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Editorial

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Arthroscopic Treatment of Septic Arthritis of the Shoulder: Decision-Making for Reoperation

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Septic arthritis is a devastating disease requiring urgent surgical treatment and systemic antibiotics administration. As noted in the literature, degradation of cartilage occurs through cytokines, bacterial endotoxins, and other destructive enzymes invoking the host immune system [1,2]. This catastrophic cascade is likely to end with irreversible damage to the cartilage. Septic arthritis can even spread into the bone causing osteomyelitis. With recent advancements in arthroscopic techniques and devices, arthroscopic debridement and irrigation have become more popular and are regarded as the first-line treatment option rather than conventional open arthrotomy [3,4]. An arthroscopic approach provides better visualization of the joint and better preserves range of motion (ROM) and affected joint function as a minimally invasive approach. Several studies have reported satisfactory outcomes with arthroscopic debridement and irrigation [1,5,6]. Nonetheless, the rate of reoperation after arthroscopic debridement remains as high as 26% to 32% [1,5,6].

In "Arthroscopic treatment of septic arthritis of the shoulder: technical pearls to reduce the rate of reoperation" by Kwon et al. [7], although there was no comment on the development of post-infectious arthritis in the affected shoulder, Jeon et al. [5] described their clinical experience with 36 patients who underwent arthroscopic debridement for septic arthritis. They sought to provide technical tips in order to reduce the reoperation rate and to achieve satisfactory shoulder functional scores and ROM. Interestingly, just two patients underwent reoperation, which is a much lower recurrence rate than reported in previous studies addressing septic arthritis in the shoulder joint [1,5,6]. The indications for reoperation in their study were: (1) failure of wound drainage output and C-reactive protein (CRP) level to decrease, or (2) evidence of persistent infection on postoperative magnetic resonance image (MRI).

On the other hand, Kim et al. [1] reported that reoperation should be considered when (1) decreasing CRP level increases again, (2) a 7- to 10-day plateau in the decrease of the CRP level, or (3) failure of postoperative wound drainage output volume to decrease. The authors [1] also suggested that persistent elevation of CRP should be an indication for reoperation. Although some authors proposed persistent pain with local warmth and limitation of motion or persistent infection on postoperative MRI as indications of reoperation, I do not think these measures are objective. Furthermore, it is difficult to differentiate resolution of infection from persistent infection on postoperative MRI. Even after the infection resolves and CRP returns to normal, soft tissue or synovium can be enhanced on gadolinium-enhanced MRI and this finding is non-specific [5,8]. Thus, CRP level can be an important and objec-

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tive indicator for reoperation. Another objective indicator for reoperation can be wound drainage output volume failing to decrease [1]. Aside from CRP level, I think that reoperation should be considered if wound drainage output does not decrease.

Lastly, one further question should be considered: should reoperation be performed as aggressive open arthrotomy? Although it may depend on surgeon preference, in the context of significant bone lesions present at advanced stages, I think an open arthrotomy would be better rather arthroscopic approach. Kwon et al. [7] indicated that to reduce the reoperation rate in septic arthritis, the use of a posterolateral portal, a 70° scope in the subacromial space, a large volume of irrigation (>20 L), and multiple suction drains after surgery are recommended.

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Arthroscopic Treatment of Septic Arthritis of the Shoulder: Technical Pearls to Reduce the Rate of Reoperation

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Background: The aim of this study was to evaluate clinical experience with arthroscopic debridement for septic arthritis of the shoulder joint and to report on our patient outcomes.
Methods: The retrospective analysis included 36 shoulders (male:female, 15:21), contributed by 35 patients (mean age, 63.8 years) treated by arthroscopy for septic arthritis of the shoulder between November 2003 and February 2016. The mean follow-up period was 14.3 months (range, 12–33 months). An additional posterolateral portal and a 70° arthroscope was used to access the posteroinferior glenohumeral (GH) joint and posteroinferior subacromial (SA) space, respectively. Irrigation was performed with a large volume of fluid (25.1±8.1 L). Multiple suction drains (average, 3.3 drains) were inserted into the GH joint and SA space and removed 8.9±4.3 days after surgery. Intravenous antibiotics were administered for 3.9±1.8 weeks after surgery, followed by oral antibiotic treatment for another 3.6±1.9 weeks.
Results: Among the 36 shoulders, reoperation was required in two cases (5.6%). The average range of motion achieved was 150.0° for forward flexion and T9 for internal rotation. The mean simple shoulder test score was 7.9±3.6 points. Nineteen shoulders (52.8%) had acupuncture or injection history prior to the infection. Pathogens were identified in 15 shoulders, with *Staphylococcus aureus* being the most commonly identified pathogen (10/15). Both the GH joint and the SA space were involved in 21 shoulders, while 14 cases involved only the GH joint and one case involved only the SA space.
Conclusions: Complete debridement using an additional posterolateral portal and 70° arthroscope, a large volume of irrigation with >20 L of saline, and multiple suction drains may reduce the reoperation rate.

