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Osteochondral autograft transplantation for the treatment of steroid-induced osteonecrosis of the humeral head: a case report

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Osteonecrosis is defined as in situ death of a bone segment.[31] The humeral head is the second most common site of symptomatic osteonecrosis after the femoral head.[5,6] However, the optimal treatment of symptomatic humeral head osteonecrosis with radiographic collapse is still a matter of controversy. Traditionally, the treatment option is defined according to the stage of disease progression introduced by Cruess.[4,18,28] The treatment options in the precollapse phase (stages I and II) include conservative treatment and core decompression.[29,30,34] Prosthetic shoulder replacement options such as humeral head resurfacing,[42,49] hemiarthroplasty, and shoulder arthroplasty[25,32,38,40] are generally indicated for the treatment of symptomatic osteonecrosis with radiographic collapse (stages III through V). As for the treatment of young patients, joint-preserving procedures should be considered because young patients under 60 years of age who undergo shoulder arthroplasty are at an increased risk of revision surgery due to glenoid loosening and glenoid arthritis.[1,7,15] To our knowledge, we report the first case of osteonecrosis of the humeral head that was treated by osteochondral autograft transplantation (OAT).

Report of the case

A 53-year-old female patient visited our orthopedic clinic with a chief complaint of pain and limited active elevation of the right shoulder. She had a medical history of systemic lupus erythematosus (SLE) and lupus nephritis. She had been treated with steroid pulse therapy, followed by oral prednisolone for 17 years. In addition, she had been diagnosed with osteonecrosis of the medial femoral condyle in her right knee joint and underwent mosaicplasty 10 years before this visit. Three months before her initial visit, she experienced shoulder pain without any history of trauma or injury and visited another clinic. She had been diagnosed with osteoarthritis of the glenohumeral joint. Oral nonsteroidal anti-inflammatory drugs were prescribed for pain relief. However, the pain in her right shoulder persisted even during daily activities. Then, she was referred to our hospital.

On physical examination, active range of motion (ROM) of the right shoulder was 100° in forward flexion, 60° in abduction, 40° in external rotation at the side, and T12 in internal rotation behind the back. All directions of active ROM were restricted owing to shoulder pain. Preoperative functional scores of the American Shoulder and Elbow

Institutional review board approval was not required for this case report.

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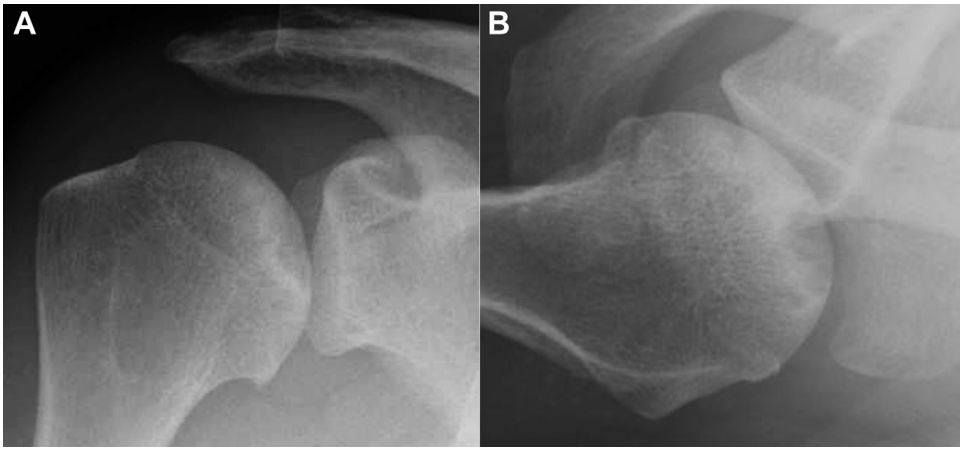

Figure 1 The initial finding of the plain radiograph. A subchondral lucency with a sclerotic rim and mild inferior osteophyte formation were noted in the humeral head. (**A**) Anterior-posterior view of the right shoulder. (**B**) Axillary view of the right shoulder.

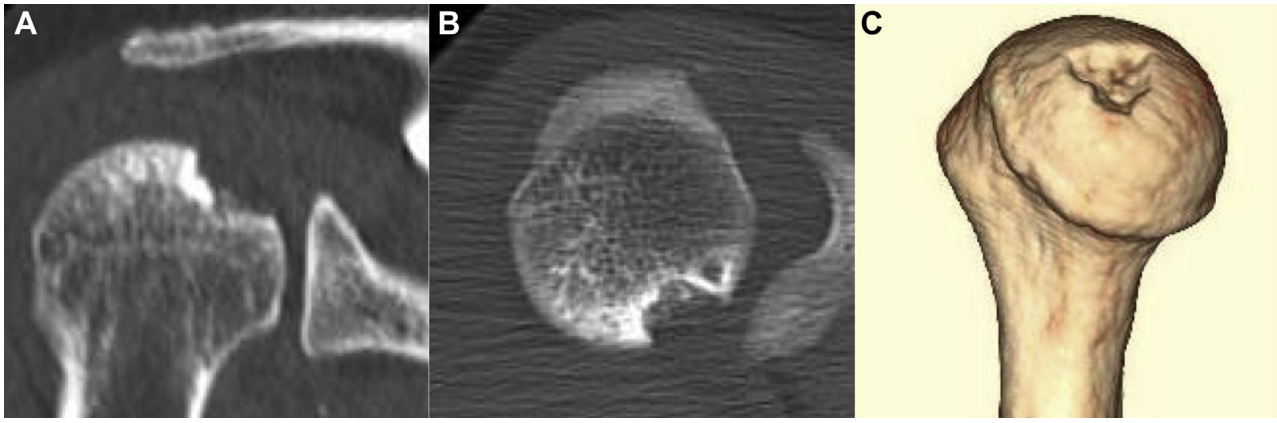

Figure 2 Preoperative computed tomography (CT) images of the right shoulder. A collapsed lesion was noted in the humeral head. (**A**) Oblique coronal image of the right shoulder. (**B**) Axial image of the right shoulder. (**C**) Reconstructed 3-dimensional CT of the right humerus.

