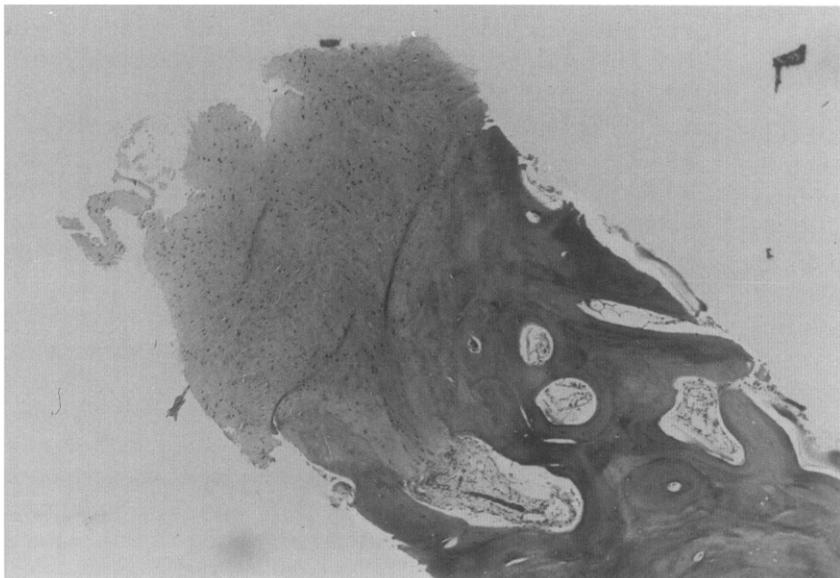
**Fig 4. Chondral lesion medial femoral condyle undergoing drilling with smooth Kirschner wire.**



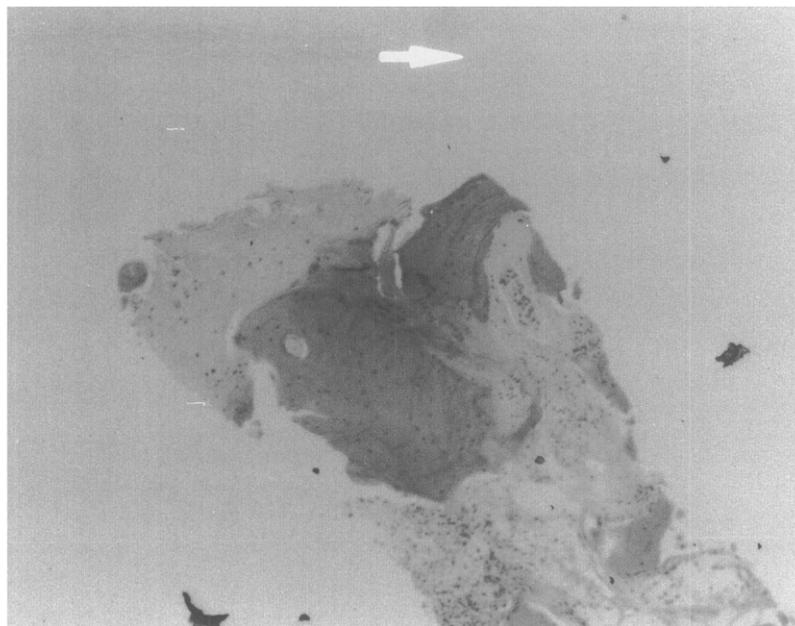
**Fig 2. Fibrocartilaginous caps formed 8 months after microfracture technique on medial femoral condyle.**



**Fig 5. Smooth appearance of medial femoral condyle 5 years after drilling.**



**Fig 3. Histologic appearance of microfractured medial femoral condyle showing fibrocartilaginous response at site of microfracture (Safranin-O staining; original magnification  $\times 10$ ).**



**Fig 6. Histologic appearance of drilled medial femoral condyle 5 years after drilling with smooth Kirschner wire showing fibrous response emanating from drill hole with poor peripheral apposition.**

Forty-five of the 60 patients had preoperative magnetic resonance (MR) images and 40 documented a significant chondral lesion. Seven MR imaging (MRI) reports did not note the lesion that was found at surgery. Meniscal tears were noted in 12 patients (8 medial, 4 lateral), and ACL tears in six patients.

