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CASE REPORT

A 10-year follow-up of autogenous osteochondral transplantation combined with medial opening-wedge high tibial osteotomy for large medial femoral condyle chondral delamination: A case report

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ABSTRACT

Chondral delamination, characterized by separation between the articular cartilage and subchondral bone, commonly affects middle-aged adults and can evolve into cartilage defects. Management of extensive chondral delamination presents a significant challenge, particularly in preserving the delaminated yet structurally intact cartilage. Despite its clinical importance, there is no standardized treatment protocol for this condition, and there are few long-term follow-up studies of its surgical management. This case report presents the long-term clinical and radiological outcomes of a novel combined surgical approach for large chondral delamination in a neutrally aligned knee, and discuss the benefits and potential complications of this treatment strategy. In conclusion, autogenous osteochondral transplantation combined with medial opening-wedge high tibial osteotomy shows excellent long-term functional outcomes for large medial femoral condyle chondral delamination.

Keywords: Autogenous osteochondral transplantation, cartilage repair, chondral delamination, high tibial osteotomy, knee surgery, patellofemoral joint.

Chondral delamination is characterized by the separation of articular cartilage from its underlying subchondral bone, frequently observed in the knee, hip, and shoulder joints in middle-aged individuals.[1-3] This condition is attributed to shear forces between the cartilage and subchondral bone, with histological separation typically occurring at the tidemark, a structurally vulnerable interface between the calcified and uncalcified layers of cartilage.[2,4] While recent studies have reported a remarkably high prevalence of chondral delamination in the hip joint, ranging from 31.5 to 86.5% in patients with femoroacetabular impingement syndrome,[1] reports of knee chondral delamination are relatively rare. This difference may be attributed to the distinct biomechanical properties of these joints; the hip joint is particularly susceptible to shear forces during rotational movements due to its ball-and-socket configuration, whereas the knee predominantly experiences compressive forces during weight-bearing activities.[1,3,4] However, when chondral delamination does occur in the

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knee, it poses similar therapeutic challenges as in other joints, requiring prompt diagnosis and appropriate management to prevent progressive cartilage damage.

Since hyaline cartilage lacks neurovascular structures and has limited healing capacity, chondral lesions without an osseous component, including chondral delamination, have little innate regenerative potential once detached from the subchondral bone.[3,5] Untreated chondral delamination carries a risk of enlargement of the lesion and complete detachment from adjacent cartilage, resulting in full-thickness cartilage defects and intra-articular loose bodies. While various surgical procedures have been introduced for chondral defects or osteochondral lesions of the knee,[6,7] few studies have reported regarding the management of chondral delamination.[3,8-10]

In this article, we present a case of large chondral delamination of the medial femoral condyle (MFC) in an adult case which was fixed with autogenous osteochondral transplantation (AOT) used as anchoring pegs, combined with medial opening-wedge high tibial osteotomy (MOWHTO). To the best of our knowledge, this is the first report of this combined procedure for a large chondral delamination of the MFC with a 10-year follow-up.

CASE REPORT

A 40-year-old woman weighing 56 kg and a height of 159 cm with a body mass index of 22 kg/m^2 injured her left knee while landing from a jump during a volleyball game. The patient had a history of repeated blows to the left knee. After the injury, she experienced persistent left knee pain during sports activities (i.e., volleyball, skiing, cycling, and jogging). She worked as a nursery teacher and maintained a Tegner activity level of 6, indicating a high level of physical activity.

She presented to our affiliate hospital approximately one year after the initial injury. Her physical examination revealed effusion without any signs of instability in the left knee. Tenderness was noted at the medial joint space. Pain limited the range of knee flexion to 140°. Plain radiographs showed only mild degenerative changes consistent with Kellgren-Lawrence Grade 1 (Figure 1). A 0.2-Tesla magnetic resonance imaging (MRI) revealed fluid effusion and a large bone marrow lesion in the MFC; however, chondral delamination was not detected (Figure 2). No meniscal or ligamentous lesions were identified.

An arthroscopic examination one week after the initial hospital visit revealed mild synovitis. Probing demonstrated softening and characteristic