Surgeons (a 100-point scoring system) and the Japanese Orthopaedic Association (a 100-point scoring system) were 53.3 and 69.0 points, respectively. The contralateral shoulder and other joints were asymptomatic. The plain radiograph revealed a subchondral lucency with a sclerotic rim and normal articular congruity of the glenoid. In addition, mild inferior osteophyte formation was noted in the humeral head (stage I osteoarthritis, according to Samilson and Prieto[44]) (Fig. 1). The contralateral shoulder showed no abnormal finding. The computed tomography images revealed focal subchondral bone collapse with an articular incongruity of the humeral head (Fig. 2). The size of the affected area was 126 mm^2 by the measurement using picture archiving and communication systems.

Magnetic resonance imaging (MRI) revealed low signal intensity on both T1- and T2-weighted images (Fig. 3). Therefore, a clinical diagnosis was made of steroid-induced osteonecrosis of the humeral head. According to the Cruess classification, this case was categorized as stage III (Table I).

To preserve the native joint, OAT was performed. A 10-cm skin incision was made on the anterior aspect of her right shoulder with the patient in the beach-chair position under general anesthesia followed by interscalene block. The shoulder joint was exposed through a standard delto-pectoral approach. The proximal two-thirds of the sub-scapularis tendon and anterior capsule were cut from the lesser tuberosity 1 cm medial to its insertion. We exposed the humeral head by retracting the proximal two-thirds of the subscapularis and anterior capsule medially and rotating the humerus externally. The size of the subchondral bone collapse was 13 mm in length and 13 mm in width (Fig. 4, *A*). The transplantation procedure was performed with an osteochondral autograft transfer system (Arthrex, Naples, FL, USA). Three recipient sockets were created to provide an adequate press-fit graft fixation. The area along the lateral edge of the trochlea of her left knee joint was chosen

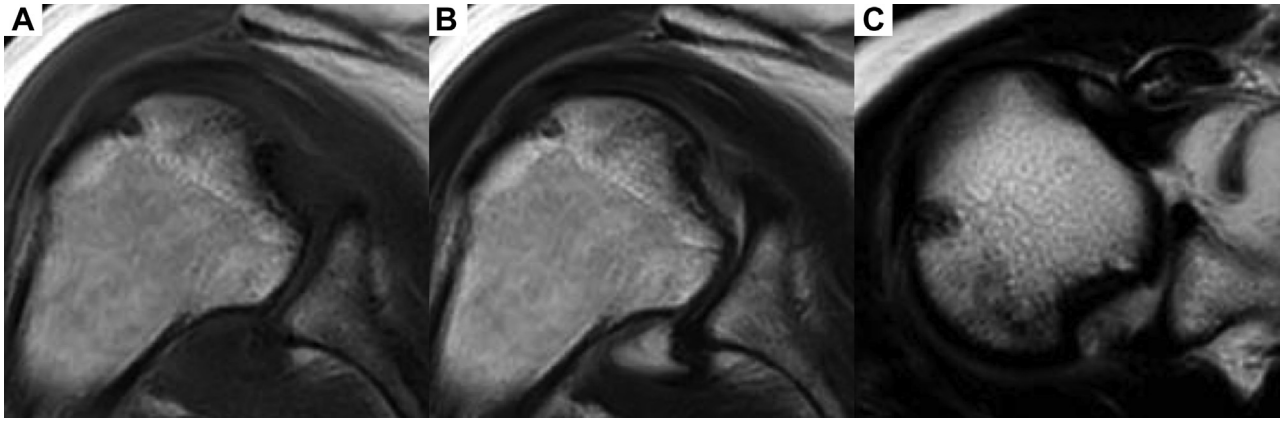

Figure 3 Preoperative magnetic resonance imaging of the right shoulder. (**A**) Oblique coronal T1-weighted image of the right shoulder. (**B**) Oblique coronal T2-weighted image of the right shoulder. (**C**) Axial T2-weighted image of the right shoulder.

Table I Classification system

Stage	Description
I	No radiographic evidence of shoulder osteonecrosis, but MRI reveals localized bone edema
II	Signs of mottled sclerosis appear, but the curvature of the humeral head remains intact
III	A crescent sign, indicating that subchondral fracture appears. The humeral head may become less spherical as the initial stages of collapse are seen
IV	Advanced subchondral collapse and articular flattening with marked loss of humeral head sphericity
V	Humeral head collapse along with and the extension of degenerative changes in the glenoid cavity

MRI, magnetic resonance imaging.

as a donor site because she had undergone mosaicplasty for the treatment of osteonecrosis of the medial femoral condyle of her right knee joint 10 years before this surgery. We harvested three 6 × 15 mm osteochondral plugs. The harvested osteochondral autografts were then transferred into the recipient site using a press-fit technique (Fig. 4, *B*). Three bone tunnels were created just lateral to the subscapularis insertion on the lesser tuberosity. Three sutures of No. 2 Fiberwire (Arthrex) were placed through the bone tunnels, and these were sutured to the tenotomized tendon in a modified Mason-Allen configuration. In addition, 3 tendon-to-tendon simple sutures were placed to complete the repair. After the repair of the subscapularis, the surgical wound was closed.