All surgeries were performed at an outpatient surgical center with the patients under local or general anesthesia. The procedure included arthroscopic evaluation of the joint with debridement of impinging scar tissue and repair or resection of torn meniscal cartilages. Ten patients underwent surgical reconstruction of the ACL with the mid third patellar tendon. Three patients underwent an ACL repair by suture anchor fixation. Thirty-eight medial femoral condyles, 17 lateral femoral condyles, 13 trochlear grooves, five medial tibial lesions, two lateral tibial plateaus, and one retro patellar lesion were deemed suitable for autogenous grafting. Of these, eight were bipolar lesions. The average size of the lesions was 213 mm<sup>2</sup> (range, 21-625 mm<sup>2</sup>), the smallest lesion was 3 × 8 mm<sup>2</sup>, and the largest lesion was 25 × 25 mm<sup>2</sup> as measured by a calibrated arthroscopic probe. The criteria for grafting was exposed bone at the site of the patients' worst symptoms or unsuccessful previous chondroplasty treatment.

## **SURGICAL TECHNIQUE**

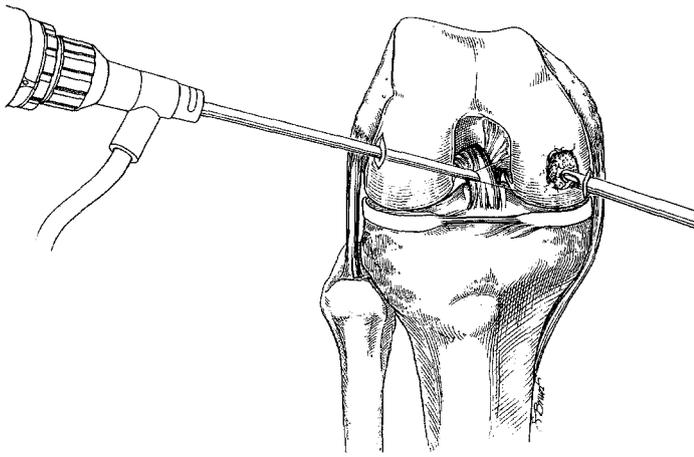
The lesion was cleared of loose or fibrillated articular cartilage by means of a manual biter and an arthroscopic 5 mm full radius shaver (Fig 7). The base of the lesion was microfractured with an arthroscopic pick (Linvatec Inc, Clearwater, FL) until bleeding occurred from the holes (Fig 8). The microfracturing was carried out until the base was entirely morselized. A 4 mm or 9 mm trephine (DePay Orthopaedic Technology Inc, Tracy, CA) was then placed from the anterior medial portal into the intercondylar notch and manually drilled into the margin of the articular cartilage and the underlying cancellous bone at the medial border of lateral femoral condyle. The trephine was impacted to a depth of 1.5 cm. Care was taken to capture articular cartilage in addition to underlying cancellous

bone. The trephined hole was initiated at the leading edge of the intercondylar notch. The trephine was removed and the graft morselized manually. The paste of articular cartilage and cancellous bone was reloaded into the trephine. The trephine was redirected to the prepared chondral defect (Fig 9). The blunt plunger of the trephine was then used to impact the graft into the defect (Fig 10). These steps were performed many times until the defect was filled to the surface. The articular cartilage and underlying cancellous bone formed a paste or grout in the interstices of the microfractured bed. The graft was held in place for 1 to 2 minutes, or until a blood clot formed, and then the instruments were removed. Fifty milliliters of 0.25% marcaine with epinephrine and 1% xylocaine was injected into the joint and the patients went to the postoperative recovery room.

Postoperatively, all patients were kept non-weight-bearing for 4 weeks and used a continuous passive motion machine (Sutter Inc, San Diego, CA) 6 hours each night for 4 weeks, usually sleeping in the machine. During the first 2 weeks all patients were instructed in non-weight-bearing exercises including calf pumps, hip exercises, pool exercises, and well leg bicycling. Those patients who underwent trochlear grafting alone were permitted immediate full weight-bearing in extension in a brace. After 2 weeks, two-legged stationary bicycling was started with low resistance. At 4 weeks, full weight-bearing was started along with knee bends, hamstring exercises, and outdoor bicycling. Nonimpact sports (swimming, cross-country skiing, weight lifting) were permitted for the next 2 months. Impact sports were delayed until after the third month.