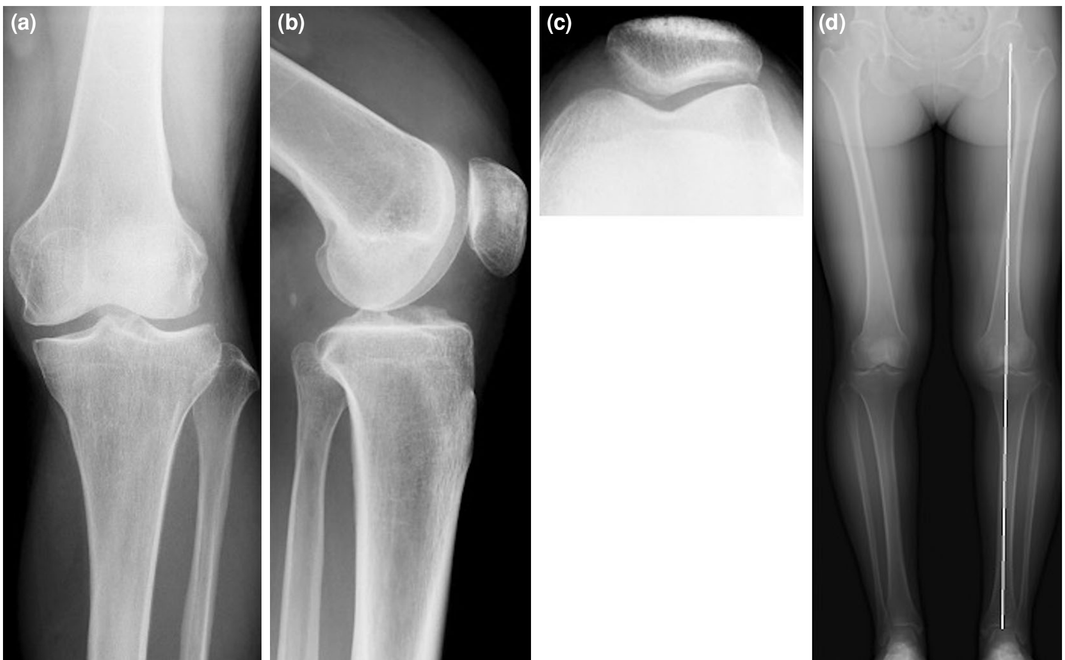

FIGURE 1. (a) Anteroposterior, **(b)** lateral, **(c)** axial, and **(d)** standing full-length radiographs show only mild degenerative changes. The white line represents the mechanical axis.

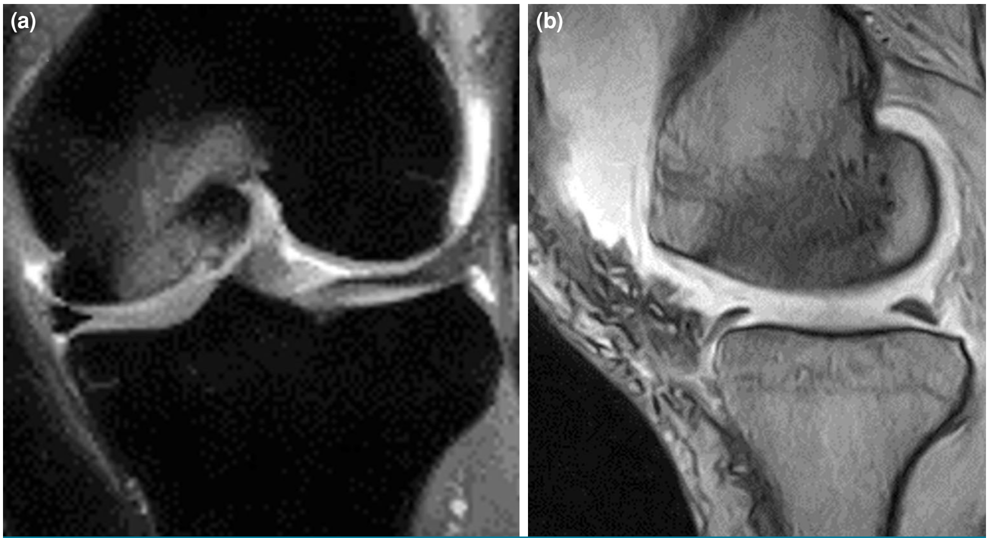

FIGURE 2. (a) Coronal and **(b)** sagittal views of magnetic resonance imaging of the affected knee show fluid effusion and a large bone marrow lesion in the medial femoral condyle. No evidence of chondral delamination is observed.

undulation of the articular surface of the MFC. A focal fissure was identified at the lateral aspect of the MFC, where the cartilage was detached from the underlying subchondral bone, although the delaminated cartilage remained attached to the surrounding normal cartilage at its periphery (Figure 3a-c). This delamination was located primarily on the weight-bearing surface of the mid-portion of the MFC. The anterior portion of the lesion corresponded to the distal portion of the femoral trochlea that contacts the patella during deep flexion. There was International Cartilage Repair Society (ICRS) Classification Grade 2 cartilage damage at the femoral trochlea (Figure 3d). No meniscal or ligamentous injuries were observed. Based on the arthroscopic findings, the patient was diagnosed with Grade 3 chondral delamination with a focal cleavage lesion of the MFC (Figure 3c), according to the classification system proposed by Konan et al.[11]

The patient was subsequently referred to our hospital two weeks after initial arthroscopic examination. Physical examination revealed left-side protective limping, knee joint swelling, and limited range of knee motion (extension –10° to flexion 140°). The assessment for generalized joint hypermobility using the Carter and Wilkinson method revealed no evidence of hypermobility. Radiographs demonstrated neutral alignment of the affected lower limb (Figure 1a, c). Alignment measurements included the hip-knee-ankle (HKA) angle –2.2°; anatomical femorotibial angle (FTA) 177.0°; medial proximal tibial angle (MPTA) 86.3°; mechanical axis of the lower limb 41.5% (percentage of tibial plateau width from the medial edge); posterior tibial slope (PTS) 7.3°; Insall-Salvati (I-S) ratio 0.97; Caton-Deschamps (C-D) index 0.89; and other alignment parameters are presented in Table I. The HKA angle was measured as positive in valgus knees and negative in varus knees. A 3.0-Tesla MRI revealed fluid infiltration between the cartilage and subchondral bone in the MFC, indicating chondral delamination approximately 20×40 mm in size (Figure 4).

For the management of the chondral delamination, we implemented a cartilage preservation strategy utilizing fixation techniques. For this fixation, we employed AOT in an unconventional manner, using the osteochondral plugs as anchoring pegs to fix the delaminated cartilage to the underlying subchondral bone. This approach was combined with subchondral bone drilling to enhance biological healing across the entire interface between the delaminated cartilage and the subchondral bone, and MOWHTO to reduce the mechanical load on the MFC. The amount of correction was determined by aiming for a mechanical axis of 65% and FTA of 170°, in which the mechanical axis crossed the lateral intercondylar eminence of the tibia, requiring an 8° tibial correction.