Keywords: Shoulder; Septic arthritis; 70° Arthroscope; Posterolateral portal

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INTRODUCTION

Septic arthritis of the shoulder joint is a rare condition, accounting for up to 3% of all joint infections [1]. However, the importance should not be understated due to its association with specific health comorbidities (e.g., diabetes, liver cirrhosis, and malignancy), the high rate of mortality if not treated promptly, the potential for long-term morbidities (including osteomyelitis, arthritis, and shoulder stiffness), and increased incidence following needle placement around the shoulder joint [1-8]. Treatment options for septic arthritis of the shoulder joint include repetitive aspiration, open arthrotomy with debridement, and arthroscopic debridement and irrigation [1-4,7]. Of these, arthroscopic debridement and irrigation has become popular owing to its many advantages, including the use of a small incision, lower level of postoperative pain, better visualization of the joint compared to an open surgical approach, and overall good clinical results [3,5,9-11]. However, the rate of reoperation after arthroscopic management remains high at 26% to 32% [3,11]. A recent article discussed the risk factors for failure of a single surgical debridement. All factors identified were preoperative in nature and were therefore not controllable by the treatment strategy or the operative method, and none of the factors identified could effectively enhance patient prognosis [12]. Therefore, our aim in this study was to describe our clinical experience with arthroscopic debridement for septic arthritis of the shoulder joint and to report on our patient outcomes. Based on our experience, we describe our novel surgical protocol for reducing the rate of reoperation and include a comparison of our outcomes to previously published data.

METHODS

This study, a retrospective review, was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB No. B1710/426-101). Owing to the retrospective design, the requirement for informed consent was waived.

Selection of Patients

We retrospectively reviewed all cases of naïve septic shoulder arthritis treated at our institution between November 2003 and February 2016. Children and patients with isolated acromioclavicular joint infection, tuberculosis infection, or a previous history of septic arthritis were excluded. Thirty-six cases, contributed by 35 patients, were identified. Among them, one male patient had a bilateral presentation without other joint involvement, and one patient had been treated for infective spondylitis. All arthroscopic surgeries were performed by a single surgeon (JHO).

Diagnostic Assessment

Plain radiographs and magnetic resonance images (MRIs) were obtained, as well as blood analyses, including white blood cell (WBC) with differential counts, the erythrocyte sedimentation rate (ESR), and the C-reactive protein (CRP) level. Assessment of preoperative joint fluid aspirate was feasible in 24 patients. Blood and intraoperative specimen cultures were examined to differentiate the type of infectious organism: aerobic, anaerobic, fungal, or mycobacterial. A provisional septic arthritis diagnosis was made based on clinical symptoms, blood test results, joint fluid aspirate analysis, and MRI findings. All patients underwent arthroscopic debridement and irrigation as the first treatment modality. The diagnosis of septic arthritis was confirmed through intraoperative findings and culture results along with the preoperative radiologic and laboratory results. All cases were classified according to the Gächter staging system, based on intraoperative findings [9,11].

Surgical Technique

All arthroscopic surgeries were performed in the lateral decubitus position. We attempted to obtain fresh specimens for culturing (pus, fluid, or infected granulation tissue) after trocar insertion to prevent dilution with the irrigation fluid. The posterior portal was used as a viewing portal, and the anterior portal as a working portal, to perform thorough synovectomy and massive irrigation. According to the preoperative MRI findings, we tried to evaluate the subacromial (SA) space and glenohumeral (GH) joint space separately to identify the focus of the infection and the presence of a rotator cuff tear. If only a GH joint space infection was suspected on the preoperative MRI, we first tried to inspect the SA space. After arthroscopic synovectomy for one space infection, the other space was evaluated to confirm that the infection was in only one space. Debridement and irrigation were used in the other space to prevent the spread of infection.