## **Second-look Arthroscopy**

Second-look arthroscopy with biopsy was performed in 14 patients with the biopsy technique developed in time for the last 11 patients. The biopsies were obtained by using a 13 gauge Jamshidi needle (Baxter Health Care Corp, Deerfield, IL) passed twice into the center of the lesion. One core



**Fig 7. First step of articular cartilage transplantation demonstrating shaving of articular cartilage lesion.**

was saved in formalin for histologic analysis, one for collagen typing by gel electrophoresis.

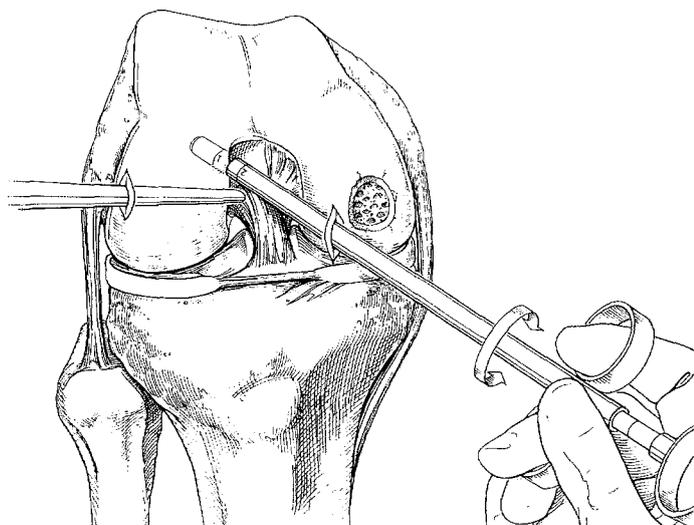
## RESULTS

Gross healing occurred in all lesions examined by second-look arthroscopy (Figs 11-13). The gross appearance of the grafted articular cartilage lesions varied from mildly fibrillated ( $n = 2$ ), moderately fibrillated ( $n = 2$ ), hypertrophic ( $n = 4$ ), to smooth ( $n = 6$ ), and one failed.

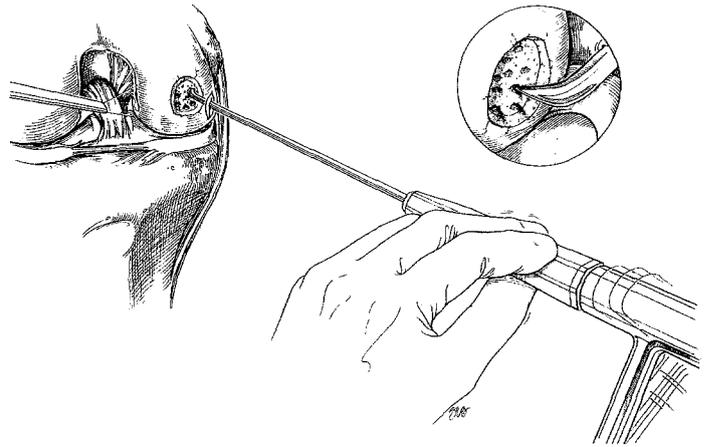
### Clinical Evaluation

The clinical evaluations noted that pain scores improved from 2.5 preoperatively to 1 postoperatively (scale 0-3), swelling scores improved from 1 preoperatively to 0.5 postoperatively (scale 0-3), giving way scores improved from 1.1 preoperatively to 0.1 postoperatively (scale 0-2), locking scores improved from 0.5 preoperatively to 0.1 postoperatively (scale 0-2), and difficulty with stairs scores improved from 0.8 preoperatively to 0.6 postoperatively (scale 0-2).

Preoperative activity levels improved from 3.1 to 2 after surgery graded on a scale of 1 to 4 (1 being strenuous



**Fig 9. Harvesting of articular cartilage with cancellous bone from the intercondylar notch.**



**Fig 8. Microfracture preparation of the base of a chondral lesion before articular cartilage grafting.**

activity, 2 being moderate activity, 3 being light activity, and 4 being sedentary activity).

