Clinical and Radiographic Outcomes After Fixation of Chondral Fragments of the Knee in 6 Adolescents Using Autologous Bone Pegs

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**Background:** Little is known regarding the optimal treatment for displaced, purely chondral fragments in the knee.

**Purpose:** To report the clinical and radiographic outcomes of chondral fragment fixation in adolescents through use of autologous bone pegs.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** This retrospective, single-center study evaluated 6 patients (mean age, 12.9 years) who underwent fixation of chondral fragments (no visualized bone attached) using autologous bone pegs (mean postoperative follow-up, 5.2 years; range, 1.4-10.9 years). The causes were trauma (n = 5) and osteochondritis dissecans (n = 1). Lesions were located in the trochlear groove (lateral, n = 3; medial, n = 2) or posterior part of the lateral femoral condyle (n = 1). The mean lesion size was 3.8 cm² (range, 0.8-9.0 cm²). Patients were evaluated via physical examination and magnetic resonance imaging (MRI) using magnetic resonance observation of cartilage repair tissue scores.

**Results:** In total, 5 patients successfully returned to sports without restrictions at a mean of 7 months (range, 6-8 months) postoperatively. At the latest follow-up, these 5 patients had full range of motion and no joint effusion. The mean magnetic resonance observation of cartilage repair tissue score was 85 (range, 70-95) at a mean duration of 3 years (range, 1-5 years). One patient experienced failure at 1.3 years postoperatively after a traumatic injury and subsequently underwent removal of the fixed fragment and a drilling procedure.

**Conclusion:** In most adolescents, fixation of chondral fragments with no visualized bony portion using autologous bone pegs provided a satisfactory success rate and good healing of cartilage tissue confirmed on MRI scans.

**Keywords:** cartilage; chondral fragment; chondral fracture; fixation; bone peg

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Cartilage injury of the knee joint is difficult to manage because its ability to heal spontaneously is poor. In adolescent patients, cartilage injuries are commonly due to trauma and osteochondritis dissecans. Recommended surgical treatment options for cartilage lesions include repair with fixation of chondral fragments,2,4,10,12,19,20,34 debridement,9 bone marrow stimulation procedures,33 autograft or allograft osteochondral transplant,7,8 and autologous chondrocyte implantation.1,21,22 A rare cartilage injury in adolescents is the delamination of cartilage, which is possibly due to weakness against the shear stress at the junction of the subchondral bone and cartilage.5 When the free body is an osteochondral fragment with an adequate bony portion, it may be replaced and fixed into its original position to restore the native articular contour because adequate bone-to-bone healing is expected.13 However, the optimal treatment for a purely cartilaginous free body with no bony

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portion attached has not been established because of concern that the cartilage fragment will not bond to the bone. For young, active patients, restoring the joint is mandatory given that previous studies have shown that removal of osteochondral fragments results in progression to osteoarthritis in the long term.11,18,28

Although several studies have shown good short-term clinical outcomes after fixation of chondral fragments using metal screws or bioabsorbable screws,2,4,10,12,19,20,34 the best fixation methods are unknown. Because of the possible advantage of biological healing enhanced by autologous tissue, we have used autologous bone pegs to fix chondral fragments and restore native joint congruity. The purpose of our study was to report clinical and radiographic outcomes of fixation of chondral fragments in adolescents through use of autologous bone pegs. We hypothesized that this procedure would provide satisfactory clinical outcomes and good healing of cartilage tissue.

**METHODS**

**Patient Cohort**

This retrospective case series was approved by our institutional review board, and assent from patients and consent from parent or guardian was obtained. Between January 2009 and October 2011, 6 patients aged <18 years were treated using open reduction and internal fixation for chondral detached fragments through use of autologous bone pegs. All 6 patients (6 knees) were included in the analysis. The patients were 2 girls and 4 boys with a mean ± SD age at surgery of 12.9 ± 1.9 years (range, 11.4-16.1 years), and the mean follow-up duration was 5.2 years (range, 1.4-10.9 years). The mean chondral lesion size was 3.8 ± 3.2 cm² (range, 0.8-9 cm²). Causes included traumatic injury (n = 5) and osteochondritis dissecans (n = 1). The chondral lesions were located in the lateral trochlear groove (n = 3), medial trochlear groove (n = 2), and posterior part of the lateral femoral condyle.