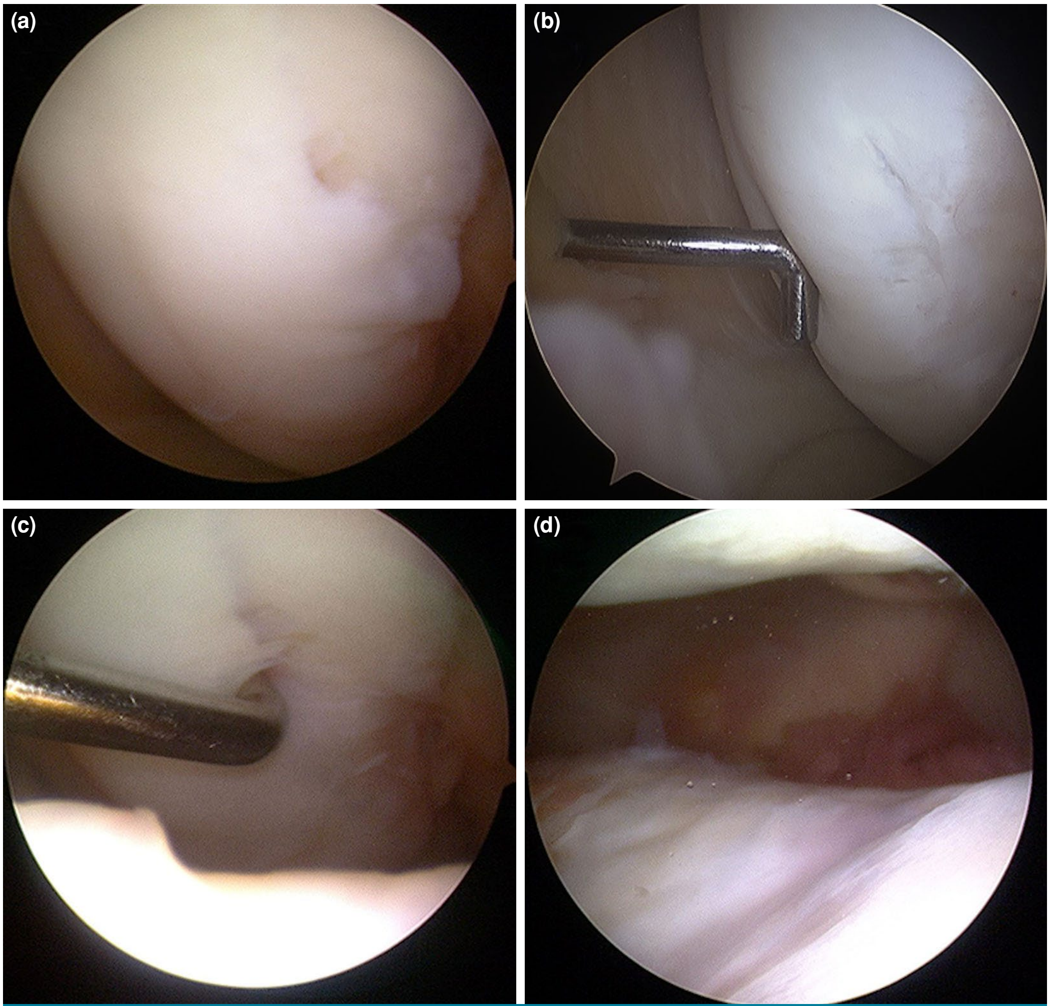

FIGURE 3. (a) Arthroscopic examination shows a large unstable chondral delamination with a focal cleavage lesion in the medial femoral condyle. **(b)** The probe demonstrates softening and wavy delaminated cartilage and **(c)** is introduced through the focal fissure into the space between the delaminated cartilage and subchondral bone. **(d)** An ICRS grade 2 cartilage lesion is observed at the femoral trochlea.
ICRS: International Cartilage Repair Society.

TABLE I
Preoperative and postoperative knee alignments

	Preoperative	Immediately after surgery	5 years after surgery	10 years after surgery
Hip-knee-ankle angle	–2.2°	5.1°	5.9°	5.7°
Femorotibial angle	177.0°	171.0°	170.5°	170.0°
mLDFA	86.7°	86.9°	87.3°	87.1°
Medial proximal tibial angle	86.3°	92.5°	92.7°	92.8°
Mechanical axis	41.5%	72.9%	72.7%	73.2%
JLCA	–1.42°	–2.58°	–2.42°	–2.00°
Posterior tibial slope	7.3°	9.7°	9.8°	10.2°
I-S ratio	0.97	0.76	0.71	0.76
C-D index	0.89	0.67	0.67	0.66
Patellar tilt	9.2°	7.1°	7.4°	6.9°

mLDFA: Mechanical lateral distal femoral angle; JLCA: Joint line convergence angle; I-S: Insall-Salvati; C-D: Caton-Deschamps.