In the patient who had an unsuccessful graft, her pain decreased from 3 to 1 and her activity level improved from 3 to 1.

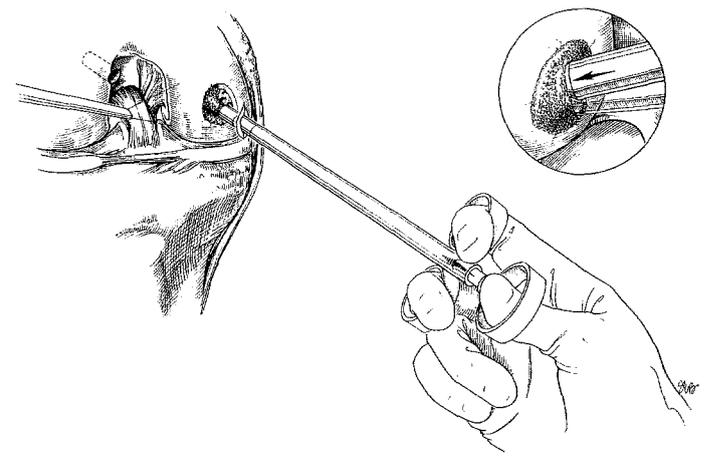
Knee Arthrometer (KT) scores for reconstructed ACL patients improved from average preoperative manual maximum side-to-side difference of 4 to 1.25 mm. KT scores for repaired ACL patients improved from average preoperative manual maximum 4 to 2 mm.

All patients regained their preoperative range of motion in flexion and extension.

The effects of tibia-femoral alignment could not be assessed because of the small numbers of severely malaligned patients. One patient who underwent a opening wedge high tibial osteotomy in association with his articular cartilage graft returned to 20 Km long-distance running at 6 months.

### Histopathological Evaluation

Hyaline-like articular cartilage was seen in four of 10 biopsies that had undergone articular cartilage grafting by the described technique (Figs 14-17). These biopsies show immature hyaline cartilage with mild to moderate chondrocyte cloning (Fig 17). Hyaline and fibrocartilage was seen in five of 11 biopsies available for review. Purely fibrocarti-



**Fig 10. Transplantation of the articular cartilage and cancellous bone graft to the prepared chondral defect.**



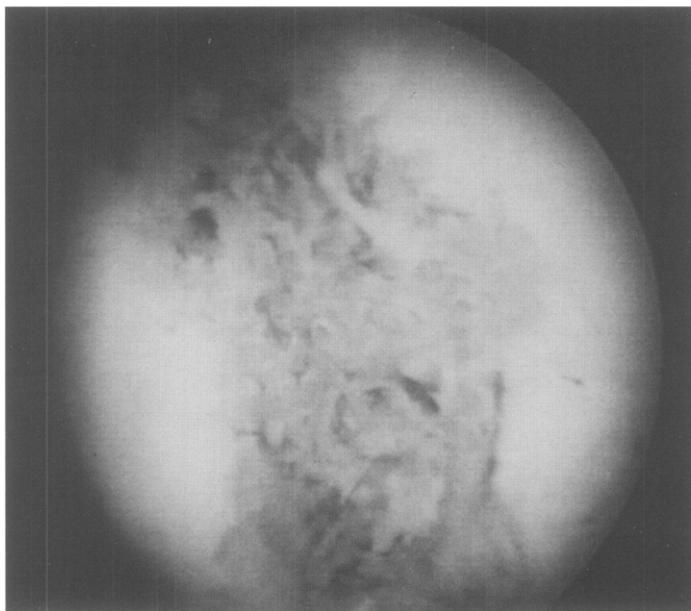
**Fig 11. Severe full-thickness chondral lesion on medial femoral condyle after failed abrasion arthroplasty.**

lage was seen in three of 11 biopsies both from severely arthritic knees with bone-on-bone changes.