In the GH joint, a posterolateral portal was created to approach the posteroinferior GH joint and bare area of the humerus. In the SA space, a conventional lateral portal was created to remove infected granulation tissue. To access the subcoracoid and posterior SA spaces, a 70° arthroscope was used for better visualization (Fig. 1). Sufficient irrigation fluid (mean volume of fluid, 25.1 ± 8.1 L; mean operation time, 103.5 ± 21.4 minutes) was used for meticulous debridement. In four cases with suspected osteomyelitis based on preoperative MRIs, either a motorized burr was used to debride the infected bony tissues or drilling was performed until uninfected bony tissue was exposed. After extensive irrigation and debridement, two to four 3.2-mm suction drains (average, 3.3 drains) were inserted, separately, into the anterior and posterior parts of the GH joint and SA spaces, in regions where the infection focus was iden-

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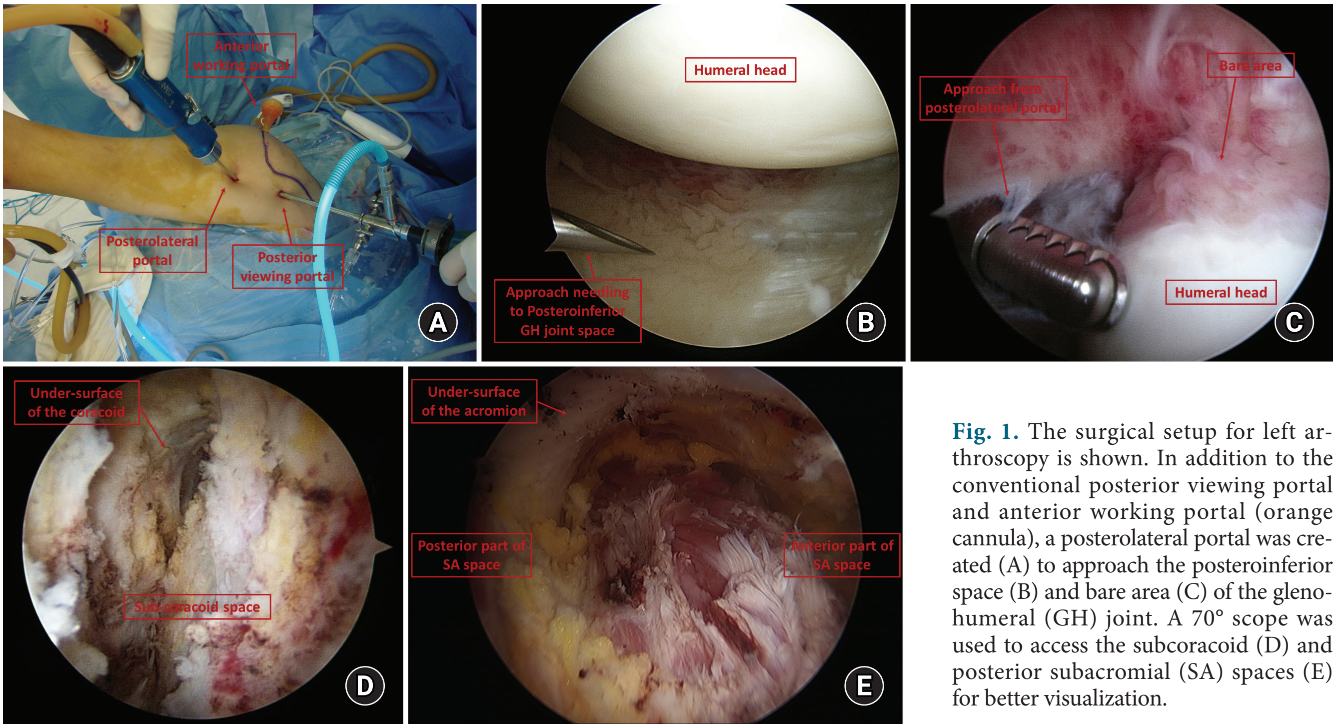

Fig. 1. The surgical setup for left arthroscopy is shown. In addition to the conventional posterior viewing portal and anterior working portal (orange cannula), a posterolateral portal was created (A) to approach the posteroinferior space (B) and bare area (C) of the glenohumeral (GH) joint. A 70° scope was used to access the subcoracoid (D) and posterior subacromial (SA) spaces (E) for better visualization.

tified during arthroscopy, for continuous postoperative drainage (Fig. 2).