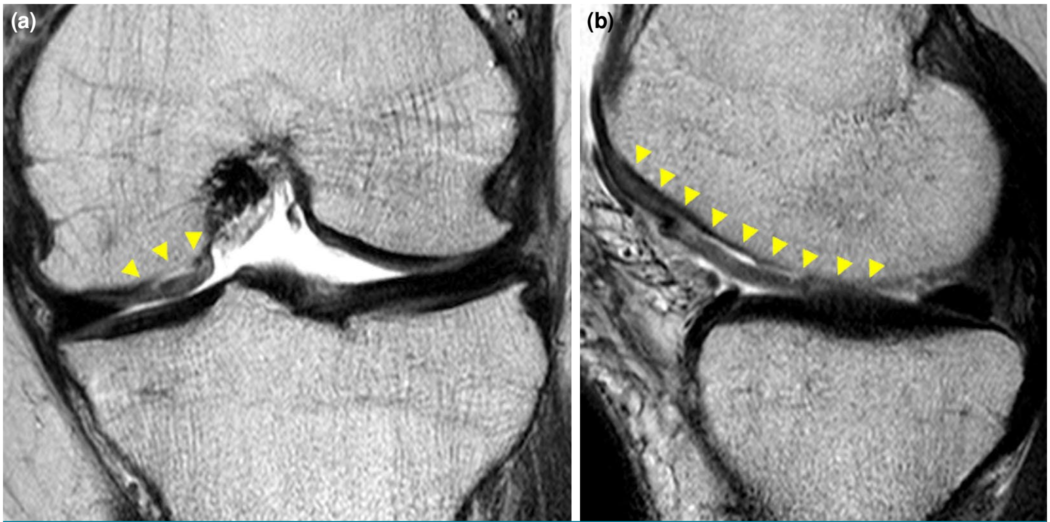

FIGURE 4. (a) Coronal and **(b)** sagittal views of T2-weighted magnetic resonance imaging show a linear hyperintense area between the articular cartilage and subchondral bone at the medial femoral condyle.
Yellow arrows indicate the area of chondral delamination.

Surgical procedure

The patient was positioned supine, and an arthrotomy was conducted via a parapatellar approach over the MFC. The subchondral bone beneath the delaminated cartilage was slightly sclerotic. Initially, bone marrow stimulation was carried out by perforating subchondral bone through delaminated cartilage using a 1.5-mm Kirschner wire (K-wire). Next, three osteochondral autografts were transferred to fix the unstable delaminated cartilage using the 6.0-mm OATS system (Arthrex, Naples, FL, USA) (Figure 5). Donor grafts were harvested from the lateral edge of the femoral trochlea.

The surgical technique for MOWHTO has been described previously.[12] In brief, a 7-cm longitudinal skin incision was made on the medial proximal tibia. The distal attachment of the superficial

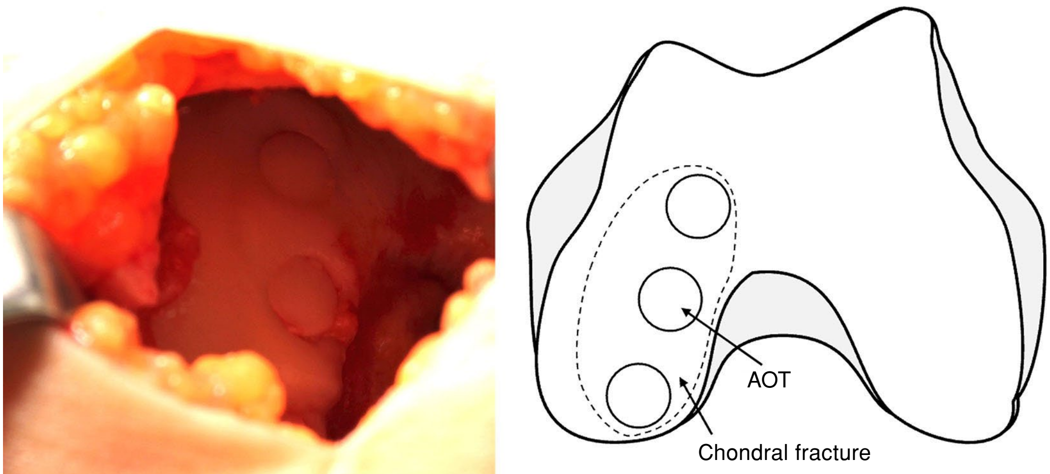

FIGURE 5. (a) Intraoperative photograph and schematic illustration of autogenous osteochondral transplantation for delaminated cartilage fixation. Gross view shows the medial femoral condyle with three cylindrical autogenous osteochondral grafts fixing the delaminated cartilage. **(b)** Schematic illustration demonstrates delaminated chondral fixation with autogenous osteochondral transplantations. The dotted line indicates the delaminated chondral lesion.
AOT: Autogenous osteochondral transplantation.

medial collateral ligament was released completely. Using a parallel guide system, three pairs of guidewires were placed from the medial tibia, starting 40 mm below the joint line and directed toward the proximal tibiofibular joint. Following the biplanar ascending osteotomy of the tibial tubercle, the osteotomy site was opened gradually with a spreader (Olympus Terumo Biomaterials, Tokyo, Japan) according to the preoperative plan. The osteotomy gap was filled with two wedge-shaped β-tricalcium phosphate spacers (Osferion 60, Olympus Terumo Biomaterials). The osteotomy was secured with a locking plate system (TomoFix, DePuy Synthes, West Chester, PA) (Figure 6).

