JSES International 7 (2023) 2330–2336

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Kinematic analysis of damaged capsulolabral structure in patients with anterior shoulder instability using cine-magnetic resonance imaging

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A R T I C L E I N F O

Keywords:
Recurrent shoulder dislocation
Damaged labrum
Glenohumeral joint
Internal immobilization
Dynamic assessment
Cine-magnetic resonance imaging

Level of evidence: Anatomy study; Imaging

Background: We assessed damaged anterior capsulolabral motion during axial shoulder rotation in patients with anterior shoulder instability.
Methods: Twenty-nine shoulders of 28 patients with anterior shoulder instability who underwent cine-magnetic resonance imaging during axial rotation of the adducted arm were included. The motion was captured after an intra-articular injection of saline solution (10-20 mL). During imaging, the shoulder was rotated passively from maximum internal rotation to maximum external rotation in the first 10 s and then back to maximum internal rotation in the subsequent 10 s. We assessed the rotational angles of the damaged labrum during compressing and pulling the humeral head against the glenoid. Evaluation of the rotational angles was performed on a series of axial images through the humeral head center.
Results: The mean angles that damaged labrum compressed and pulled off against the glenoid were 12.0 ± 19.1° and 2.8 ± 21.2°, respectively. Additionally, seven of the 29 shoulders showed that the damaged labrum compressed on the glenoid rim before the rotational angle exceeded 0° during external rotation. In 13 shoulders, the damaged labrum could remain repositioned on the glenoid rim over the neutral position during internal rotation. In two shoulders, the damaged labrum was not compressed against the glenoid at the maximum external rotation. The injected saline moved from the posterior to the anterior side of the glenohumeral joint during internal rotation in each shoulder.
Conclusion: The damaged labrum could be positioned on the glenoid when the arm was in a traditional internal immobilization.

The range of motion of the shoulder joint is the largest in the human body, making it the most commonly dislocated joint. In addition, a traumatic shoulder dislocation is notorious for its high recurrence rate after initial dislocation, particularly among younger patients.[7,20,22] The recurrence rate after first-time dislocation ranges between 20% and 90% and tends to increase with a younger age of occurrence at the time of initial dislocation.[5,7-10,20,22,27]

The main cause of recurrent shoulder dislocation is incomplete healing of the antero-inferior capsulolabral structure after detachment from the glenoid rim.[13,23,28] Moreover, the external rotational position of the glenohumeral joint can be used to compress the damaged anterior capsulolabrum to the glenoid rim.[14,26] Therefore, external rotational immobilization after initial shoulder dislocation is considered to facilitate healing and decrease the recurrence rate.[12] However, randomized control studies that compared the recurrence rate after immobilization in external and internal rotation have reported controversial results.[13,17] Thus, the recommended immobilization position after the initial shoulder dislocation remains unclear.

Dynamic assessment of the damaged anterior capsulolabrum during axial rotation of the shoulder could illuminate this controversial problem underlying the proper immobilization position that would facilitate reduction in the damaged labrum after shoulder dislocation. Some previous studies have assessed the damaged labrum position at different rotational positions.[14,26] To the best of our knowledge, there has been no report on the assessment of the

The experimental protocol was approved by the Institutional Review Board for Observation and Epidemiological Study, Kitasato University Medical Ethics Organization (reference no. KMEO B11-87).

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https://doi.org/10.1016/j.jseint.2023.08.003

dynamic motion of the damaged labrum during rotational motion. For visualizing the dynamic rotational motion of the shoulder, analysis of the axial rotation of the shoulder using dynamic assessment by magnetic resonance imaging (cine-magnetic resonance imaging [MRI]) has been reported.[16] Cine-MRI allows for dynamic evaluation of patients and has been used in various fields, such as the dynamic evaluation of cardiac function.[1,4] Cine-MRI sequences can capture one to two images per second. Hence, it can clearly visualize the actual glenohumeral rotation.[11,16] In addition, it has been reported that cine-MRI could be able to obtain movements of the capsulolabrum during rotation with vivid clarity in 10 examined shoulders.[18]

This study aimed to assess the damaged anterior capsulolabral motion during glenohumeral rotation in patients with anterior shoulder instability. We hypothesized that some cases could be successfully reduced by immobilization in an internal rotational position, as the external rotational position could be used to compress the damaged labrum on the glenoid. We also suggest that the findings of this study would lead to recommendations for optimal immobilization positions after dislocation reduction by evaluating each patient using cine-MRI.

Materials and methods

Participants

All procedures performed in this study were in accordance with the ethical standards of our Institutional Research Committee as well as the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. After approval by the institutional review board was granted, written informed consent was obtained from all participants. To confirm whether cine-MRI could assess the dynamics of the damaged labrum, this study included patients with anterior shoulder instability or following primary shoulder dislocation and who were pain-free in passive rotational motion between January 2012 and March 2015. Although cine-MRI was performed at two facilities, all patients were evaluated by a single orthopedic surgeon.