One of the osteochondral plugs collected from the collapsed lesion was used for histopathologic diagnosis, and several empty lacunae were identified (Fig. 5). Thus, an experienced pathologist made a histologic diagnosis of osteonecrosis of the humeral head.

The right shoulder was immobilized using an abduction sling (Block Shoulder Abduction Sling; Nagano Prosthetics & Orthotics Co. Ltd., Osaka, Japan) for 4 weeks after surgery. After the immobilization period, passive- and active-assisted exercises were initiated. Eight weeks after the surgery, the patient began to perform exercises to strengthen the rotator cuff and the scapula stabilizers. The patient was able to return to her desk work 2 months after surgery. She fully recovered the ability to perform daily activities, and computed tomography images showed graft union at 6 months after surgery (Fig. 6). At 2 years after surgery, the glenohumeral joint space was maintained, although the size of the inferior osteophyte was increased compared with that observed at the preoperative examination by the plain radiograph (Fig. 7). MRI showed complete graft integration and no osteonecrosis of the humeral head 2 years after surgery (Fig. 8). The patient was asymptomatic and active ROM in the right shoulder improved to 170° in forward flexion, 170° in abduction, 70° in external rotation at the side, and T10 in internal rotation behind the back (Fig. 9). The postoperative American Shoulder and Elbow Surgeons and Japanese Orthopaedic Association scores improved to 95.0 points and 100 points, respectively. The Lysholm score of the left knee, from which the osteochondral graft had been harvested, was 95 points 2 years after surgery.

The patient was informed that the data and photographs from the case would be submitted for publication and gave their consent.

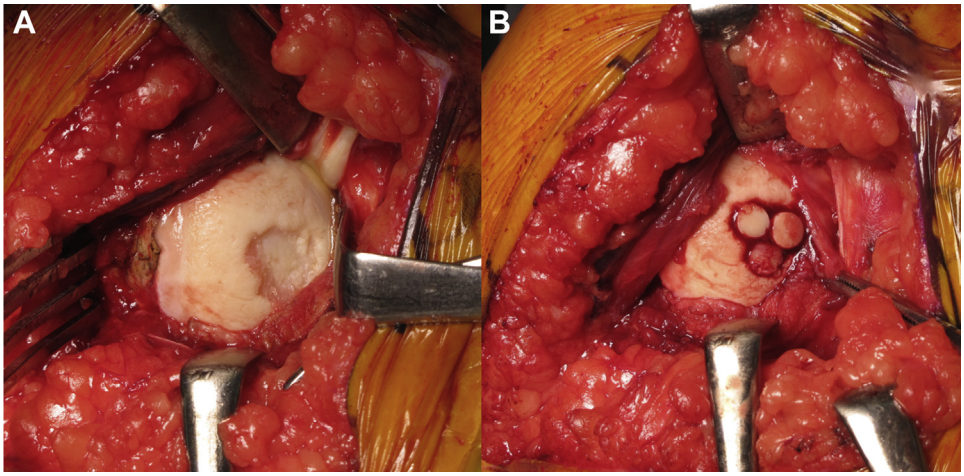

Figure 4 Intraoperative findings of the right shoulder. (**A**) A collapsed lesion noted in the right humeral head. (**B**) Three 6-mm-diameter osteochondral autografts transferred into the recipient site using a press-fit technique.

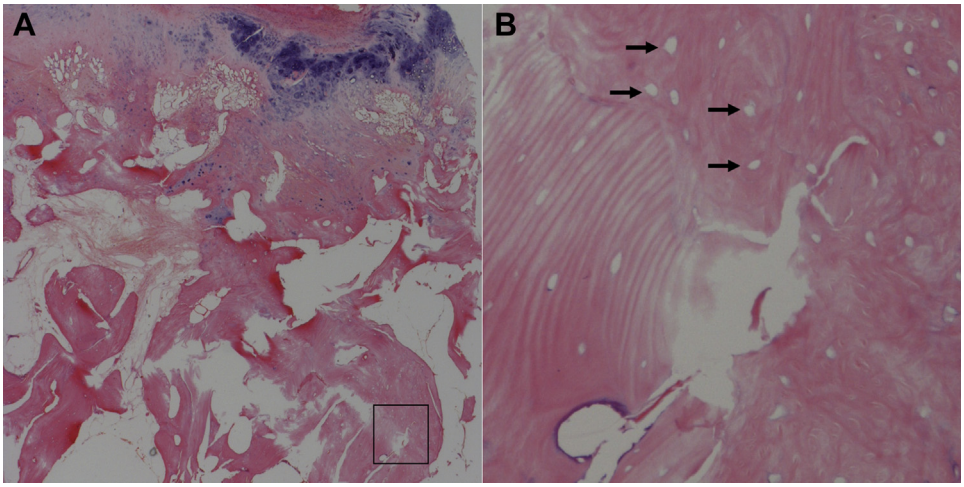

Figure 5 Histologic findings of the collapsed lesion in the right shoulder. Hematoxylin and eosin staining (**A**, magnification: ×20; **B**, magnification: ×100). (**A**) An image of tissue section of an osteochondral plug collected from the collapsed lesion. (**B**) High-magnification image of the □ in image (**A**). Several empty lacunae (→) were noted.