Postoperative course

After surgery, the knee was corrected to valgus and postoperative HKA angle, FTA, MPTA, and mechanical axis were 5.1°, 171.0°, 92.5°, and 72.9%, respectively (Table I, Figure 6). The mechanical axis exceeded our target of 65%, indicating unintentional overcorrection. Regarding the parameters influencing the patellofemoral (PF) joint, the PTS, I-S ratio, and C-D index were 9.7°, 0.76, and 0.67, respectively (Table I).

After two weeks of knee joint immobilization, continuous passive motion exercise was initiated. Partial weight-bearing was permitted at Week 4, with progression to full weight-bearing at Week 6. The patient gradually regained knee mobility, achieving full range of motion by six months postoperatively. Meanwhile, sports activities were allowed, and she was able to resume her regular activities. The patient returned to her previous job as a nursery teacher without any knee problem.

The second-look arthroscopy was performed concurrently with the clinically indicated plate removal at one year after surgery, as Japanese

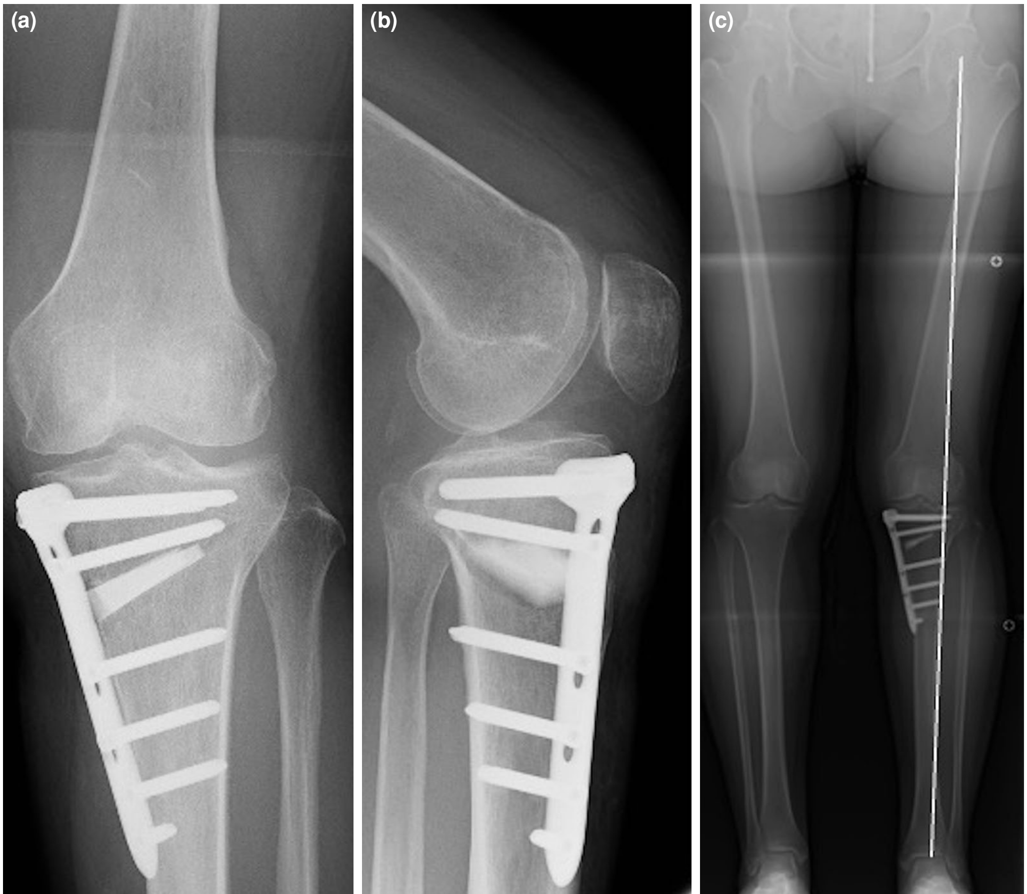

FIGURE 6. (a) Plain radiographs of anteroposterior, **(b)** lateral, and **(c)** standing full-length views immediately after chondral fixation and medial opening high tibial osteotomy demonstrate the knee corrected to valgus position, with patella baja and increased posterior tibial slope observed.
The white line represents the mechanical axis.

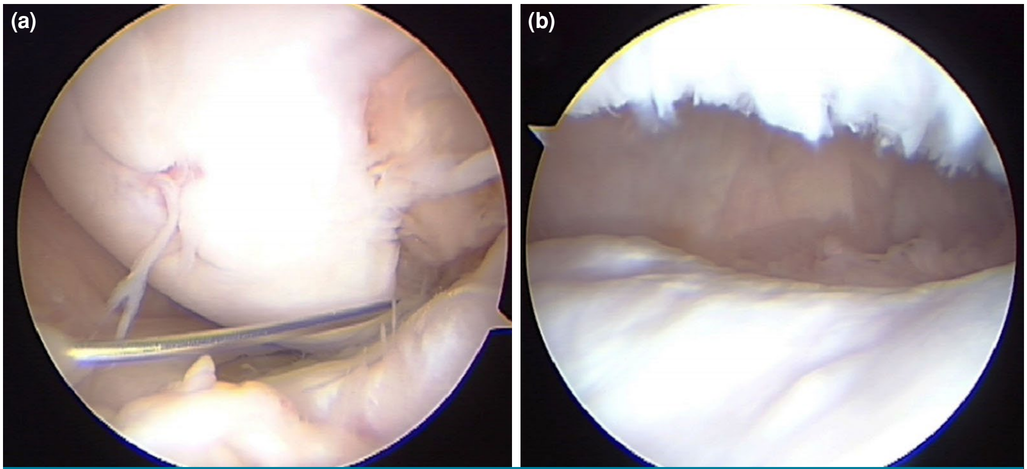

FIGURE 7. (a) Second-look arthroscopy at postoperative one year reveals well-fixed cartilage at the location of chondral delamination. **(b)** Evidence of exacerbated cartilage degeneration is observed in the patellofemoral joint.