**TABLE 1**

| Patient | Age, y; Sex | BMI, kg/m² | Cause/Sport | Time to Surgery, mo | Location of Injury | Insall-Salvati Index, deg | Femoral Sulcus Angle, deg | Chondral Lesion Area, cm² | Bone Pegs |
|---------|-------------|------------|-------------|---------------------|-------------------|---------------------------|---------------------------|--------------------------|-----------|
| 1       | 12; male    | 16.5       | Trauma/basketball | 4.9                  | Lateral trochlea  | 1.3                       | 138                       | 6                        | 4         | 2.5/15    |
| 2       | 16; male    | 17.8       | Osteochondritis dissecans / basketball | 1.1                  | Posterior lateral femoral condyle | —                        | —                        | 0.8                      | 2         | 2.7/15    |
| 3       | 14; male    | 18.0       | Trauma/soccer  | 2.8                  | Lateral trochlea  | 1.2                       | 136                       | 3                        | 5         | 2.5/18    |
| 4       | 11; female  | 15.3       | Trauma/basketball | 0.5                  | Medial trochlea  | 1.4                       | 128                       | 0.8                      | 2         | 2.0/15    |
| 5       | 11; male    | 17.8       | Trauma/basketball | 0.6                  | Lateral trochlea  | 1.1                       | 134                       | 9                        | 4         | 2.1/12    |
| 6       | 11; female  | 15.1       | Trauma/basketball | 0.4                  | Medial trochlea  | 1.3                       | 133                       | 3                        | 3         | 3/17      |

*All patients had open physes. BMI, body mass index. Dash indicates not applicable.

**Figure 1.** Preoperative reconstructed computed tomography (CT) scans (representative patient 3). (A) Front and (B) anterior oblique plane CT views show no bony fragment in the knee joint.
The mean duration of symptoms was 1.7 ± 1.8 months (range, 0.4-4.9 months) (Table 1). In total, 5 patients were injured while playing basketball and 1 while playing soccer. No patients underwent concomitant surgical procedures during the index surgery, and no patients had previous surgery on the index knee. Among the 4 patients who had chondral injuries in the trochlear groove, no patient had patellar instability and all had normal values for the Insall-Salvati index and femoral sulcus angle.

**Patient Evaluation**

Preoperatively, patients were evaluated via physical examination, radiography, computed tomography (CT) (Figure 1), and magnetic resonance imaging (MRI) (Figure 2). Radiographs were taken to identify whether the distal femoral physis was open or closed at the time of the index surgery. For the purpose of this study, chondral fragments were defined as fragments that could not be seen on radiographs and CT images. Moreover, no bony portion attached to the chondral fragments was confirmed intraoperatively.

**Surgical Technique**

An arthroscopic examination was performed, and chondral fragments were gently removed (Figure 3). Autologous bone was harvested from the anterior tibia below the level of the tibial tuberosity to avoid the tibial growth plate, and bone pegs were made by dividing the harvested cortical bone using osteotomes (Figure 4). Depending on the size of the chondral fragments, bone pegs were adjusted to a mean diameter of 2.4 mm (range, 2-3 mm) and mean length of 15.3 mm (range, 12-18 mm). We debrided the damaged femoral articular surface of the lesions and then removed
the fibrous tissue and calcified cartilage while trying not to damage the subchondral bone. After arranging hole sites to be placed, we drilled each hole to the same depth as the prepared bone pegs using a 1.9 or 2.4 mm–diameter drill, inserted the bone pegs, and tapped the bone pegs with a mallet for fixation (Figure 5). We did not countersink the pegs; however, we did not allow protrusion of the bone pegs from the joint surface. Caution was taken not to cross the distal femoral physis if it was still open (Figure 6). Stable fixation was confirmed by probing the area, and the joint was closed in layers.

**Postoperative Course**

Knees were immobilized immediately after surgery. Patients were allowed to start range of motion exercises between 0° and 60° a few days after surgery, with a gradual increase to full range of motion by 4 to 6 weeks. Patients with trochlear lesions were not allowed to bear weight for 1 to 2 weeks. Then, activity progressed to full weightbearing over the next 4 to 6 weeks. For the patient with a femoral condylar lesion, no weightbearing was allowed for 6 weeks. Afterward, there was gradual progression to full weightbearing by 12 weeks. Patients were permitted to return to most activities of daily living after approximately 3 months.