Postoperative Management

There was no information on patient antibiotic use prior to being transferred to our institution. No antibiotics were administered before surgery; broad-spectrum antibiotics were started immediately after collecting the intraoperative specimens and were subsequently changed according to the culture and sensitivity study results, after consulting with an infectious disease specialist. Intravenous antibiotics were continued until the ESR and CRP levels were normalized [9,13,14]. Then, oral antibiotics were determined by the infectious disease specialist. The drains inserted during the arthroscopic procedure were removed sequentially when the daily drainage output was < 5 mL. Passive range of motion (ROM) exercises were initiated after removal of all drains, under the supervision of a physiatrist.

The clinical outcomes, including the ROM and simple shoulder test scores, were evaluated at the final follow-up visit. Three components of the ROM were measured using a goniometer: forward flexion, external rotation at side, and internal rotation at back. Forward flexion was measured as the angle between the forearm and the thorax, with the elbow in full extension. External rotation at side was measured as the angle between the thorax and the forearm, with the arm at the side of the body with 90° of elbow flexion.

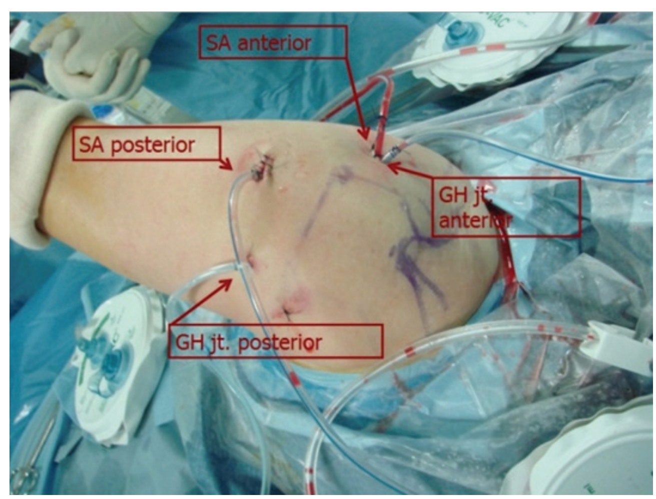

Fig. 2. After extensive debridement and irrigation, four separate suction drains were inserted into the anterior and posterior aspects of the glenohumeral (GH) joint (jt) space and subacromial (SA) space for continuous drainage. Images are of the left shoulder with the patient in a lateral decubitus position.

Internal rotation at back was measured by the vertebral level reached by the thumb of the hand reaching behind the back. The inferior pole of the scapula was referenced as the seventh thoracic vertebra and the iliac crest as the fourth lumbar vertebra [15,16].

RESULTS

The 35 patients enrolled in our study group included 14 men (40%) and had a mean age of 63.8 ± 13.0 years (range, 41–91 years). The mean follow-up period was 14.3 ± 5.1 months (range, 12–33 months). Injection or acupuncture to the involved shoulder was the suspected cause of infection in 19 of the 36 shoulders (52.8%). Arthroscopic surgery was performed 10.9 ± 9.6 days (range, 1–35 days) after symptom onset. Eleven of the 35 patients (31.4%) were immunocompromised, with seven (20%) having diabetes mellitus (DM), four (11.4%) having a malignancy (lung cancer, multiple myeloma, adrenal cancer with spleen metastasis, and breast cancer with thyroid cancer), and two patients having liver cirrhosis, one with DM and one with DM and a malignancy.

The preoperative WBC count, ESR, and CRP were 9.39 ± 4.14 $\times 10^9$/L (normal, 4.0–10.0 $\times 10^9$/L), 60.30 ± 30.55 mm/hr (normal, 0–9 mm/hr), and 9.23 ± 8.07 mg/dL (normal, 0–0.5 mg/dL), respectively. The WBC count of the preoperatively aspirated joint fluid was 128.867 ± 106.09 $\times$ 10^9/L, with a mean differential neutrophil count of 88.3%. To avoid unnecessary contamination, the extent of the infection was determined based on preoperative MRIs. Both the GH joint and the SA space were involved in most cases (21 cases), while only the GH joint was involved in 14 cases, and only the SA space was involved in one case. A full-thickness rotator cuff tear was present in 15 shoulders (41.7%). With regard to infection severity, the distribution of Gächter stages was as follows: stage 1, nine shoulders (25%); stage II, 11 shoulders (30.6%); stage III, 12 shoulders (33.3%); and stage IV, four shoulders (11.1%) (Table 1).