Discussion

The treatment of advanced stages of osteonecrosis of the humeral head characterized by the collapse of the subchondral bone in young patients remains an unsolved burden in shoulder surgery. Here, we report the first case of osteonecrosis of the humeral head with a focal collapse (stage III) that was treated by OAT. Our patient showed excellent clinical and radiographic outcomes 2 years after surgery.

Osteonecrosis is a potentially painful and disabling bone disease that involves the death of bone tissue.[31] The etiology of humeral head necrosis can be divided into posttraumatic or nontraumatic. The known etiological factors for nontraumatic osteonecrosis of the humeral head are corticosteroid administration, alcohol abuse, pancreatitis, hemoglobinopathies, diabetes, radiation therapy, and other systemic diseases such as Cushing's syndrome, rheumatoid arthritis, and SLE.[12,23,45] Our patient had no history of trauma and injury. However, she had a history of steroid pulse therapy followed by chronic administration of corticosteroids for the treatment of SLE. In addition, the histopathologic section of the collapsed lesion showed the findings of empty lacunae, indicating osteonecrosis. Thus, our patient was diagnosed with steroid-induced osteonecrosis of the humeral head.

Hernigou et al[26] investigated the natural history of osteonecrosis of the humeral head related to corticosteroid use by assessing plain radiographs and MR images. They reported that the interval between the initial corticosteroid treatment and the diagnosis of osteonecrosis of the humeral head averaged 15 months (range, 6-24 months). The average age of onset is reported to be between 37 and 46 years.[26,29,30] The progressive patterns of osteonecrosis of

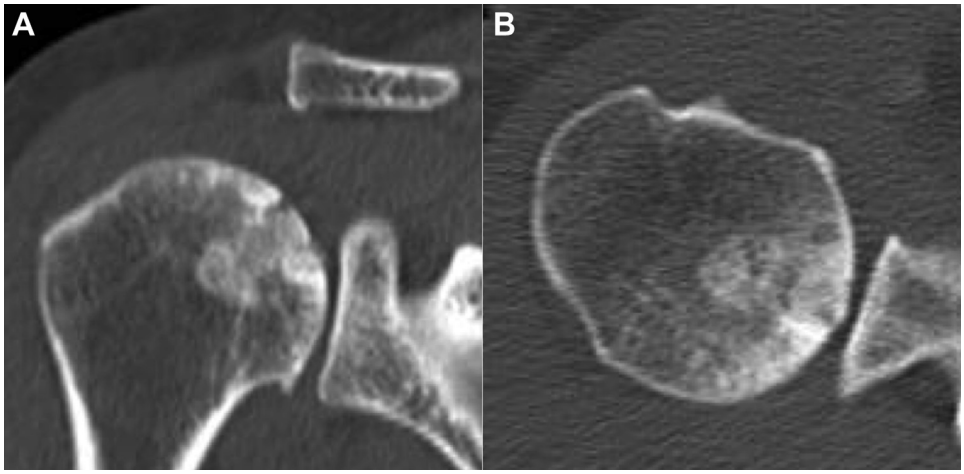

Figure 6 Computed tomography (CT) images 6 months after surgery. CT images showed the graft union. (**A**) Oblique coronal image of the right shoulder. (**B**) Axial image of the right shoulder.

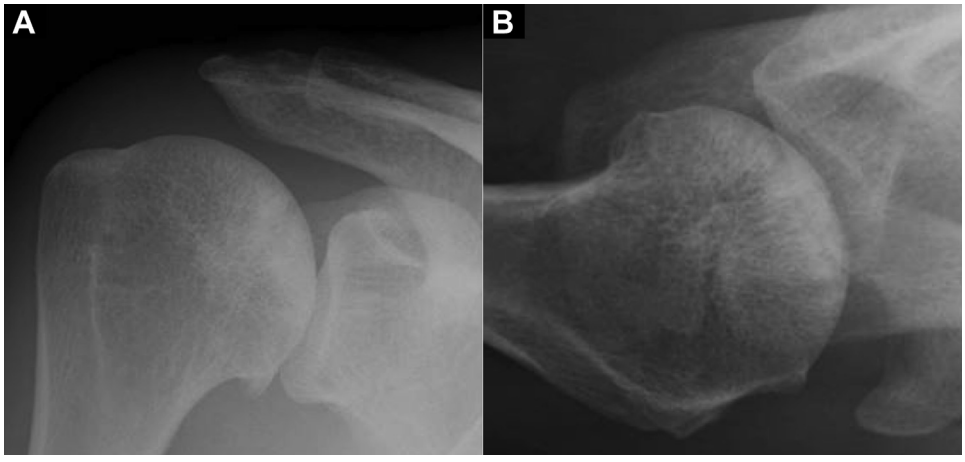

Figure 7 Finding of the plain radiograph 2 years after surgery. The glenohumeral joint space was maintained, although the size of the inferior osteophyte was increased compared with that observed at the preoperative examination. No recurrent osteonecrosis of the humeral head was noted. (**A**) Anterior-posterior view of the right shoulder. (**B**) Axillary view of the right shoulder.