MRI acquisition

Imaging was performed with a 1.5 T MRI system using a four-channel shoulder array coil (Signa; GE Medical Systems, Milwaukee, WI, USA) or a 1.5 T system with one of the manufacturer's shoulder coils (shoulder 16, Magnetom Aera; Siemens Healthcare, Malvern, PA, USA). Cine-MRI of the shoulder was performed using either of the two following models. The first was two-dimensional fast imaging employing steady-state acquisition techniques (GE Medical Systems) (imaging parameters: the repetition time/the echo time = 4.6/2.1 ms; flip angle, 20°; bandwidth, ±62.5 kHz; matrix, 256 × 224; number of excitations, 1.0; field of view, 28 × 28 cm; section thickness, 6.0 mm). The second used true fast imaging with steady state precession (Siemens Healthcare) (imaging parameters: the repetition time/the echo time = 4.91/2.46 ms; flip angle, 20°; bandwidth, 349 Hz/pixel; matrix, 256 × 256; number of excitations, 1.0; field of view, 28 × 28 cm; section thickness, 6.0 mm). Sequential images were recorded at a rate of one image/s during the activity. Image acquisition was performed on axial slices that included the center of the humeral head, which was determined using a best-fit circle for the humeral head on a scout oblique coronal image.[16] The MRI model used for imaging was determined by the facility the patient visited.

The motion was captured after an intra-articular injection of 10-20 mL of saline solution. A soft plate cushion was placed under the arm to maintain the long axis parallel to the trunk. The acquisition began with the arm fully rotated internally (with the dorsum of the hand on the greater trochanter). To perform passive rotation, an orthopedic surgeon grasped the participant's wrist and rotated the participant's arm so that the shoulder was rotated to the maximum external rotation for over 10 s and then reversed to the maximum internal rotation for the subsequent 10 s. We recorded the motion of at least two glenoid levels for each participant. The images are shown in Figure 1.

MRI evaluations

The maximum internal and external rotational angles of the glenohumeral joint were measured as previously described.[16] We also measured two additional rotational angles of the glenohumeral joint. The first was the angle at which the damaged labrum compressed against the glenoid rim during external rotation. The second was the angle at which the damaged labrum was pulled off from the glenoid rim during internal rotation (Video). Whether the damaged labrum was compressed or pulled off was defined according to a previous report.[14] The rotational angle was defined as the angle formed by the axes of the glenoid and humeral head, as previously reported (Fig. 2).[16] The glenoid axis was defined as the line perpendicular to the glenoid fossa at its midpoint. The humeral head axis was defined as the line connecting the midpoint of the articular surface of the humeral head and the center of the best-fit circle applied to the humeral head. When the two axes were parallel, the joint was considered in a neutral position. In addition, we have evaluated the extent of the damaged labrum using the classification by Habermeyer et al.[2]

Statistical analysis

Data are presented as mean ± standard deviations (SDs). The internal rotational angle is presented as a negative value.

Interclass correlation coefficients (ICC) were calculated to assess the inter- and intraexaminer reliability of the angle measurements. For inter-examiner reliability, two shoulder surgeons with 5 and 10 years of experience in shoulder research independently measured all shoulders, and the ICC (2,1) was determined. For intra-examiner reliability, the surgeon with 10 years of experience measured all shoulders twice at a 1-week interval, and ICC (1,1) was determined. All examiners were blinded to the personal and clinical information of the patients. All statistical analyses were performed using the JMP Pro software, version 14.1 (SAS Institute Inc., Cary, NC). Statistical significance was set at a 5% level.

Results

Participants' demographics

Twenty-nine consecutive shoulders of 28 patients with anterior shoulder instability or following primary shoulder dislocation (19 men and nine women) were included. Each patient had experienced the most recent dislocation more than 6 weeks previously. The mean age at the time of assessment was 28 ± 11 years (range: 16-70 years). The age at the time of primary shoulder dislocation was 23 ± 13 years (range: 10-70 years). The mean time of study after their most recent shoulder dislocation or subluxation was 8.3 ± 1.8 weeks (range: 6-15.6 weeks). The mean Rowe score for these patients at the time of assessment was 54.7 points (range: 25-90 points). Table I presents patient demographic data by sex. Four of the 29 patients did not undergo surgery. One patient underwent surgery at a different hospital. Thus, 24 cases underwent arthroscopic Bankart repair at our hospital. According to the classification reported by Habermeyer et al, five, 14, four, and one shoulders were stage 1, stage 2, stage 3, and stage 4, respectively.