The causative organism was identified in 15 cases (41.7%) from either the preoperative aspiration or the intraoperative specimen culture. The most common pathogen identified was *Staphylococcus aureus* (10 shoulders [27.8%]), specifically methicillin-sensitive *S. aureus* (MSSA, six shoulders) and methicillin-resistant *S. aureus* (MRSA, four shoulders). Other identified organisms are listed in Table 2. On blood culture analyses, five cases showed positive results (two cases of MRSA infection and one case each of MSSA, *Streptococcus pneumoniae*, and *Streptococcus dysgalactiae* infection).

CRP levels normalized at 3.7 ± 2.9 weeks after surgery, and intravenous antibiotics were used for 3.9 ± 1.8 weeks, until the ESR and CRP levels normalized, with further use of oral antibiotics for an additional 3.6 ± 1.9 weeks. Drains were removed sequentially according to the daily output, with all drains removed by 8.9 ± 4.3 days after surgery. The average length of hospital stay, which depended on the duration of intravenous antibiotic treatment recommended by the infectious disease specialist, was 4.0 ± 2.6 weeks. At the final follow-up, the mean ROM was 150.0° ± 37.3° for forward flexion, 65.3° ± 16.1° for external rotation, and T9 ± 2 for internal rotation. The mean simple shoulder test score was 7.9 ± 3.6 points.

Among the 36 shoulders treated, reoperation was required in two cases (5.6%), both with Gächter stage III infection. Reoperation was performed when the drain output and CRP level did not decrease, and there was evidence of persisting infection on postoperative MRIs. One of these two cases presented with progressive osteomyelitis despite an intact rotator cuff and localized infection to the GH joint space. This patient underwent reoperation 2 weeks after the first arthroscopic procedure, using an open arthrotomy and massive curettage of the bone lesion on the humeral head. The second patient suffered from infective spondylitis. After an initial successful arthroscopic debridement, he had taken intravenous antibiotics for 4 weeks, followed by oral antibiotics for 3 weeks under the supervision of the infectious disease specialist. Seven weeks after surgery, he had elevated ESR and CRP levels, with aggravated shoulder pain after his CRP level normalized. This patient underwent revision arthroscopic debridement. The infection in each of these two cases was eradicated successfully after the second surgery.

Table 1. Classification using the Gächter staging system [9]

Stage	Description	No. (%)
I	Opacity of fluid, redness of the synovial membrane, possible petechiae	9 (25)
II	Purulent material, severe inflammation, and fibrinous deposition	11 (30.6)
III	Thickening of the synovial membrane, with cartilage erosion	12 (33.3)
IV	Most aggressive stage, with subchondral delamination	4 (11.1)

DISCUSSION

Thirty-six cases of septic arthritis of the shoulder were successfully

Table 2. Causative organisms identified by preoperative aspiration or intraoperative specimen culture

Organism	No. (%)
Staphylococcus aureus	10 (27.8)
Methicillin-sensitive *S. aureus*	6 (16.7)
Methicillin-resistant *S. aureus*	4 (11.1)
Staphylococcus epidermidis	1 (2.8)
Coagulase-negative *Staphylococcus*	1 (2.8)
Streptococcus pneumoniae	1 (2.8)
Serratia marcescens	1 (2.8)
Streptococcus dysgalactiae	1 (2.8)
No growth	21 (58.3)

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treated using the arthroscopic debridement approach with an additional posterolateral portal, use of a 70° arthroscope, irrigation with >20 L of normal saline, placement of multiple separate suction drains, and use of appropriate antibiotics. Only two cases required reoperation (5.5%), a rate which was strikingly lower than rates of 26% to 32% that have been previously reported [3,11] for arthroscopic treatment of septic arthritis of the shoulder.