patients desire to remove the metal materials after surgery due to religious reasons and cultural factors, which include sitting on tatami flooring. At the site of previous delamination and AOT fixation, the arthroscopic examination revealed mild cartilage surface fibrillation, although the repaired cartilage demonstrated native articular cartilage-like hardness and remained well-fixed to the underlying bone with no signs of recurrent delamination (Figure 7). In addition, the fibrillation of the patellar cartilage and longitudinal fissures were observed in the central portion of the femoral trochlea, graded as cartilage injury of ICRS Grade 3, which was indicative of advanced PF joint osteoarthritis. In addition, T2-weighted MRI at postoperative 24 months confirmed integration of the delaminated cartilage into the surrounding articular cartilage and subchondral bone (Figure 8).

At two years after surgery, the functional knee score (Japanese Orthopaedic Association score) and Lysholm score improved from 45 to 90 points, and 54 to 94 points, respectively (Table II). Knee Injury and Osteoarthritis Outcome Score (KOOS) improved throughout postoperative two years (Table II).

At five-year follow-up, the patient had no extension and flexion contractures and could sit comfortably in the Japanese style seiza, with improved clinical scores (Table II, Figure 9). Plain radiographs showed stable correction without progression of osteoarthritis in the lateral compartment, although degenerative changes in the PF joint advanced.

At 10-year follow-up, the patient maintained full knee mobility and a preinjury level of sports

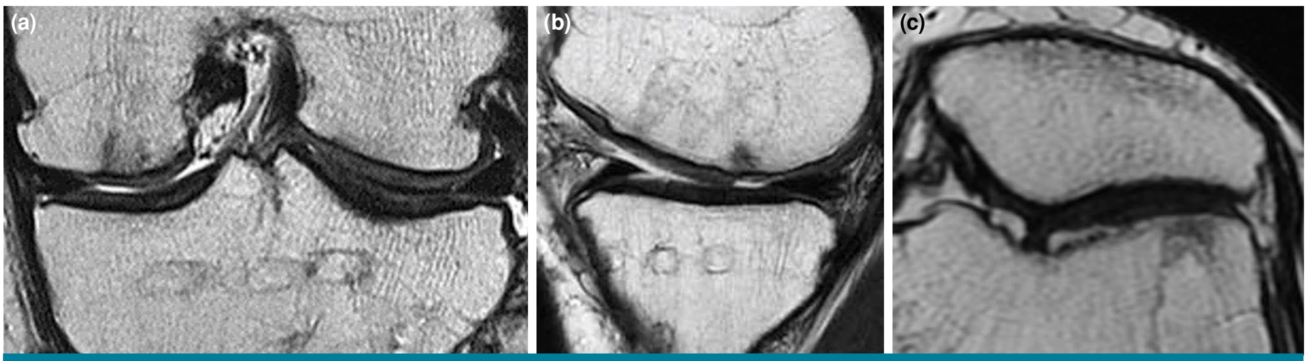

FIGURE 8. Magnetic resonance imaging of the lesion of cartilage delamination at 24 months. **(a)** Coronal, **(b)** sagittal, and **(c)** axial views demonstrate integration of the delaminated cartilage into the surrounding articular cartilage and subchondral bone.

TABLE II
Preoperative and postoperative clinical outcome

	Preoperative	2 years after surgery	5 years after surgery	10 years after surgery
JOA score, points	45	90	100	100
Lysholm score, points	54	94	99	100
KOOS symptoms	36.0	86.0	100	94.4
Pain	58.0	100	100	92.8
ADL	56.0	97.0	98.5	98.0
Sports/Rec	5.0	60.0	70.0	85.0
Quality of life	13.0	94.0	93.8	87.5

JOA: Japanese Orthopaedic Association; KOOS: Knee injury and Osteoarthritis Outcome Score; ADL: Activities of Daily Living; Sports/Rec: Sports and Recreation.

FIGURE 9. Postoperative photograph shows the patient sitting in the Japanese style (seiza) position comfortable at 5 years postoperatively.

activities (Tegner activity score: level 6) such as running, cycling, and skiing. Both the JOA and Lysholm scores reached 100 points, and the KOOS remained high (Table II). Plain radiographs revealed no loss of correction. However, the radiological stage of knee osteoarthritis progressed from Grade 1 to Grade 2 in the femorotibial joint according to the Kellgren-Lawrence grading system, and significant progression of osteoarthritic changes was observed in the PF joint (Figure 10). An MRI obtained at the 10-year follow-up detected thinning of the cartilage at the lesion site and PF joint, while the lateral femorotibial compartment