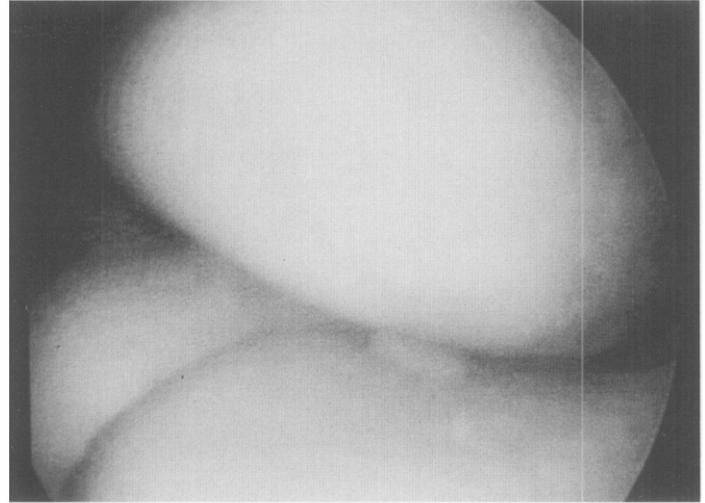
## DISCUSSION

Articular cartilage grafting to full thickness chondral lesions offers the possibility of dramatic pain relief. This report describes a method of delivering articular cartilage matrix, cells, and underlying cancellous bone to these lesions. In the patients evaluated to date, pain relief has been obtained in both those knees that regenerated pure hyaline-like articular cartilage and those with a component of fibrocartilage.

Previous work has documented that articular cartilage lesions left alone fail to heal.<sup>12</sup> Treatment with de-