The surgical methods for septic arthritis of shoulder include both open arthrotomy and arthroscopic debridement. There is no consensus on which method is the best treatment for septic shoulder. Several studies have been conducted regarding surgical methods. Böhler et al. [17] compared 38 cases of arthrotomy to 21 cases of arthroscopic debridement. They showed that open arthrotomy is the more effective surgical method. However, Bovonratwet et al. [18] reported similar rates of reoperation and postoperative complications between the two surgical methods. Jiang et al. [19] also reported no difference in the reoperation rate between these two surgical methods. Some studies showed that arthroscopic surgery is ineffective on higher Gächter stages of septic arthritis [9,20]. However, Jeon et al. [3] conducted arthroscopic debridement in patients with higher Gächter stages (nine cases in stage III and two cases in stage IV). They reported reoperation in two of nine cases in stage III and in one of two cases in stage IV. In our study, all patients underwent primary arthroscopic surgery. There were 12 cases (33.3%) in Gächter stage III and four cases (11.1%) in Gächter stage IV. Two cases of Gächter stage III required reoperation. We believe that arthroscopic surgery would be an excellent treatment for septic shoulder arthritis even in higher Gächter stages if sufficient irrigation and debridement are performed and proper drains are used.

When we included data from studies [4,7,21] in which a mixed treatment approach was used, including open arthrotomy, our rate of reoperation of 5.6% was still low compared to reported rates ranging from 14.7% to 32%. We reviewed several studies that reported the reoperation rate for their case series (Table 3). Jeon et al. [3] reported a 26% rate of reoperation among 19 cases where arthroscopic treatment was performed for septic shoulder arthritis, with the number of arthroscopic procedures required to achieve infection resolution being correlated to the stage of infection. Abdel et al. [11] reported that, among 50 patients, nearly one in three required additional surgical intervention. In the study by Klinger et al. [4], 12 cases of septic shoulder were treated with the arthroscopic technique, and the other 11 cases used a combination of arthroscopic and open techniques. The need for an additional open technique was determined based on the clinical extent of the infection, duration of symptoms, the intraoperative Gächter stage, and the observation of an abscess or spread of the septic area on preoperative MRI. The authors noted a 26% rate of reoperation overall and a 25% rate of reoperation among cases treated with only the arthroscopic technique. Cho and Oh [7] reported a 14.7% rate of reoperation among 34 septic shoulders, with 22 treated by arthroscopy and 12 by an open approach; an 18.2% rate of reoperation was noted among cases treated with arthroscopy only. The open method was performed when there was evidence of osteomyelitis or abscess formation in the subcoracoid space on preoperative MRI. Duncan and Sperling [21] reported a 21% rate of reoperation among 19 septic shoulders treated with an open (nine cases) or arthroscopic (10 cases) technique, with the approach selected based on the surgeon's preference.

Currently, there is no standardized treatment method or protocol for septic arthritis of the shoulder. They tend to be selected based on the surgeon's preference and experience. Based on our data, we emphasize the importance of complete debridement and sufficient irrigation, with drainage, when treating septic shoulders. Complete debridement using an additional posterolateral portal, 70° arthroscope, abundant irrigation (with >20 L of normal sa-

Table 3. Comparison to previous studies on septic arthritis of the shoulder joint

Study	No. of cases	Method (open:arthroscopic)	Reoperation rate (only in arthroscopic, %)	Mean age (yr)	Mean follow-up (mo)	Mean symptom duration (day)	Irrigation (L)	Suction drain		Culture positive rate (%)
								Number	Duration (day)	
Duncan and Sperling [21]	19	Mix (9:10)	21	75.5 (49–94)	6	NA	NA	NA	NA	100
Klinger et al. [4]	23	Mix (12:11)	26 (25)	64 (41–85)	3	16 (5–76)	10	NA	2	87
Cho and Oh [7]	24	Mix (22:12)	14.7 (18.2)	61.8 (32–79)	32.4	23.3 (1–120)	12	NA	15.6±9.7	38
Jeon et al. [3]	19	Arthroscopic	26	59 (23–85)	16.4	21 (7–56)	5–20	NA	NA	68
Abdel et al. [11]	50	Arthroscopic	32	66 (25–97)	31	8 (1–60)	10	Only 1	NA	100
This study	36	Arthroscopic	5.5	63.8 (41–91)	11.4	10.9 (1–35)	25.1±8.1	3.3 (Maximum 4)	8.9±4.3	42

Values are presented as median (range) or mean±standard deviation unless otherwise indicated.
NA, not applicable.

line), and sufficient drainage (using multiple separate suction drains) may reduce the rate of reoperation.