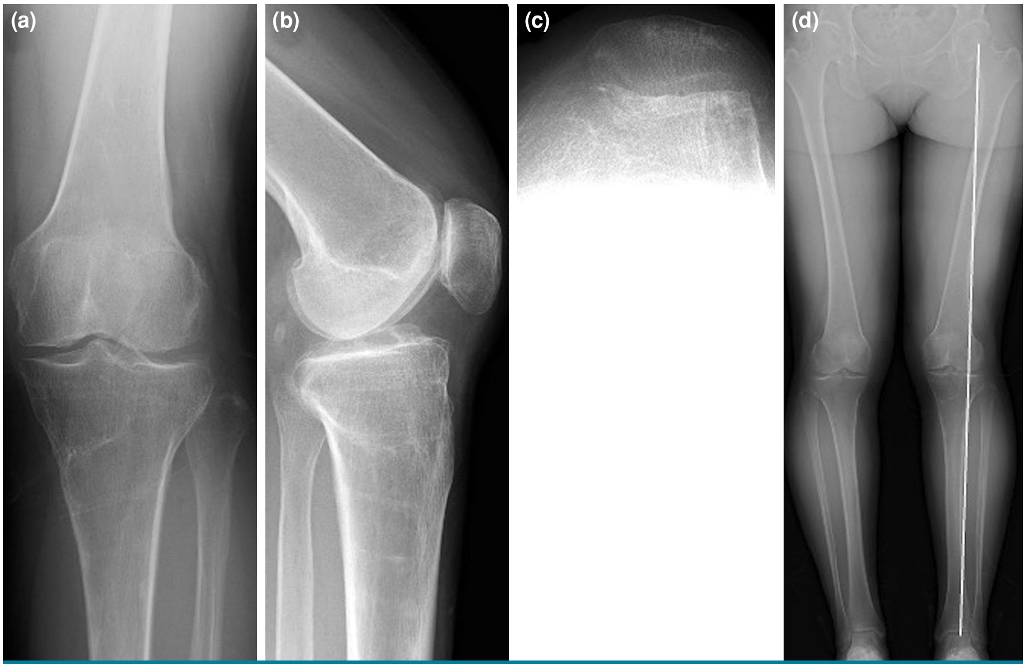

FIGURE 10. Plain radiographs of **(a)** anteroposterior, **(b)** lateral, **(c)** axial, and **(d)** standing full-length images at 10 years after chondral fixation and medial opening high tibial osteotomy demonstrate progression of femorotibial and patellofemoral osteoarthritis. The white line represents the mechanical axis.

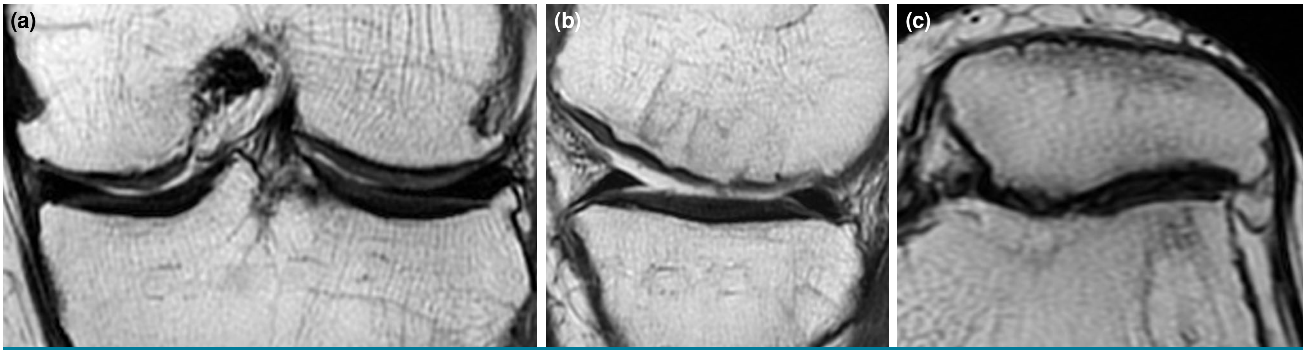

FIGURE 11. Magnetic resonance imaging of the lesion of cartilage delamination at 10 years postoperatively. **(a)** Coronal, **(b)** sagittal, and **(c)** axial views demonstrate cartilage thinning at the lesion site and patellofemoral joint.

maintained normal cartilage thickness (Figure 11). A written informed consent was obtained from the patient.

DISCUSSION

This case report describes the 10-year outcomes of large chondral delamination of the MFC managed with AOT fixation combined with MOWHTO. The surgical approach provided significant clinical improvements, including pain relief, functional recovery, and stable cartilage integration. Despite favorable outcomes, the development of patella baja and advanced PF osteoarthritis was likely attributable to MOWHTO.

Chondral delamination occurs at the cartilage-bone interface due to various mechanical factors. Mechanisms contributing to chondral delamination include shear forces, direct trauma, and repetitive loading.[2,3] In this case, the mechanism of chondral delamination was likely related to her volleyball activities, particularly the significant shear forces during jumping and landing maneuvers. Biomechanical studies have shown that these movements generate considerable anteroposterior and vertical ground reaction forces at the knee joint.[13] Furthermore, her occupation as a nursery teacher involved repetitive knee loading, which may have contributed to the development of the lesion. The combination of these multiple mechanical stresses likely played a crucial role in the development of chondral delamination in this case, emphasizing the importance of detailed activity history in diagnosis, particularly when initial imaging studies are inconclusive.

High-resolution MRI has been recognized as a valuable tool for diagnosing chondral delamination, capable of detecting fluid signals at the cartilage-subchondral bone interface.[2,10,14] In this case, while initial low-resolution MRI failed to detect the lesion, subsequent high-resolution imaging demonstrated the delamination. However, the diagnostic sensitivity of MRI remains limited, even with high-resolution techniques.[2,10,14] Therefore, when chondral delamination is suspected based on clinical history and injury mechanisms, diagnostic arthroscopy should be considered. Direct arthroscopic visualization and probing enable detailed assessment of cartilage abnormalities that may not be apparent on imaging studies. Early detection and appropriate characterization of these lesions are crucial for determining optimal treatment strategies and preventing progression to full-thickness cartilage defects.