**MRI Evaluation**

All MRI scans were performed on a 1.5-T system (Intera 1.5 T; Philips) with an extremity coil, using a 14- to 16-cm field of view and a slice thickness of 3.5 mm. The repair sites were evaluated using the magnetic resonance observation of cartilage repair tissue (MOCART) score, in which 9 variables were used to describe the features of the repair tissue compared with those of the adjacent native cartilage.14,15 All MRI scans were evaluated via the MOCART scoring system by 2 musculoskeletal radiologists with 8 years (M.F.) and 23 years (C.S.W.) of experience, respectively, in assessing images of cartilage repairs; the radiologists were blinded to the patient characteristics and clinical outcomes. Each radiologist read the cases separately, and differences in assessments were resolved by consensus.

**Clinical Outcome Evaluation**

Patients were evaluated via physical examination for characteristics including the presence of joint effusion, joint line tenderness, and limitation in range of motion. The postoperative Lysholm score and Knee injury and Osteoarthritis Outcome Score (KOOS) are reported if they were recorded.

**Statistical Analysis**

No sample size calculation was performed before conducting this study because this is a rare injury and all patients who met the inclusion criteria were included. The Lysholm score and KOOS subscale scores were calculated for each patient who was available to answer the questionnaires. Means and SDs were calculated for the MOCART scores.

**RESULTS**

**Clinical Outcomes**

In total, 5 of the 6 patients (83%) were successfully treated and returned to the same sports activities without restrictions at a mean of 7 ± 0.8 months (range, 6-8 months) postoperatively. At the final follow-up, none of these patients...
had joint effusion or knee tenderness, and all patients had full range of motion. The postoperative Lysholm score and KOOS from 4 patients (patients 1, 3, 4, and 6) were available at a mean of 5.9 years (Table 2) and showed excellent results, with nearly full scores for both.

We found that 1 patient (patient 5) experienced failure at 1.3 years postoperatively during an accidental fall from standing height. The patient underwent removal of the unhealed chondral fragment and a drilling procedure. The patient subsequently returned to sports activity without any limitations.

MRI Outcomes

In the 5 successfully treated patients with healed chondral fragments, postoperative MRI scans at a mean of 3 years (range, 1-5 years) postoperatively were available for evaluation (Figure 7). The mean MOCART score was 85 ± 10 (range, 70-95) (Table 3). All repair cartilage showed normal signal intensity with a complete cartilage-repair interface. In total, 4 patients had a homogeneous structure with an intact cartilage, 3 patients showed complete defect filling, and 2 patients had minor underfilling; there were no deep cartilage abnormalities. The underlying bone showed abnormalities in all patients with a subchondral lamina that was not intact. We noted that 4 of the 5 patients had subchondral bone abnormalities, including cyst and central osteophyte in 1 patient, sclerosis in 2 patients, and both sclerosis and an edema-like marrow signal in 1 patient. No patient had adhesions or effusions. No fluid lines were seen between the fixed chondral fragment and the underlying bone in these 5 patients.

In the patient who experienced failure, the lesion was located in the lateral trochlear groove (Figure 8A). After successful fixation using bone pegs, cystic lesions in the underlying subchondral bone were seen at 3 months postoperatively, which gradually increased in size and number (Figure 8, B and C). At 1 year, the fixed fragment appeared unstable with a high signal line on the T2-weighted image between the fixed fragment and underlying subchondral bone (Figure 8D). At 1.3 years, the fixed chondral fragment became completely detached after an accidental traumatic injury (Figure 8E). The patient underwent removal of the unhealed chondral fragment followed by a drilling procedure. At 3 years postoperatively, the defect was covered with fibrous tissue after removal, and drilling was performed as a salvage procedure (Figure 8F).

DISCUSSION

Our retrospective case study of 6 adolescents who underwent fixation of purely chondral fragments using autologous bone pegs showed a success rate of 83% over a 5.2-year follow-up. MRI scans showed good structural results of the healed cartilage tissue with a mean MOCART score of 85 in the successfully treated patients. To our knowledge, this is the first study to report outcomes after fixation of chondral-
only fragments using autologous bone pegs in adolescents with objective MRI evaluations.