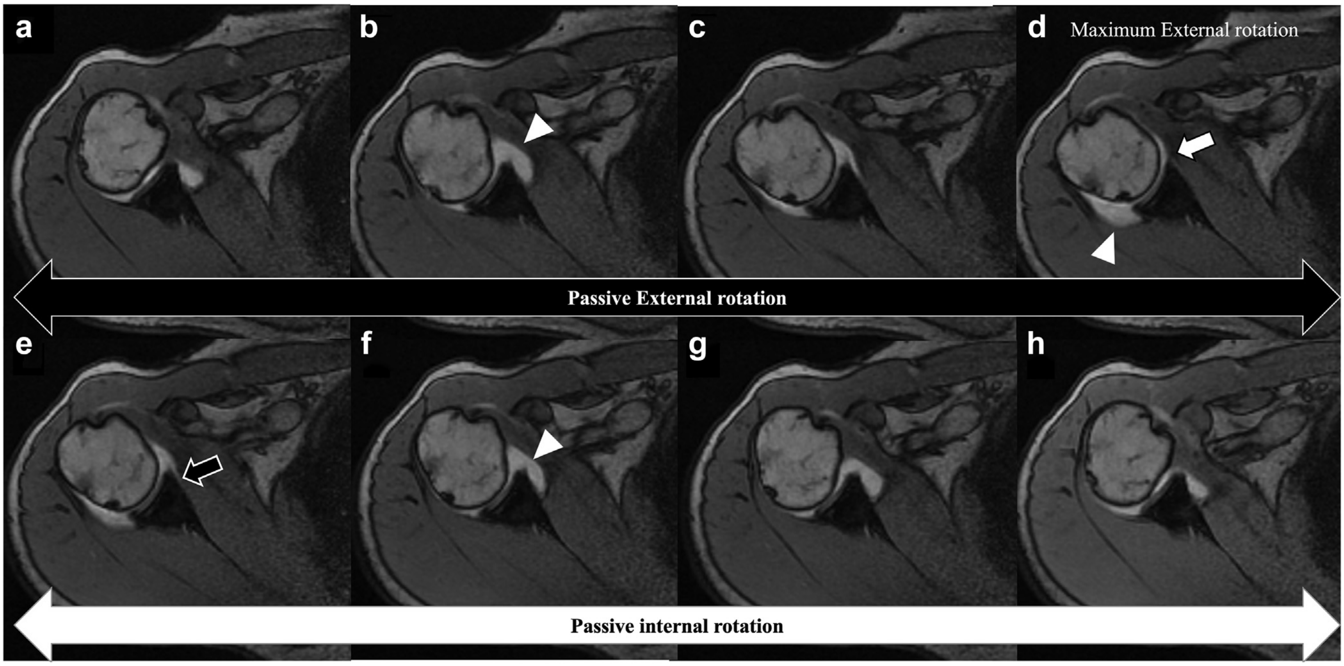

Figure 1 Dynamic assessment of the damaged labrum during axial rotation of the glenohumeral joint using cine-MRI. Images (**a** and **h**) Maximum internal rotation; from images (**a**-**d**), images during passive external rotation; from images (**e**-**h**), images during passive internal rotation; white arrow, damaged labrum compresses on the glenoid; black arrow, damaged labrum pulls off from the glenoid; white triangles, joint fluid with saline. *MRI*, magnetic resonance imaging.

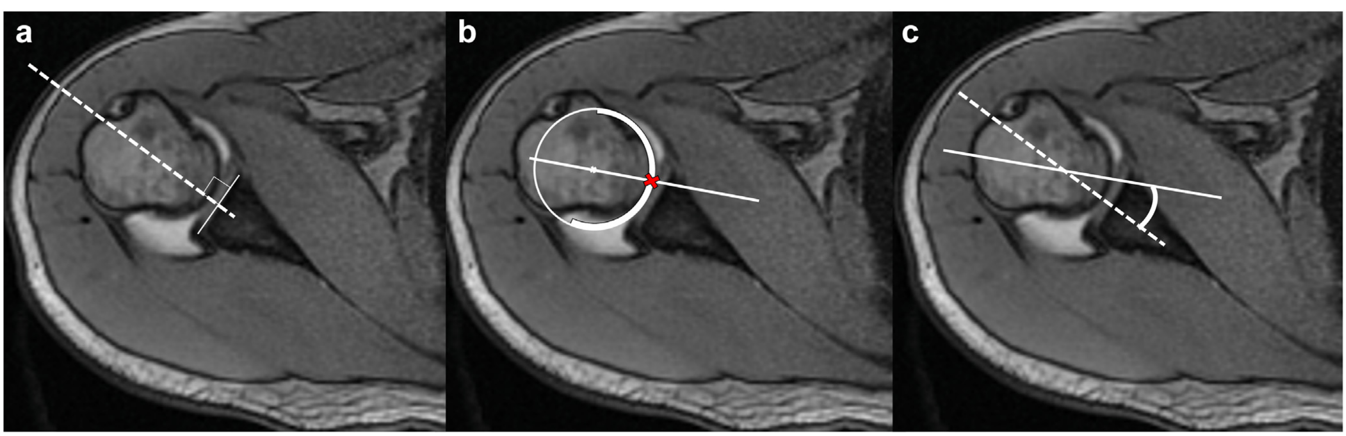

Figure 2 The rotational angle of cine-MRI. The glenoid axis (dotted line) is defined as the line perpendicular to the surface of the glenoid fossa at its midpoint (**a**). The humeral head axis (white line) is defined as the line connecting the midpoint of the articular surface (red ×) to the *Center* of the humeral head (white dot), which is the *Center* of the best-fit circle (white circle) applied to the humeral head (**b**). The articular surface is identified using the articular cartilage (bold white line). The rotational angle is defined as the angle between the axes of the glenoid and humeral head (**c**). *MRI*, magnetic resonance imaging.