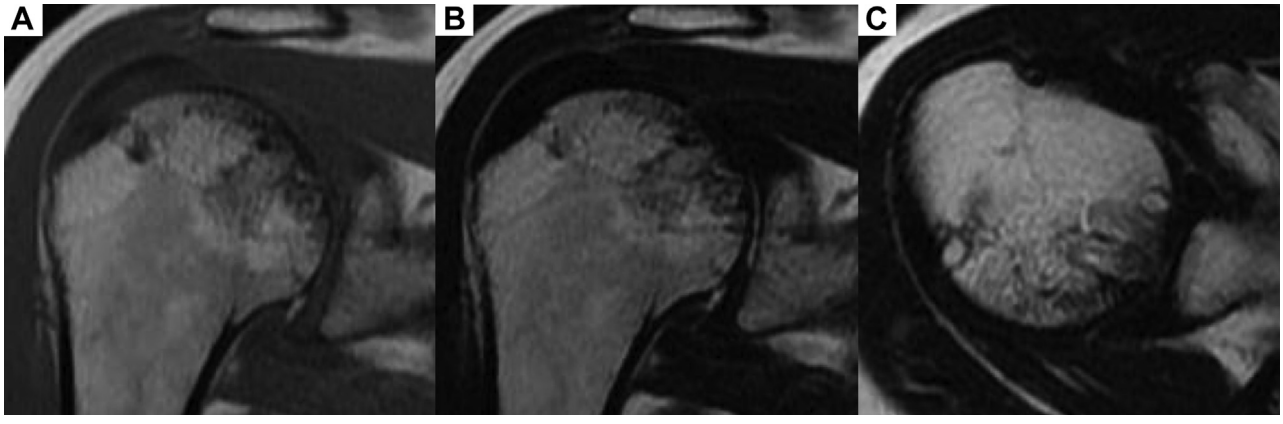

Figure 8 Magnetic resonance imaging 2 years after surgery. Complete graft integration and no recurrence of osteonecrosis were noted. (**A**) Oblique coronal T1-weighted image of the right shoulder. (**B**) Oblique coronal T2-weighted image of the right shoulder. (**C**) Axial T2-weighted image of the right shoulder.

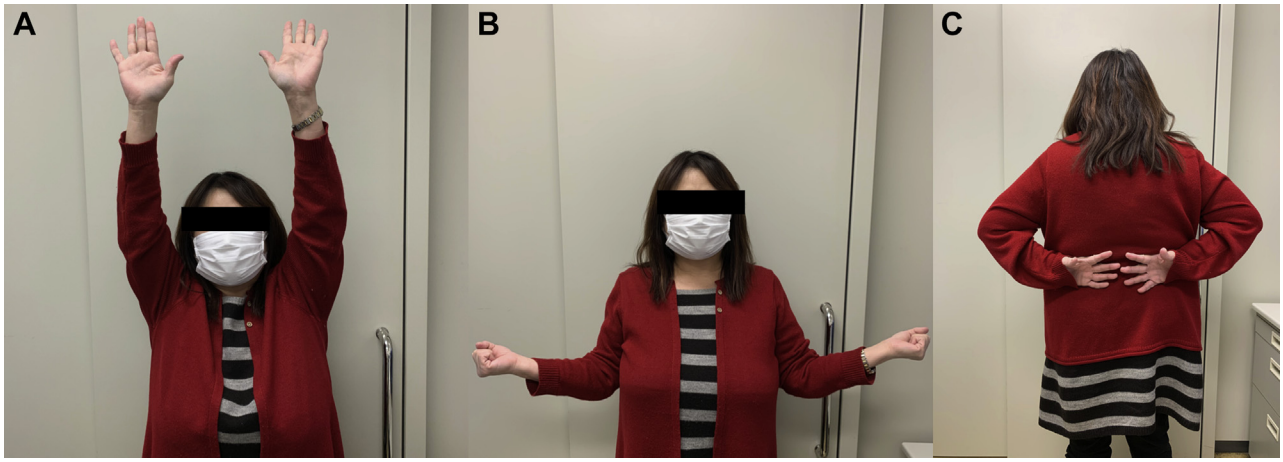

Figure 9 Active range of motion 2 years after surgery. (**A**) Shoulder elevation. (**B**) External rotation. (**C**) Internal rotation.

the humeral head have been described previously. The most widely used staging system for steroid-induced osteonecrosis of the humeral head is the Cruess classification, which is the modification of Ficat's staging system for osteonecrosis of the femoral head.[4,9] The humeral head collapse was always preceded by pain. The time between diagnosis and collapse averaged 10 years for symptomatic stage I shoulders and 3 years for symptomatic stage II shoulders. The prognosis for shoulders with more advanced stages is less favorable.[24] L'Insalata et al[29] reported that radiographic stages of III or greater and the presence of radiographic progression were sensitive predictors and each strongly associated with a poor outcome.

The initial treatment of osteonecrosis of the humeral head is conservative, including exercises and the avoidance of overhead shoulder movements and strenuous activities.[5] Surgical treatments for osteonecrosis of the humeral head include core decompression,[29,30,34] vascularized bone grafting,[10,27] humeral head resurfacing,[49] and shoulder arthroplasty.[32,40] As for the joint-preserving surgery, a small number of autogenous bone grafting studies have been reported, including the fibular strut bone graft[14] and the vascularized scapular bone graft;[27] however, these procedures are complex. Core decompression is a widely used straightforward procedure achieving favorable clinical outcomes identified before collapse.[29,30,34] Nevertheless, the best success with core decompression is when it is performed in the earlier stages (stages I and II) of this disease before humeral head collapse as with osteonecrosis of the femoral head.[29,34] For later stages (stages III, IV, and V) after the head collapse, joint replacement such as hemiarthroplasty or total shoulder arthroplasty (TSA) has been widely used. Generally, shoulder arthroplasties are designed to last 10-20 years. However, young patients under 60 years of age have an increased risk of revision at early follow-up.[7] In addition, younger patients who undergo shoulder arthroplasty have declining rates of self-reported satisfaction because of higher functional demands and expectations.[8] Therefore, joint-preserving procedures should be considered for the treatment of young patients even in the later stage of the disease.