Using a 70° arthroscope and a posterolateral portal is useful to achieve complete debridement. To access the posteroinferior SA space, where the infraspinatus and teres minor exist, open debridement was preferred. Cho and Oh [7] chose an open debridement in patients with subcoracoid abscesses to achieve thorough debridement and irrigation [6]. However, a 70° arthroscope can easily access the subcoracoid and posteroinferior SA space. Furthermore, we created an additional posterolateral portal to approach the posterior and inferior GH joint space and bare area of the humerus, which allowed us to complete a meticulous debridement of this difficult-to-reach area. We performed thorough debridement and irrigation without conversion to the open arthrotomy.

Among 36 patients, only one space was involved in 41.7% (GH joint only in 14 cases and the SA space only in one case). In patients with intact rotator cuff tear, these two spaces may be fully separated. However, contamination into the other space is difficult to avoid. Even if the two spaces are separated, arthroscopic instruments should be passed into the SA space to access the GH joint. Because irrigation with normal saline is performed under positive pressure, the surgeon should be careful to prevent the spread of infection.

Sufficient irrigation with drainage also contributes to successful surgical management of septic arthritis. Previous studies [3,4,7,11] have used up to 10 L of normal saline for irrigation, whereas we used 25.1 ± 8.1 L of saline for irrigation to ensure a thorough debridement. Recently, Joo et al. [22] reported that a large volume of irrigation (> 16.8 L) was important to lower recurrence after arthroscopic surgery of septic shoulder. Utilizing large volumes of irrigation solution is better for infection control, despite being time consuming. Furthermore, we inserted multiple separate 3.2-mm-diameter suction drains (average, 3.3 drains) after the procedure, usually two drains into the anterior and posterior GH joint spaces, and two drains into the anterior and posterior SA space, wherever the infection focus was identified during arthroscopy. These drains were removed sequentially, according to the daily output. In most previous studies, information regarding the number, location, and duration of indwelling drains was not reported (Table 3). Jung et al. [23] reported on the successful treatment and management of septic arthritis of the shoulder using continuous negative pressure drainage. They inserted a small-diameter (3.2 mm) drain into the GH joint space and a large-diameter (6.7 mm, 20-Fr chest tube) drain into the SA space, with 15-cm H_2O of continuous negative pressure applied. Similarly, in our arthroscopic protocol, multiple drains placed in separate locations and connected to separate suction bags facilitated proper drainage after surgery and, consequently, lowered the rate of reoperation, with smaller size drains used and a shorter indwelling duration of the drain.

The use of appropriate antibiotics for the treatment of septic arthritis is important. The overall recommended duration for antibiotics is at least 4–6 weeks, and oral antibiotics may be considered if symptoms improve after intravenous antibiotics have been administered for at least 2 weeks [24]. In the current study, the antibiotics were chosen according to the results of microbial culture with consultation from an infectious disease specialist. We changed intravenous antibiotics to oral antibiotics after normalization of the CRP level, as advised by the infectious disease specialist. CRP is the most widely used parameter to evaluate treatment of septic arthritis [24,25]. We used intravenous antibiotics for 3.9 ± 1.8 weeks, followed by oral antibiotics for 3.6 ± 1.9 weeks. In the current study, mixing antibiotics into the irrigation fluid was not performed because sufficient antibiotics level in the synovial fluid can be reached after intravenous administration [26,27]. Moreover, a chemical synovitis may occur after intra-articular use of antibiotics [28].

In our study, the most common causative organism of septic arthritis was *S. aureus* (10 shoulders), specifically MSSA (six shoulders) and MRSA (four shoulders), and this overall trend was similar to that of previous studies [3,4,6,7,11,21,23]. However, the rate of positive results for the culture was relatively low (42%). As our institution is a tertiary hospital, many patients were referred from another hospital and had been prescribed antibiotics prior to aspiration or operation, which may explain the low positive culture rate [7]. *Cutibacterium acnes* may also be the cause for the low positive results rate because we could not perform long-term cultures of specimens. *C. acnes* is an anaerobic bacterium found in moist skin areas, including the axilla, sebaceous gland, and hair follicles. It is one of the most common shoulder infection pathogens identified after arthroscopic operation [29,30] and is occasionally found in naïve septic arthritis of the shoulder [21]. Importantly, *C. acnes* is a slow-growing organism and, thus, longer culture duration is needed. Therefore, multiple culture specimens must be kept for over 2 weeks to determine the causative organism to inform the selection of effective antibiotics.