Reliability of the methodology

Inter- and intraexaminer reliability indicated excellent agreement (ICC [2,1] = 0.99; 95% confidence interval [CI], 0.95–0.99; standard error of mean = 1.13; minimal detectable change$_{95}$ = 3.14; ICC [1,1] = 0.98; 95% CI, 0.97–0.99; standard error of mean = 1.99; minimal detectable change$_{95}$ = 7.78).

Dynamic analysis of the damaged labrum

The mean internal and external rotational angles were −48.9 ± 8.9° and 38.9 ± 17.4°, respectively. The damaged labrum compressed at maximum external rotation in all shoulders except for two. The mean angle at which the damaged labrum compressed during external rotation was 12.0 ± 19.1° (range, −34° to 39°) and displacement during internal rotation was 2.8 ± 21.2° (range, −54° to 39°) (Table I and Fig. 3).

In 13 shoulders, the damaged labrum could remain repositioned on the glenoid rim over the neutral position during internal rotation. However, the damaged labrum pulled off from the glenoid rim during internal rotation (Fig. 1 and Video). In 19 of 29 shoulders, the compressed and damaged labrum during internal rotation remains on the glenoid rim without detaching to the same angle that compressed (Fig. 3). In two of the 29 shoulders, the damaged labrum did not compress on the glenoid at maximum external rotation (Fig. 4 and Video). In seven shoulders, the damaged labrum compressed on the glenoid rim before the rotational angle exceeded 0° during external rotation (Fig. 5).

Table I
Patient demographic data.

	Female (n = 9)	Male (n = 19)
Age (y)	31 (range, 16-70)	27 (range, 16-47)
Side	Right, 5; Left, 4	Right, 9; Left, 11
Primary dislocation age (y)	24 (range, 13-70)	22 (range, 10-47)
* (weeks)	8.0 (range, 6.0-10.4)	8.5 (range, 6.0-15.6)
Clinical score		
Rowe score (points)	51.1 ± 15.8	56.3 ± 19.8
ROM determined by cine-MRI		
External rotation (°)	44.6 ± 24.7°	36.2 ± 13.2°
Internal rotation (°)	−53.7 ± 5.8°	−46.5 ± 9.3°
Angles at which the damaged labrum coaptated or departed from the glenoid rim		
Compressed angle (°)	−2.9 ± 17.7°	15.1 ± 18.2°
Displacement angle (°)	−6.1 ± 23.6°	3.8 ± 18.9°

F, female; *M*, male; *MRI*, magnetic resonance imaging; *ROM*, range of motion.
*The mean time of study after their most recent shoulder dislocation or subluxation.

In all examined shoulders, the injected saline pooled on the anterior side in the internal rotation position. The saline moved to the posterior side during external rotation and back to the anterior side during internal rotation (Figs. 2, 4, and 5; Video).

Discussion

In this study, all shoulders, except for two, were compressed on the glenoid rim at maximum external rotation. The mean coordinated and departure angles were 12.0 °and 2.8°, respectively. In addition, seven of the 29 shoulders compressed on the glenoid rim without external rotation. These findings suggest that traditional internal rotational immobilization could prevent the recurrence of shoulder dislocation after primary shoulder dislocation.

After an initial dislocation, over 90% of shoulders show detachment of the inferior glenohumeral ligament labral complex from the glenoid.[28,29] Therefore, incomplete healing of detached inferior glenohumeral ligament labral complex is thought to be the main cause of recurrent shoulder dislocation.[13,23,28] However, consistent redislocation has not been shown in 52%-80% of patients after initial dislocation.[7,24] In this study, the 13 damaged labrums could remain repositioned on the glenoid rim in the neutral position during internal rotation. The anteversion of the glenoid axis related to the coronal plane can be large in a slouched position.[15] Immobilization in the internal position with a slouched position nearly placed the glenohumeral joint in a neutral position. Therefore, these findings imply that the damaged labrum compressed on the glenoid rim during manual repositioning of the dislocated shoulder and remained on the glenoid rim even during immobilization in internal rotation.

Immobilization in external rotation aims to compress the damaged labrum to the glenoid rim to heal the injured area.[12-14] Our findings support the evidence indicating that immobilization with shoulder external rotation could compress the damaged labrum during external rotation, which is consistent with a previous report.[14,26] However, in all cases, even when compressed in the external rotation position, the damaged labrum pulled off when internally rotated. Therefore, the compliance rate of patients is an important factor for the clinical application of immobilization, regardless of rotation.[13,17]

In this study, we found that the injected saline moved from the posterior to the anterior side of the glenohumeral joint during the internal rotation of every shoulder. In previous studies, MRI of the shoulder captured during internal rotation also showed saline pooled in the anterior side of the glenohumeral joint, similar to our results.[14,26] The dynamics of joint fluid can be explained by the capsular effect.[3] The joint fluid remains 3-7 weeks after shoulder dislocation.[9,31] The pooled joint fluid on the anterior side pushes away the damaged labrum and is thought to disturb the healing of the Bankart lesion.[30] However, hematoma after injury acts as a scaffold for the inflammatory and mesenchymal cells. Thus, it creates a suitable environment for healing, which enables the cells to migrate, attach, proliferate, and perform their pathophysiological function.[19] In addition, a hematoma includes growth factors that help the damaged tissue heal.[21,25] Traditional immobilization in internal rotation after primary dislocation prevents recurrent shoulder dislocation in more than 45% of patients aged ≤40 years.[5,9] Moreover, more than 15% of recurrent shoulder dislocations became stable over time. [5,9] Therefore, we thought that the position of joint fluid may also explain the spontaneous healing by immobilization in internal rotation after an initial dislocation.