The preservation of patients' native joint anatomy has a significant advantage over hemiarthroplasty and TSA. Humeral offset, retroversion, neck-shaft angle, head height, and radius of curvature are patient-specific. Restoring these parameters with an implant can pose a challenge to the surgeon.[2,41] The changes in biomechanics affect the contact pressure and stress distribution across the glenohumeral joint.[2,20] The resultant eccentric loading can lead to glenoid loosening after TSA and can increase the rate of glenoid arthritis after hemiarthroplasty. Therefore, it is important to preserve or reconstruct the normal anatomy and biomechanics.

Osteochondral allograft transplantation and allogenic bone grafting are the alternative treatment options of osteochondral defects in the shoulder.[16,17,33,43] Previous studies demonstrated favorable clinical outcomes after osteochondral allograft or allogenic bone grafting for the biologic resurfacing of osteochondral defects in the humeral head and/or glenoid.[16,17,33,43] However, the use of allografts has the potential risks of disease transmission or immune graft rejection.[3,35,47]

OAT is a well-established joint-preserving surgery for focal cartilage lesions or osteochondral lesions of the knee, talus, and humeral head.[21,22,46] Previous studies reported that OAT had good long-term durability with successful outcomes in patients with articular cartilage defect or osteochondral defect in the knee or ankle joints.[19,21,39,48] As for the treatment of steroid-induced osteonecrosis, a few reports have described the use of OAT for the necrosis of femoral condyle[13,36] and femoral head.[11] To date, however, there have been no reports about the use of OAT for the osteonecrosis of the humeral head.

The main advantage of OAT is the reconstruction of the mechanically durable articular cartilage and subchondral bone and the removal of the collapsed lesion, including the necrotic bone tissue. OAT is typically used for the treatment of 100-400 mm^2 focal chondral and osteochondral lesions.[21] In our case, the size of the collapsed lesion was 126 mm^2, which was within the indicated size used for the osteochondral lesions; we found the complete graft integration and no recurrent osteonecrosis of the humeral head at 2 years after surgery based on a plain radiograph and MRI examination. Although an increase in the size of humeral osteophyte formation was observed, the patient was asymptomatic and glenohumeral joint space was maintained 2 years after surgery. Furthermore, her right knee joint with osteonecrosis of the medial femoral condyle, which had been treated by OAT (mosaicplasty), demonstrated good clinical outcomes 10 years after surgery. Therefore, we believe that OAT has the potential to preserve the shoulder joint and prevent or delay the prosthetic shoulder replacement. Further observation is necessary to clarify the long-term result.

A disadvantage of OAT is the necessity to expose the knee joint. However, previous studies reported that knee complaints were relatively rare in the group of patients in which grafts were transferred outside the knee joint.[22,37] Our patient showed excellent clinical score with no complication in the donor site, which was consistent with the previous reports.

Conclusion

We report a case of osteochondral autograft transplantation for steroid-induced osteonecrosis in a patient with SLE. Our patient showed excellent clinical and radiographic outcomes without any sign of recurrence of pain, a radiological progression of osteonecrosis in the shoulder, or donor site pain 2 years after surgery. Osteochondral autograft transplantation may be a viable treatment option for osteonecrosis of the humeral head in young patients with focal collapse.