Several studies of pediatric and adolescent patients after fixation of chondral fragment using bioabsorbable screws have shown promising clinical outcomes over a short-term period, with most of these studies being case reports. To our knowledge, only 1 previous case report of a single patient has reported the use of autologous bone pegs for the fixation of chondral fragments. The report showed successful healing of a chondral fragment to bone in an adolescent, confirmed using MRI at 4 months and second-look arthroscopy at 12 months. Our study expands on these results with a larger sample size, longer follow-up, and MRI evaluation with MOCART score. A recent multicenter study by Fabricant et al reported successful short-term (median of 12 months) outcomes for 15 pediatric patients with chondral fragment repair using various bioabsorbable screws. In their study, the median time to return to sports was 26.0 weeks, and 1 patient required the removal of a failed chondral fragment, similar to the results of our study. In patients in the Fabricant et al study who had postoperative MRI findings, 56% showed a restoration of cartilage contour and the resolution of subchondral edema; however, in our patients, 60% exhibited complete defect filling, and all showed a normal-appearing cartilage interface, homogeneous structure, and normal cartilage signal intensity. It is difficult to directly compare the MRI results of these 2 studies because the timing of evaluation was different (12 months for Fabricant et al vs 3.3 years in our study) and Fabricant et al did not report MOCART scores. Thus, it is unclear whether autologous tissue enhanced cartilage healing, resulting in the good MOCART scores for our cohort.

Even among 5 patients who retained the repaired fragments, all but 1 patient in our study showed subchondral abnormality including cyst, sclerosis, and edema-like signaling. These observations are usually seen after bone marrow stimulation for the treatment of cartilage lesions. Debridement of the cartilage lesion and penetration of subchondral bone for drilling and insertion of the bone pegs at the time of surgery might have resulted in the subchondral bone abnormalities in our study. A longer follow-up will be needed to determine the significance of the subchondral bone abnormality because subchondral bone changes may be associated with the failure of other cartilage repair techniques.

We used autologous bone pegs to fix the chondral fragments to bone because we thought that there may be improvement in the biological healing between cartilage

| Patient | Time to evaluation, y | Lysholm Score | Pain | Symptoms | ADL | Sports/Recreation | QOL |
|---------|----------------------|----------------|------|----------|-----|-------------------|-----|
| 1       | 10.9                 | 100            | 100  | 100      | 100 | 100               | 100 |
| 3       | 1.8                  | 95             | 100  | 100      | 100 | 100               | 94  |
| 4       | 9.2                  | 100            | 100  | 100      | 100 | 100               | 100 |
| 6       | 1.9                  | 100            | 100  | 100      | 100 | 100               | 100 |

KOOS Subscale Scores

aADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, Quality of Life.

Figure 7. Magnetic resonance imaging (MRI) results at 5 years postoperatively (representative patient 3). (A) Sagittal and (B) axial plane MRI scans show good healing of the fixed chondral fragment into the lateral femoral condyle (marked by arrow). The MOCART score was 95. MOCART, magnetic resonance observation of cartilage repair tissue.
tissue and underlying subchondral bone and there would be no need for subsequent screw removal. Moreover, several complications have been reported after the use of bioabsorbable screws.6,29 The disadvantage of using autologous bone pegs is that it can be technically more demanding to produce bone pegs from harvested cortical bone and to insert these pegs because of insertional friction. Moreover, the method introduces potential morbidity of the bone harvest site, although no patient in our study exhibited any symptoms at the harvest site. Thus, further study will be needed to ascertain what method of fixation is optimal for the chondral fragment over a long-term follow-up.

In our cohort, all chondral injuries occurred during sports activities. In the adolescent patient, chondral injury is thought to result from twisting injury during sports activities, which was consistent with our patients’ injuries. Twisting injury may impose shearing stress resulting in fracture between cartilage and subchondral bone. A previous biomechanical study has indicated that the interface between the cartilage and bone is weaker in adolescents than in adults.8

| Patient | Time of MRI After Surgery, y | Degree of Defect Repair and Filling of the Defect | Integration to Border Zone | Surface of the Repair Tissue | Structure of the Repair Tissue | Signal Intensity of the Repair Tissue | Subchondral Lamina | Subchondral Bone Adhesions | Effusion | Total MOCART Score |
|---------|-----------------------------|-----------------------------------------------|---------------------------|-----------------------------|--------------------------------|-------------------------------------|------------------|------------------------|----------|-------------------|
| 1       | 2.2                         | Complete (<50%)                               | Complete                  | Intact                      | Homogeneous                    | Isointense                          | Not intact       | Not intact             | No       | Absent            |
| 2       | 1.0                         | Complete (<50%)                               | Complete                  | Intact                      | Homogeneous                    | Isointense                          | Not intact       | Not intact             | No       | Absent            |
| 3       | 5.0                         | Complete (<50%)                               | Complete                  | Intact                      | Homogeneous                    | Isointense                          | Not intact       | Intact                 | No       | Absent            |
| 4       | 3.9                         | Incomplete (<50%)                             | Complete                  | Damaged (<50%) of the depth | Homogeneous                    | Isointense                          | Not intact       | Not intact             | No       | Absent            |
| 5       | 1.9                         | Incomplete (<50%)                             | Complete                  | Damaged (<50%) of the depth | Homogeneous                    | Isointense                          | Not intact       | Not intact             | No       | Absent            |

*MOCART, magnetic resonance observation of cartilage repair tissue; MRI, magnetic resonance imaging.