Limitations

This study has several limitations. First, the major limitation of this study was the small number of patients. Owing to the evaluation of unknown kinetics, standard deviations could not be established for this study. Therefore, the sample size was not calculated. Second, the shoulders examined in this study included those after the initial dislocation and those with recurrent dislocation. In addition, the lack of consensus on the modalities of orthopedic treatment after the first dislocation in each patient in our study. Therefore, both angles of compression and departure from the glenoid rim may not be accurate angles after initial shoulder dislocation. However, the lesions that cause initial and recurrent dislocations are morphologically the same.[6] The fact that 43% of initial dislocations never recur and 14.4% of recurrent dislocations stabilize spontaneously[5] implies that these two entities may be not only morphologically similar but also biologically similar. Therefore, we suggest that combining the two types of shoulder might not have affected the results of this study. However, we hypothesized that the acute phase may rather be a more conducive condition for greater dynamics and being more easily compressed. Thus, as the next step, we need to conduct further study within 1 week after the first dislocation. Third, as this is a pilot study, we did not apply conservative treatment in the immobilized position based on cine-MRI results. Therefore, there is a need for further evaluation to confirm the healing rate after conservative treatment in the immobilized position based on cine-MRI results.

Conclusion

Immobilization of the arm in external rotation can enhance compression of the damaged labrum on the glenoid rim better than immobilization in internal rotation. However, once the shoulder rotated internally during external immobilization, the effect of compression on the glenoid rim decreased. In approximately 25% of the shoulders, the damaged labrum could remain on the glenoid rim in the internal rotational position. In addition, the glenohumeral joint fluid pooled on the anterior side in the internal rotational position. These findings suggest that in some cases, healing of the damaged labrum after an initial shoulder dislocation could be facilitated using a traditionals internal immobilization. Moreover, the position of the joint fluid may also suggest that hematoma in the glenohumeral joint after shoulder dislocation support healing of the damaged labrum.

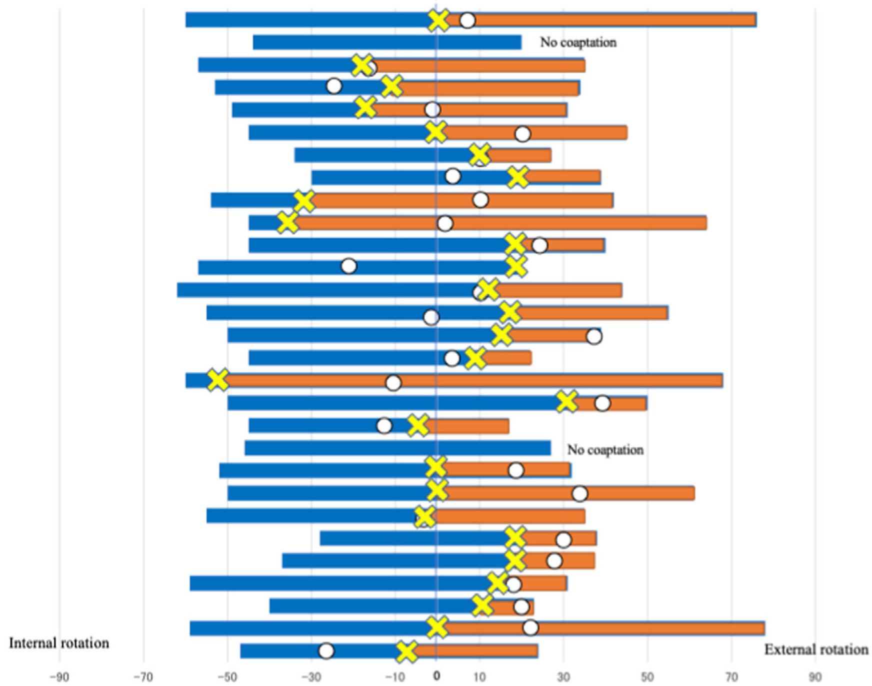

Figure 3 Internal/external rotational angle and compressed/ pulled-off angle. This graph shows the internal/external rotational angle and compressed/ pulled-off angle of every patient. White circle, the angle that the damaged labrum compresses on the glenoid during external rotation; Orange bar, the term for the compressed labrum is on the glenoid during internal rotation; Yellow cross, the angle that the damaged labrum pulls off from the glenoid during internal rotation.