Disclaimer

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References

1. Bartelt R, Sperling JW, Schleck CD, Cofield RH. Shoulder arthroplasty in patients aged fifty-five years or younger with osteoarthritis. J Shoulder Elbow Surg 2011;20:123-30. https://doi.org/10.1016/j.jse.2010.05.006
2. Buchler P, Farron A. Benefits of an anatomical reconstruction of the humeral head during shoulder arthroplasty: a finite element analysis. Clin Biomech (Bristol, Avon) 2004;19:16-23. https://doi.org/10.1016/j.clinbiomech.2003.09.009
3. Bugbee WD, Convery FR. Osteochondral allograft transplantation. Clin Sports Med 1999;18:67-75.
4. Cruess RL. Steroid-induced avascular necrosis of the head of the humerus. Natural history and management. J Bone Joint Surg Br 1976;58:313-7.
5. Cruess RL. Experience with steroid-induced avascular necrosis of the shoulder and etiologic considerations regarding osteonecrosis of the hip. Clin Orthop Relat Res 1978;130:86-93.
6. Cruess RL. Corticosteroid-induced osteonecrosis of the humeral head. Orthop Clin North Am 1985;16:789-96.
7. Dillon MT, Inacio MC, Burke MF, Navarro RA, Yian EH. Shoulder arthroplasty in patients 59 years of age and younger. J Shoulder Elbow Surg 2013;22:1338-44. https://doi.org/10.1016/j.jse.2013.01.029
8. Eichinger JK, Miller LR, Hartshorn T, Li X, Warner JJ, Higgins LD. Evaluation of satisfaction and durability after hemiarthroplasty and total shoulder arthroplasty in a cohort of patients aged 50 years or younger: an analysis of discordance of patient satisfaction and implant survival. J Shoulder Elbow Surg 2016;25:772-80. https://doi.org/10.1016/j.jse.2015.09.028
9. Ficat RP. Idiopathic bone necrosis of the femoral head. Early diagnosis and treatment. J Bone Joint Surg Br 1985;67:3-9.
10. Fisher DE, Bickel WH. Corticosteroid-induced avascular necrosis. A clinical study of seventy-seven patients. J Bone Joint Surg Am 1971;53:859-73.
11. Fotopoulos V, Mouzopoulos G, Floros T, Tzurbakis M. Steroid-induced femoral head osteonecrosis in immune thrombocytopenia treatment with osteochondral autograft transplantation. Knee Surg Sports Traumatol Arthrosc 2015;23:2605-10. https://doi.org/10.1007/s00167-014-3239-3
12. Franceschi F, Franceschetti E, Paciotti M, Torre G, Samuelsson K, Papalia R, et al. Surgical management of osteonecrosis of the humeral head: a systematic review. Knee Surg Sports Traumatol Arthrosc 2017;25:3270-8. https://doi.org/10.1007/s00167-016-4169-z
13. Fujita N, Matsumoto T, Kubo S, Matsushita T, Ishida K, Hoshino Y, et al. Autogenous osteochondral graft transplantation for steroid-induced osteonecrosis of the femoral condyle: a report of three young patients. Sports Med Arthrosc Rehabil Ther Technol 2012;4:13. https://doi.org/10.1186/1758-2555-4-13
14. Galloway MR, Horodyski M, Wright TW. Arthroscopically assisted fibular strut allograft for treatment of osteonecrosis of proximal humerus. J Surg Orthop Adv 2013;22:277-82. https://doi.org/10.3113/jsoa.2013.0277
15. Gauci MO, Bonnevialle N, Moineau G, Baba M, Walch G, Boileau P. Anatomical total shoulder arthroplasty in young patients with osteoarthritis: all-polyethylene versus metal-backed glenoid. Bone Joint J 2018;100-B:485-92. https://doi.org/10.1302/0301-620X.100B4.BJJ-2017-0495.R2
16. Gerber C, Lambert SM. Allograft reconstruction of segmental defects of the humeral head for the treatment of chronic locked posterior dislocation of the shoulder. J Bone Joint Surg Am 1996;78:376-82.
17. Gobezie R, Lenarz CJ, Wanner JP, Streit JJ. All-arthroscopic biologic total shoulder resurfacing. Arthroscopy 2011;27:1588-93. https://doi.org/10.1016/j.arthro.2011.07.008
18. Gruson KI, Kwon YW. Atraumatic osteonecrosis of the humeral head. Bull NYU Hosp Jt Dis 2009;67:6-14.
19. Gudas R, Gudaite A, Pocius A, Gudiene A, Cekanauskas E, Monastyreckiene E, et al. Ten-year follow-up of a prospective, randomized clinical study of mosaic osteochondral autologous transplantation versus microfracture for the treatment of osteochondral defects in the knee joint of athletes. Am J Sports Med 2012;40:2499-508. https://doi.org/10.1177/0363546512458763