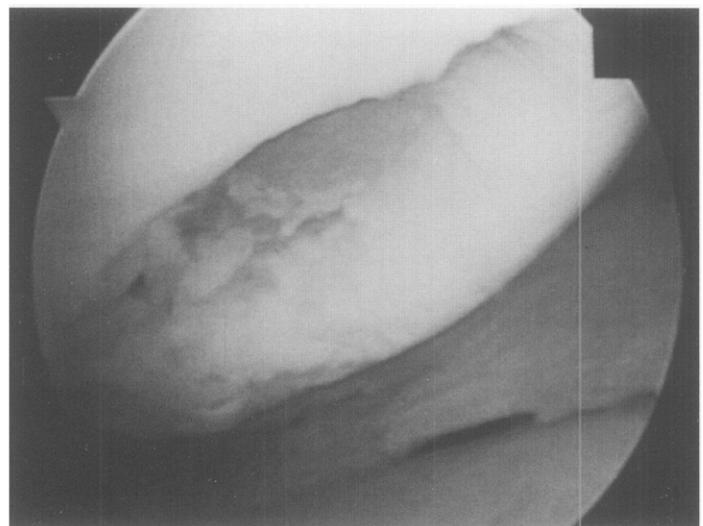


**Fig 12. Articular cartilage grafting of severe femoral condylar lesion.**

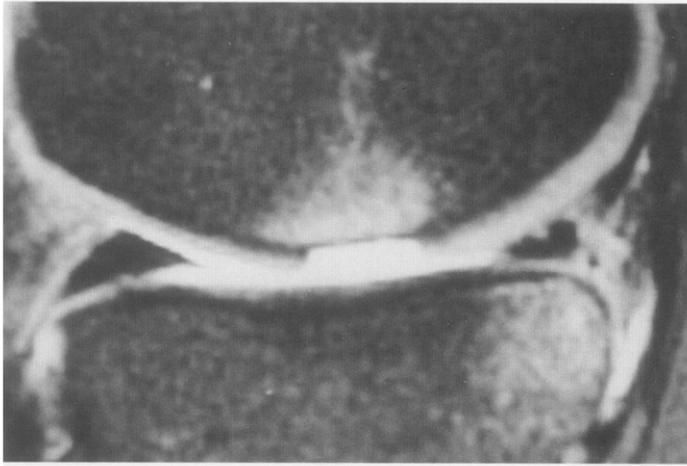


**Fig 13. Appearance at 6 months of medial femoral condyle after articular cartilage grafting.**

bridement, drilling, and microfracturing have produced variable results.<sup>6</sup> Resurfacing efforts by means of perichondrium, periosteum, fascia, carbon fibers, and collagen matrices have produced hyaline-like articular cartilage in various animal studies.<sup>7,9,13</sup> However, long-term studies generally have noted breakdown of the newly formed cartilage caps at the peripheral edges. In general, the interface between new and old cartilage has not fused,<sup>20</sup> leading to poor force transduction and, eventually, tissue degeneration. Mesenchymal cells and growth factors have been added to various matrices again with promising short-term results but limited clinical experience.<sup>10,19</sup> Combinations of articular cartilage cells and perichondrium were reported initially by Grande et al<sup>7</sup> and more recently by Brittberg et al<sup>5</sup> again with variable results. Johnson presented early data of traumatic chondral defects treated with cancellous bone grafting from the tibial tubercle (Bay Area Knee Society, San Francisco, CA, May 1992). The pictures appeared to show cartilage covering of the defects. No formal report has been made, but the technique inspired our work.



**Fig 14. Full-thickness traumatic lesion of medial femoral condyle.**



**Fig 15. MRI appearance of full-thickness medial femoral condyle lesion.**

We speculated that cancellous bone alone would lead to a fibrous matrix similar to what we had observed in lesions that had been microfractured or drilled. We further speculated that the presence of some articular cartilage matrix and cells, even if only a small amount, might provide the necessary signaling to the pluripotential cells found in the cancellous matrix to produce hyaline cartilage and not fibrocartilage. The histology noted in this study appears to partially support that hypothesis. The histologic appearance does not correlate with the amount of pain relief. We are in the process of obtaining both collagen typing and immunohistochemical data to further characterize the regenerated tissue.

## CONCLUSION

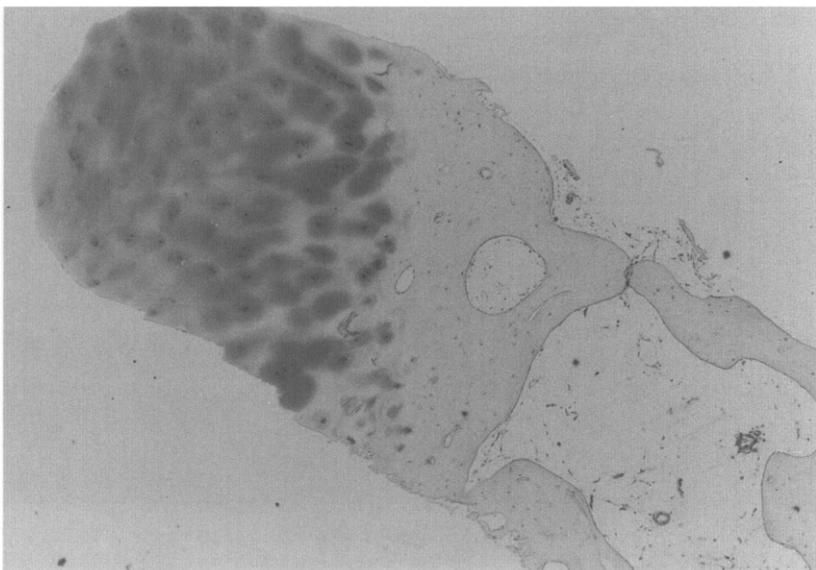
The technique described in this study for harvesting graft material has the benefit that it is relatively easy for anterior femoral condyle, anterior tibial plateau, and trochlear lesions. The technique can be performed under local anesthesia as an inexpensive outpatient procedure. Unfortunately, the technique is difficult for patellar, posterior femoral or posterior tibial lesions.



**Fig 16. Appearance at 7 months of medial femoral condyle lesion after articular cartilage transplantation.**

At this time an insufficient number of biopsies have been obtained, partly because patients whose knees are feeling so much better wish to forget about their commitment to a second-look arthroscopy. Because the biopsy data are limited, and because no biomechanics data are available, we can only speculate about the durability and quality of the regenerated tissue, although we would like to say at this time that because the patients have improved so much symptomatically, the cartilage must be good enough. However, in the one patient who experienced a clearly unsuccessful technique, a patient with bipolar disease and valgus deformity, there also was symptomatic improvement. We therefore caution that conclusions made about any cartilage grafting technique must await both prolonged follow-up and large numbers of second-look arthroscopies with biopsies that include histologic and biochemical evaluations of the tissue.

At this time we believe that this procedure offers pain relief and the possibility of articular cartilage regeneration for patients with painful chondral lesions.