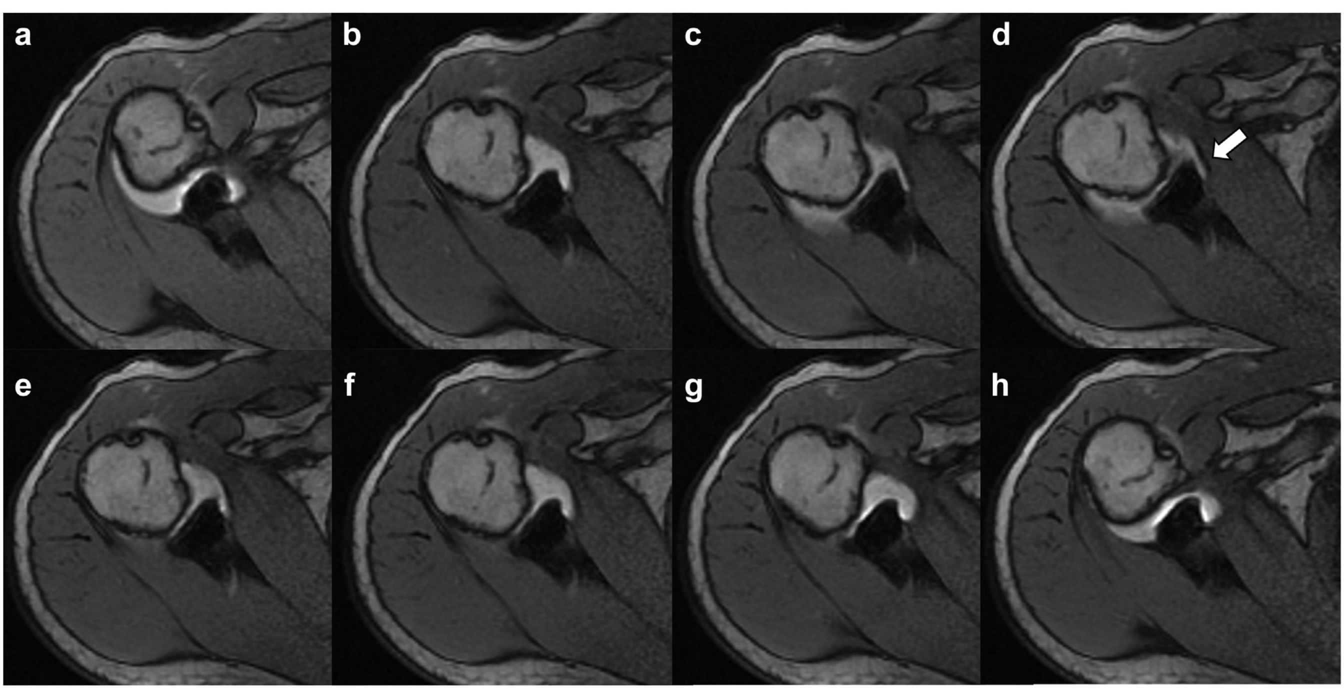

Figure 4 The case in which the damaged labrum does not compress at the external rotation. Images (**a**-**d**), images during passive external rotation; images (**e**-**h**), images during passive internal rotation; white arrow, the damaged labrum does not compress on the glenoid at maximum external rotation.

Disclaimers:

Funding: TK was supported by Japan Society for the Promotion of Science KAKENHI [Grant no. 25861340]. The funding body had no control over the design of the study, the collection, analysis, and interpretation of data, or the writing of this manuscript.

Conflicts of interest: The authors, their immediate families, and any research foundations with which they are affiliated have not