Figure 8. Pre- and postoperative magnetic resonance imaging (MRI) results of the patient with a failed chondral fixation (patient 5). (A) Preoperative MRI scan shows cartilage delamination in the lateral trochlear groove with the chondral fragment remaining within the defect. (B) Postoperative MRI scan at 3 months shows small cysts beneath the fixed chondral fragment. (C) Cystlike lesions enlarged at 8 months. (D) MRI scan at 1 year shows a high signal line between the fixed chondral fragment and underlying subchondral bone. (E) At 15 months postoperatively, the repaired chondral fragment had completely detached and displaced. (F) After the subsequent drilling procedure, the defect was covered with repair tissue (3 years after chondral fixation but 1.9 years after drilling).
Although previous studies have suggested that patellar instability causes cartilage delamination in the trochlear groove, no patient had a history of patellar dislocation or instability in our study. However, surgeons should consider the presence of patellar instability when lesions are located in the trochlear groove.

Overall, good clinical outcomes have been reported with a variety of fixation methods possibly because of high chondrocyte viability in the chondral fragment. Robinson et al evaluated chondrocyte viability in osteochondral bodies in adolescents. In microscopic and histologic comparisons, those investigators found no significant difference in viability between the loose body (94%) and intercondylar notch (93%, control) groups. Pascual-Garrido et al evaluated patients with osteochondral fragments who underwent open reduction and internal fixation and noted no difference in chondrocyte viability between biopsies from the loose body and native cartilage. Although no study has assessed the viability of chondral fragment without a bony portion in the knee, a similar observation might be expected. High chondrocyte viability in the chondral fragment might have allowed for the production of extracellular matrix and integration to adjacent native cartilage, which led to the good clinical outcomes and good healing as determined on MRI scans in our study. In our case series, the preoperative duration of symptoms ranged from 0.4 to 4.9 months (mean, 1.7 months). Although several patients did not undergo surgery in the acute phase, the results were promising possibly because chondrocyte viability was maintained by nutrition from the synovial fluid. Robinson et al found no significant difference in chondrocyte viability between biopsies from the loose body and native cartilage. Although previous studies have suggested that patellar instability causes cartilage delamination in the trochlear groove, no patient had a history of patellar dislocation or instability in our study. However, surgeons should consider the presence of patellar instability when lesions are located in the trochlear groove.

In our study, 1 patient experienced failure at 1.3 years after surgery. The fragment size was 9 cm² in the lateral trochlear groove, the largest fragment in this cohort. A number of previous studies have shown that larger chondral lesions resulted in unfavorable outcomes in patients who underwent cartilage repair. The risk factors for failure after this procedure need to be determined by future studies. This patient underwent removal of the unhealed chondral fragment and a subsequently successful drilling procedure that allowed for return to sports without limitations. Thus, attempted direct fixation of purely chondral fragments using autologous bone pegs should be primarily considered because this procedure does not appear to negatively affect any salvage cartilage repair procedure.

The strengths of this study are that all patients with retained fixed fragments underwent postoperative MRI to evaluate the healing of the cartilage fragment and that we present intermediate-term results. Nevertheless, this study has a number of limitations. First, this was a small case study with no control group. However, this injury is rare, making it difficult to include a control group. Second, we were unable to compare preoperative and postoperative patient-reported outcomes, as these data are not obtained consistently in our clinical practice. Third, we did not conduct a histological assessment to ascertain whether there were any bony portions in the chondral fragment. However, the definition of “chondral-only” used in our study is consistent with that used in the previous studies and in common clinical practice.

CONCLUSION

The fixation of chondral fragments in adolescents using autologous bone pegs provided successful results with good quality of repaired tissue as noted on MRI scans. The attempt to restore joint congruity by fixation of chondral fragments should be considered for this type of injury in young and active patients. Further study will be needed to validate our findings and to ascertain whether this technique prevents progression to osteoarthritis.

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