On the other hand, untreated delaminated cartilage is at risk of spreading and degenerating into complete detachment and loose bodies, resulting in a full-thickness chondral defect.[1,3,8] Therefore, prompt surgical intervention has to be considered upon its detection. Although there are few reports regarding the treatment of chondral delamination, considerable treatment options are debridement, bone marrow stimulation, cartilage fixation, and autologous chondrocyte implantation (ACI), depending on the lesion location, size, quality of delaminated cartilage, continuity status with adjacent cartilage, time since injury, and patient characteristics and activities. In this case, despite the extensive delamination involving a significant portion of the weight-bearing surface of the mid-portion of the MFC, the delaminated cartilage maintained a smooth surface with a focal cleavage, and the majority of the lesion remained continuous with the surrounding normal cartilage. The preservation of cartilage quality and continuity made fixation a viable option, as debridement would have resulted in an extensive cartilage defect, and ACI would have been overly invasive given the intact nature of the native cartilage. Additionally, the age and high activity level of the patient warranted a treatment which could preserve the native cartilage tissue.

In the literature, various chondral fixation techniques, including bioabsorbable pins, screws, sutures, and fibrin glue, have been reported.[3,8-10] Given the large lesion size and estimated low healing potential of the delaminated cartilage in our case, a rigid fixation procedure was considered necessary. The AOT was selected for its ability to provide reliable osseous fixation. Although AOT has been employed predominantly in younger patients for chondral detachment,[15,16] its efficacy in older individuals with reduced cell viability in cartilage and subchondral bone is limited.[17,18] To enhance the healing of delaminated cartilage and AOT, we combined the procedure with subchondral bone drilling and MOWHTO. Subchondral bone drilling is expected to refresh the sclerotic subchondral bone bed and also recruits bone marrow-derived stem cells, to promote chondral integration into subchondral bone.[2,16] Although combined approach of AOT and HTO is rarely reported, previous studies have shown favorable outcomes, with a graft survival rate of 90.1% at 8.5 years after surgery in patients with massive full-thickness osteochondral defects and varus malalignment of the knee.[19,20] Our case differs in that we used AOT for fixation of delaminated cartilage rather than reconstruction, and in a patient with mild varus alignment (HKA angle –2.2°). Despite these differences, in our case, HTO was expected to reduce the load on the MFC and grafted tissue, potentially enhancing the healing of both the delaminated cartilage and osteochondral grafts.[21,22] This approach is supported by recent studies demonstrating significantly higher survival rates (89.5% *vs.* 58.33%), when HTO was added to cartilage procedures even in patients with mild varus deformities less than 5°,[23] and by a recent comprehensive review concluding that knee osteotomy should be added to planned cartilage procedures in the presence of varus malalignment regardless of the severity of the deformity.[24]

Biomechanical studies have demonstrated that the medial compartment transmits the majority of load during normal walking, even in neutrally aligned knees.[25,26] Therefore, although alignment correction in patients with neutral alignment remains controversial, we decided to perform HTO to reduce medial compartment loading. The 10-year follow-up revealed that despite this realignment, cartilage thinning was observed at the medial repair site, while the graft and delaminated cartilage maintained secure integration. More intriguingly, the lateral compartment showed no osteoarthritic progression despite the valgus correction, suggesting that the load redistribution by HTO was well tolerated.

In this case, although there were no obvious symptoms related to the PF joint throughout the follow-up period, significant radiological changes were observed. The MOWHTO induced patella baja and increased PTS, which may have contributed to the progression of PF osteoarthritis over the 10-year follow-up period. Of note, MOWHTO is known to alter patellar height and PTS, particularly with large correction angles, affecting PF kinematics and potentially leading to PF osteoarthritis.[27,28] For young and highly active patients, surgical procedures that minimize the risk of patella baja should be considered to prevent long-term PF osteoarthritic progression. These alternative procedures include closed-wedge HTO and open wedge distal tuberosity tibial osteotomy, although they carry their own potential complications such as patella alta, non-union, and peroneal nerve injury.[27,29,30]

There are several limitations in this report. First, the postoperative alignment resulted in unexpected overcorrection of the lower limb, although the ideal alignment remains controversial for the middle-aged patients with neutral alignment. Second, without histological evaluation, we could not determine the biological properties of the repair tissues, including both the integration of osteochondral plugs and the healing between the delaminated cartilage and subchondral bone. Although MRI demonstrated maintained integration at 10 years, cartilage thinning was observed at the repair site, raising concerns about the long-term durability of both the osteochondral grafts and the reattached delaminated cartilage. Further follow-up and evaluation are needed to better understand the long-term outcomes of this procedure.

In conclusion, this case report describes the 10-year outcomes of large chondral delamination in the MFC treated with AOT fixation and MOWHTO. Although cartilage thinning was observed at the repair site, the patient maintained good clinical function and high activity levels without progression of lateral compartment osteoarthritis. However, significant PF osteoarthritic changes developed over time. Taken together, these findings indicate that the combined AOT and MOWHTO procedure is a viable treatment option for large chondral delamination, including in patients with neutral alignment. However, careful evaluation of surgical techniques and alignment strategies is warranted to minimize potential complications such as PF joint degeneration.

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