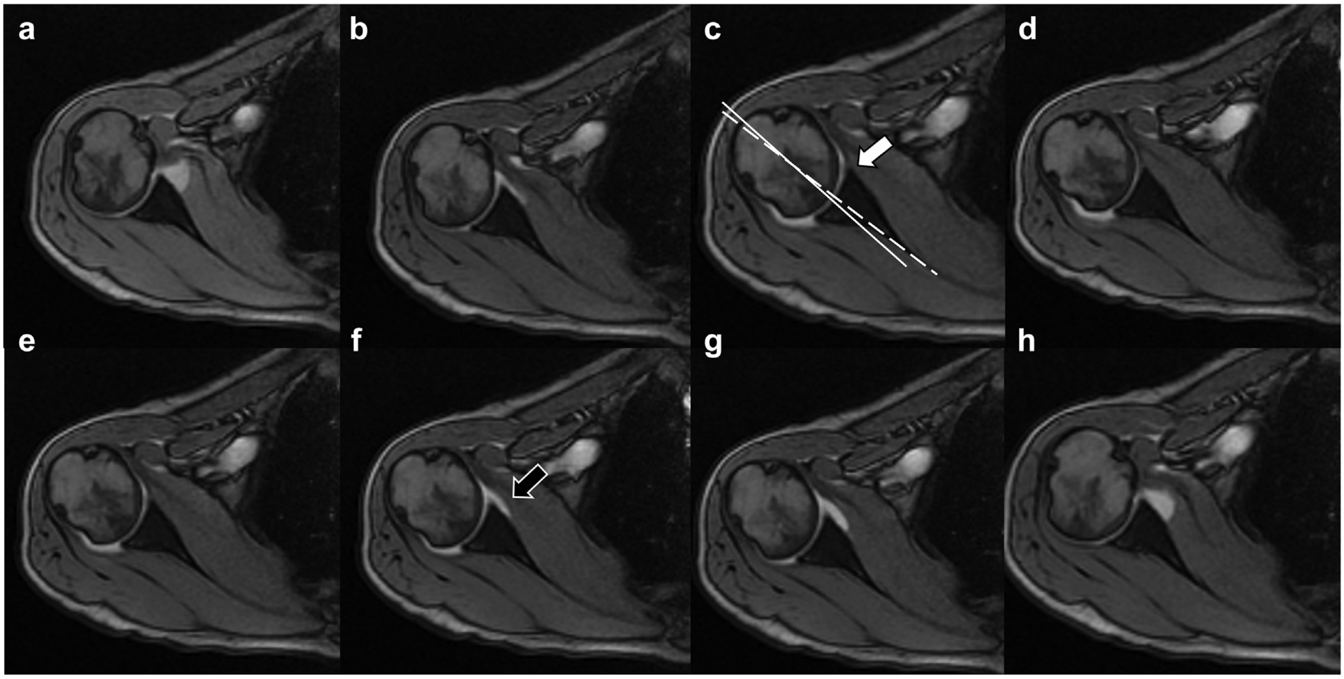

Figure 5 The case in which the damaged labrum compresses before the rotational angle exceeded 0° during external rotation. Images (**a**-**d**), images during passive external rotation; images (**e**-**h**), images during passive internal rotation; white arrow, damaged labrum compresses on the glenoid before the rotational angle exceeds 0° during external rotation; black arrow, damaged labrum pulls off from the glenoid rim; dotted line, glenoid axis; white line, humeral head axis.

received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jseint.2023.08.003.