20. Hammond G, Tibone JE, McGarry MH, Jun BJ, Lee TQ. Biomechanical comparison of anatomic humeral head resurfacing and hemiarthroplasty in functional glenohumeral positions. J Bone Joint Surg Am 2012;94:68-76. https://doi.org/10.2106/JBJS.I.00171
21. Hangody L, Dobos J, Balo E, Panics G, Hangody LR, Berkes I. Clinical experiences with autologous osteochondral mosaicplasty in an athletic population: a 17-year prospective multicenter study. Am J Sports Med 2010;38:1125-33. https://doi.org/10.1177/0363546509360405
22. Hangody L, Vasarhelyi G, Hangody LR, Sukosd Z, Tibay G, Bartha L, et al. Autologous osteochondral grafting—technique and long-term results. Injury 2008;39(suppl 1):S32-9. https://doi.org/10.1016/j.injury.2008.01.041
23. Hasan SS, Romeo AA. Nontraumatic osteonecrosis of the humeral head. J Shoulder Elbow Surg 2002;11:281-98. https://doi.org/10.1067/mse.2002.124347
24. Hattrup SJ, Cofield RH. Osteonecrosis of the humeral head: relationship of disease stage, extent, and cause to natural history. J Shoulder Elbow Surg 1999;8:559-64.
25. Hattrup SJ, Cofield RH. Osteonecrosis of the humeral head: results of replacement. J Shoulder Elbow Surg 2000;9:177-82.
26. Hernigou P, Flouzat-Lachaniette CH, Roussignol X, Poignard A. The natural progression of shoulder osteonecrosis related to corticosteroid treatment. Clin Orthop Relat Res 2010;468:1809-16. https://doi.org/10.1007/s11999-009-1094-1
27. Inoue K, Suenaga N, Oizumi N, Tanaka Y, Minami A. A vascularized scapular graft for juvenile osteonecrosis of the humeral head. J Shoulder Elbow Surg 2012;21:e9-13. https://doi.org/10.1016/j.jse.2011.08.070
28. Kennon JC, Smith JP, Crosby LA. Core decompression and arthroplasty outcomes for atraumatic osteonecrosis of the humeral head. J Shoulder Elbow Surg 2016;25:1442-8. https://doi.org/10.1016/j.jse.2016.01.022
29. L'Insalata JC, Pagnani MJ, Warren RF, Dines DM. Humeral head osteonecrosis: clinical course and radiographic predictors of outcome. J Shoulder Elbow Surg 1996;5:355-61.
30. LaPorte DM, Mont MA, Mohan V, Pierre-Jacques H, Jones LC, Hungerford DS. Osteonecrosis of the humeral head treated by core decompression. Clin Orthop Relat Res 1998;355:254-60.
31. Mankin HJ. Nontraumatic necrosis of bone (osteonecrosis). N Engl J Med 1992;326:1473-9.
32. Mansat P, Huser L, Mansat M, Bellumore Y, Rongieres M, Bonnevialle P. Shoulder arthroplasty for atraumatic avascular necrosis of the humeral head: nineteen shoulders followed up for a mean of seven years. J Shoulder Elbow Surg 2005;14:114-20. https://doi.org/10.1016/j.jse.2004.06.019
33. Miyazaki AN, Silva LA, Sella GDV, Checchia CS, Simionato MC, Checchia SL. Articular reconstruction of the humeral head with autogenous allograft in the treatment of the osteonecrosis. Rev Bras Ortop 2018;53:113-7. https://doi.org/10.1016/j.rboe.2017.11.011
34. Mont MA, Maar DC, Urquhart MW, Lennox D, Hungerford DS. Avascular necrosis of the humeral head treated by core decompression. A retrospective review. J Bone Joint Surg Br 1993;75:785-8.
35. Mroz TE, Joyce MJ, Steinmetz MP, Lieberman IH, Wang JC. Musculoskeletal allograft risks and recalls in the United States. J Am Acad Orthop Surg 2008;16:559-65. https://doi.org/10.5435/00124635-200810000-00001
36. Nakagawa Y, Matsusue Y, Nakamura T. Osteochondral graft transplantation for steroid-induced osteonecrosis of the femoral condyle. Lancet 2003;362:402. https://doi.org/10.1016/S0140-6736(03)14031-7
37. Nakagawa Y, Mukai S, Setoguchi Y, Goto T, Furukawa T, Nakamura T. Clinical outcomes of donor sites after osteochondral graft harvest from healthy knees. Orthop J Sports Med 2017;5:2325967117732525. https://doi.org/10.1177/2325967117732525
38. Orfaly RM, Rockwood CA Jr, Esenyel CZ, Wirth MA. Shoulder arthroplasty in cases with avascular necrosis of the humeral head. J Shoulder Elbow Surg 2007;16:S27-32. https://doi.org/10.1016/j.jse.2006.06.005
39. Pareek A, Reardon PJ, Maak TG, Levy BA, Stuart MJ, Krych AJ. Long-term outcomes after osteochondral autograft transfer: a systematic review at mean follow-up of 10.2 years. Arthroscopy 2016;32:1174-84. https://doi.org/10.1016/j.arthro.2015.11.037
40. Parsch D, Lehner B, Loew M. Shoulder arthroplasty in nontraumatic osteonecrosis of the humeral head. J Shoulder Elbow Surg 2003;12:226-30. https://doi.org/10.1016/s1058-2746(02)00040-x
41. Pearl ML. Proximal humeral anatomy in shoulder arthroplasty: implications for prosthetic design and surgical technique. J Shoulder Elbow Surg 2005;14:99S-104S. https://doi.org/10.1016/j.jse.2004.09.025
42. Ranalletta M, Bertona A, Tanoira I, Rossi LA, Bongiovanni S, Maignon GD. Results of partial resurfacing of humeral head in patients with avascular necrosis. Rev Esp Cir Ortop Traumatol 2019;63:29-34. https://doi.org/10.1016/j.recot.2018.08.001
43. Riff AJ, Yanke AB, Shin JJ, Romeo AA, Cole BJ. Midterm results of osteochondral allograft transplantation to the humeral head. J Shoulder Elbow Surg 2017;26:e207-15. https://doi.org/10.1016/j.jse.2016.11.053
44. Samilson RL, Prieto V. Dislocation arthropathy of the shoulder. J Bone Joint Surg Am 1983;65:456-60.
45. Sarris I, Weiser R, Sotereanos DG. Pathogenesis and treatment of osteonecrosis of the shoulder. Orthop Clin North Am 2004;35:397-404.xi. https://doi.org/10.1016/j.ocl.2004.03.004
46. Scheibel M, Bartl C, Magosch P, Lichtenberg S, Habermeyer P. Osteochondral autologous transplantation for the treatment of full-thickness articular cartilage defects of the shoulder. J Bone Joint Surg Br 2004;86:991-7. https://doi.org/10.1302/0301-620x.86b7.14941
47. Strong DM, Friedlaender GE, Tomford WW, Springfield DS, Shives TC, Burchardt H, et al. Immunologic responses in human recipients of osseous and osteochondral allografts. Clin Orthop Relat Res 1996;326:107-14.
48. Ulstein S, Aroen A, Rotterud JH, Loken S, Engebretsen L, Heir S. Microfracture technique versus osteochondral autologous transplantation mosaicplasty in patients with articular chondral lesions of the knee: a prospective randomized trial with long-term follow-up. Knee Surg Sports Traumatol Arthrosc 2014;22:1207-15. https://doi.org/10.1007/s00167-014-2843-6
49. Uribe JW, Botto-van Bemden A. Partial humeral head resurfacing for osteonecrosis. J Shoulder Elbow Surg 2009;18:711-6. https://doi.org/10.1016/j.jse.2008.10.016