**Fig 17. Histologic appearance of regenerated cartilage 7 months after grafting showing immature hyaline-like appearance with chondrocyte cloning.**

## ACKNOWLEDGMENT

The authors thank Lisa McDevitt and Richard Mitchell for excellent technical support for this paper preparation.

## REFERENCES

1. Aston J, Bentley G: Repair of articular surfaces by allografts of articular and growth-plate cartilage. *J Bone Joint Surg Br* 68:29-35, 1986
2. Bentley G, Greer R: Homotransplantation of isolated epiphyseal and articular cartilage chondrocytes into joint surfaces of rabbits. *Nature* 230:385-388, 1971
3. Bobic V: Arthroscopic osteochondral autograft transplantation in anterior cruciate ligament reconstruction: A preliminary study. *Knee Surg, Sports Traumatol, Arthroscopy* 3:262-264, 1996
4. Brittberg M, Faxen E, Peterson L: Carbon fiber scaffolds in the treatment of early knee osteoarthritis. *Clin Orthop* 307:155-164, 1994
5. Brittberg M, Lindahl A, Nilsson A, et al: Treatment of deep cartilage defects in the knee with autologous chondrocyte transplantation. *New Engl J Med* 331:889-895, 1994
6. Buckwalter J, Lohmander S: Operative treatment of osteoarthritis: Current practice and future development. *J Bone Joint Surg Am* 76:1405-1418, 1994
7. Grande D, Pitman M, Peterson L, et al: The repair of experimentally produced defects in rabbit articular cartilage by autologous chondrocyte transplantation. *J Orthop Res* 7:208-218, 1989
8. Hendrickson D, Nixon A, Grande D, et al: Chondrocyte-fibrin matrix transplant for resurfacing extensive cartilage defects. *J Orthop Res* 12:485-497, 1994
9. Homminga G, Bulstra S, Bouwmeester P, et al: Perichondrial grafting for cartilage lesions of the knee. *J Bone Joint Surg Br* 72:1003-1007, 1990
10. Hunziker E, Rosenberg R: Induction of repair of partial thickness articular cartilage lesions by timed-release of TGF-Beta. *Trans Orthop Res Soc* 19:236, 1994
11. Itay S, Abramovici A, Nevo Z: Use of cultured embryonal chick epiphyseal chondrocytes as grafts for defects in chick articular cartilage. *Clin Orthop* 220:284-303, 1987
12. Mankin H, Buckwalter J: Restoring the osteoarthritic joint. *J Bone Joint Surg Am* 78:1-2, 1996
13. Muckle D, Minns R: Biological response to woven carbon fiber pads in the knee: A clinical and experimental study. *J Bone Joint Surg Br* 72:60-62, 1990
14. Nixon A, Sarm A, Lust G, et al: Temporal matrix synthesis and histologic features of a chondrocyte-laden porous collagen cartilage analogue. *Am J Vet Res* 54:349-356, 1993
15. Noguchi T, Oka M, Fujino M, et al: Repair of osteochondral defects with grafts of cultured chondrocytes: Comparison of allografts and isografts. *Clin Orthop* 302:251-258, 1994
16. Robinson D, Halperin N, Nevo Z: Regenerating hyaline cartilage in articular defects of old chickens using implants of embryonal chick chondrocytes embedded in a new natural delivery substance. *Calcif Tissue Int* 46:246-253, 1990
17. Rodrigo JJ, Sakovich L, Travis C, et al: Osteochondral allografts as compared with autograft in the treatment of knee joint osteochondral defect in dogs. *Clin Orthop* 134:342-349, 1978
18. Seradge H, Kutz J, Kleinert H, et al: Perichondrial resurfacing arthroplasty in the hand. *J Hand Surg* 9:880-886, 1984
19. Wakitani S, Goto T, Pineda S, et al: Mesenchymal cell-based repair of large, full-thickness defects of articular cartilage. *J Bone Joint Surg Am* 76:579-592, 1994
20. Shapiro F, Koide S, Glimcher MJ: Cell origin and differentiation in the repair of full thickness defects of articular cartilage. *J Bone Joint Surg Am* 75:532-553, 1993