References

1. Barkhausen J, Ruehm SG, Goyen M, Buck T, Laub G, Debatin JF. MR evaluation of ventricular function: true fast imaging with steady-state precession versus fast low-angle shot cine MR imaging: feasibility study. Radiology 2001;219:264-9.
2. Habermeyer P, Gleyze P, Rickert M. Evolution of lesions of the labrum-ligament complex in posttraumatic anterior shoulder instability: a prospective study. J Shoulder Elbow Surg 1999;8:66-74.
3. Harryman DT 2nd, Sidles JA, Clark JM, McQuade KJ, Gibb TD, Matsen FA 3rd. Translation of the humeral head on the glenoid with passive glenohumeral motion. J Bone Joint Surg Am 1990;72:1334-43.
4. Heitner J, Bhumireddy GP, Crowley AL, Weinsaft J, Haq SA, Klem I, et al. Clinical application of cine-MRI in the visual assessment of mitral regurgitation compared to echocardiography and cardiac catheterization. PLoS One 2012;7:e4049. https://doi.org/10.1371/journal.pone.0040491.
5. Henry JH, Genung JA. Natural history of glenohumeral dislocation—revisited. Am J Sports Med 1982;10:135-7.
6. Hintermann B, Gächter A. Arthroscopic findings after shoulder dislocation. Am J Sports Med 1995;23:545-51.
7. Hovelius L, Augustini BG, Fredin H, Johansson O, Norlin R, Thorling J. Primary anterior dislocation of the shoulder in young patients. A ten-year prospective study. J Bone Joint Surg Am 1996;78:1677-84.
8. Hovelius L, Olofsson A, Sandström B, Augustini BG, Krantz L, Fredin H, et al. Nonoperative treatment of primary anterior shoulder dislocation in patients forty years of age and younger. A prospective twenty-five-year follow-up. J Bone Joint Surg Am 2008;90:945-52. https://doi.org/10.2106/JBJS.G.00070.
9. Hovelius L, Rahme H. Primary anterior dislocation of the shoulder: long-term prognosis at the age of 40 years or younger. Knee Surg Sports Traumatol Arthrosc 2016;24:330-42. https://doi.org/10.1007/s00167-015-3980-2.
10. Hovelius L, Saeboe M. Neer Award 2008: arthropathy after primary anterior shoulder dislocation—223 shoulders prospectively followed up for twenty-five years. J Shoulder Elbow Surg 2009;18:339-47. https://doi.org/10.1016/j.jse.2008.11.004.
11. Ishii D, Kenmoku T, Tazawa R, Nakawaki M, Nagura N, Muneshige K, et al. Limitation of the external glenohumeral joint rotation is associated with subacromial impingement syndrome, especially pain. JSES Int 2021;5:430-8. https://doi.org/10.1016/j.jseint.2021.01.015.
12. Itoi E, Hatakeyama Y, Kido T, Sato T, Minagawa H, Wakabayashi I, et al. A new method of immobilization after traumatic anterior dislocation of the shoulder: a preliminary study. J Shoulder Elbow Surg 2003;12:413-5. https://doi.org/10.1016/s1058-2746(03)00171-x.
13. Itoi E, Hatakeyama Y, Sato T, Kido T, Minagawa H, Yamamoto N, et al. Immobilization in external rotation after shoulder dislocation reduces the risk of recurrence. A randomized controlled trial. J Bone Joint Surg Am 2007;89:2124-31. https://doi.org/10.2106/JBJS.F.00654.
14. Itoi E, Sashi R, Minagawa H, Shimizu T, Wakabayashi I, Sato K. Position of immobilization after dislocation of the glenohumeral joint. A study with use of magnetic resonance imaging. J Bone Joint Surg Am 2001;83:661-7.
15. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. Arch Phys Med Rehabil 1999;80:945-50.
16. Kenmoku T, Matsuki K, Ochiai N, Sonoda M, Ishida T, Sasaki S, et al. Comparison of glenohumeral joint rotation between asymptomatic subjects and patients with subacromial impingement syndrome using cine-magnetic resonance imaging: a cross-sectional study. BMC Musculoskelet Disord 2019;20:475. https://doi.org/10.1186/s12891-019-2818-3.
17. Liavaag S, Brox JI, Pripp AH, Enger M, Soldal LA, Svenningsen S. Immobilization in external rotation after primary shoulder dislocation did not reduce the risk of recurrence: a randomized controlled trial. J Bone Joint Surg Am 2011;93:897-904. https://doi.org/10.2106/JBJS.J.00416.
18. Miyajima G, Kenmoku T, Nakawaki M, Sasaki S, Oodera A, Ochiai N. Kinematic analysis of damaged capsulolabral structure in patients with anterior shoulder instability using Cine-MRI. Katakansetsu 2015;39:619-22. https://doi.org/10.11296/katakansetsu.39.619. In Japanese.
19. Oryan A, Moshiri A, Meimandiparizi AH. Effects of sodium-hyaluronate and glucosamine-chondroitin sulfate on remodeling stage of tenotomized superficial digital flexor tendon in rabbits: a clinical, histopathological, ultrastructural, and biomechanical study. Connect Tissue Res 2011;52:329-39. https://doi.org/10.3109/03008207.2010.531332.
20. Owens BD, Dawson L, Burks R, Cameron KL. Incidence of shoulder dislocation in the United States military: demographic considerations from a high-risk population. J Bone Joint Surg Am 2009;91:791-6. https://doi.org/10.2106/JBJS.H.00514.
21. Pfeiffenberger M, Bartsch J, Hoff P, Ponomarev I, Barnewitz D, Thöne-Reineke C, et al. Hypoxia and mesenchymal stromal cells as key drivers of initial fracture healing in an equine in vitro fracture hematoma model. PLoS One 2019;14:e0214276. https://doi.org/10.1371/journal.pone.0214276.
22. Robinson CM, Howes J, Murdoch H, Will E, Graham C. Functional outcome and risk of recurrent instability after primary traumatic anterior shoulder dislocation in young patients. J Bone Joint Surg Am 2006;88:2326-36. https://doi.org/10.2106/JBJS.E.01327.

23. Rowe CR, Zarins B. Recurrent transient subluxation of the shoulder. J Bone Joint Surg Am 1981;63:863-72.
24. Rys C, Matter P. The initial traumatic shoulder dislocation. Prospective study. Z Unfallchir Versicherungsmed 1993;(Suppl 1):204-12. In German.
25. Sharma P, Maffulli N. Tendon injury and tendinopathy: healing and repair. J Bone Joint Surg Am 2005;87:187-202. https://doi.org/10.2106/JBJS.D.01850.
26. Siegler J, Proust J, Marcheix PS, Charissoux JL, Mabit C, Arnaud JP. Is external rotation the correct immobilization for acute shoulder dislocation? an MRI study. Orthop Traumatol Surg Res 2010;96:329-33. https://doi.org/10.1016/j.otsr.2010.02.005.
27. Simonet WT, Cofield RH. Prognosis in anterior shoulder dislocation. Am J Sports Med 1984;12:19-24.
28. Taylor DC, Arciero RA. Pathologic changes associated with shoulder dislocations. Arthroscopic and physical examination findings in first-time, traumatic anterior dislocations. Am J Sports Med 1997;25:306-11.
29. Thomas SC, Matsen FA 3rd. An approach to the repair of avulsion of the glenohumeral ligaments in the management of traumatic anterior glenohumeral instability. J Bone Joint Surg Am 1989;71:506-13.
30. Wintzell G, Haglund-Akerlind Y, Nowak J, Larsson S. Arthroscopic lavage compared with nonoperative treatment for traumatic primary anterior shoulder dislocation: a 2-year follow-up of a prospective randomized study. J Shoulder Elbow Surg 1999;8:399-402.
31. Wintzell G, Hovelius L, Wikblad L, Saebö M, Larsson S. Arthroscopic lavage speeds reduction in effusion in the glenohumeral joint after primary anterior shoulder dislocation: a controlled randomized ultrasound study. Knee Surg Sports Traumatol Arthrosc 2000;8:56-60.