Limitations

The major limitation of our study was the absence of a control group, which was not possible for ethical reasons. In addition, our reoperation rate was so low that we were unable to include a comparison to eradiated patients and recurred patients. We instead compared our results to those from previous studies to emphasize that our techniques may lead to better outcomes relative to those of previous studies. The lack of long-term follow-up was another limitation. However, infection control of septic arthritis is usually

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completed within 6 months following surgery, and any required reoperation is usually performed within this time. Furthermore, assessments of the definite treatment outcome for the accompanying rotator cuff tear or osteoarthritis were not included in this study. Other limitations included the retrospective study design, small sample size, limited ability to compare preoperative and postoperative clinical information, and lack of specific endpoints for the outcome or eradication of infection markers. However, as septic arthritis of the shoulder joint is a relatively rare disease requiring urgent treatment, these limitations were inevitable and do not alter the importance of our results.

Our findings indicate that to reduce the reoperation rate of septic arthritis of the shoulder, complete debridement and sufficient irrigation with proper drainage are essential. We performed complete debridement with thorough GH synovectomy, using an additional posterolateral portal and SA bursectomy with a 70° arthroscope, as well as sufficient irrigation with > 20 L of normal saline and proper drainage using multiple separate suction drains in each location. Arthroscopic treatment for septic arthritis of the shoulder may yield better outcomes, especially in terms of the rate of reoperation.

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Evaluation of Deltoid Origin Status Following Open and Arthroscopic Repair of Large Rotator Cuff Tears: A Propensity-Matched Case-Control Study

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Background: The purpose of this study was to evaluate and compare deltoid origin status following large rotator cuff repair carried out using either an open or an arthroscopic method with a propensity score matching technique.
Methods: A retrospective review of 112 patients treated for full-thickness, large rotator cuff tear via either a classic open repair (open group) or an arthroscopic repair (arthroscopic group) was conducted. All patients included in the study had undergone postoperative magnetic resonance imaging (MRI) and clinical follow-up for at least 12 and 18 months after surgery, respectively. Propensity score matching was used to select controls matched for age, sex, body mass index, and affected site. There were 56 patients in each group, with a mean age of 63.3 years (range, 50–77 years). The postoperative functional and radiologic outcomes for both groups were compared. Radiologic evaluation for postoperative rotator cuff integrity and deltoid origin status was performed with 3-Tesla MRI.
Results: The deltoid origin thickness was significantly greater in the arthroscopic group when measured at the anterior acromion (P=0.006), anterior third (P=0.005), and middle third of the lateral border of the acromion level (P=0.005). The deltoid origin thickness at the posterior third of the lateral acromion was not significantly different between the arthroscopic and open groups. The arthroscopic group had significantly higher intact deltoid integrity with less scarring (P=0.04). There were no full-thickness deltoid tears in either the open or arthroscopic group.
Conclusions: Open rotator cuff repair resulted in a thinner deltoid origin, especially from the anterior acromion to the middle third of the lateral border of the acromion, at the 1-year postoperative MRI evaluation. Meticulous reattachment of the deltoid origin is as essential as rotator cuff repair when an open approach is selected.

Keywords: Propensity score; Rotator cuff; Arthroscopy; Magnetic resonance imaging

INTRODUCTION

Rotator cuff repair is one of the most commonly performed types of shoulder surgery. Improvements in arthroscopy techniques have shifted the preference for open repairs to all-arthroscopic rotator cuff procedures. All-arthroscopic rotator cuff repair has been accepted as the gold standard to treat rotator cuff repair [1,2]. An arthroscopic approach is favored by shoulder surgeons due to its

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minimally invasive nature, which causes less insult to the deltoid muscle. Reducing trauma to the deltoid is believed to favor rehabilitation and therefore produce better clinical outcomes [3,4]. Despite movement toward all-arthroscopic rotator cuff repairs, open repairs are still being performed in cases where arthroscopic surgery is not feasible. In a traditional open repair of a large rotator cuff tear, deltoid detachment is performed to allow visualization of and access to the torn rotator cuff. The deltoid muscle is then repaired following rotator cuff repair. Previous studies have reported negative effects resulting from deltoid detachment that lead to more postoperative pain and poor shoulder function [5-7]. For this reason, the risk of deltoid insult is considered an indication for arthroscopic rotator cuff repair. Conversely, severe rotator cuff retraction and adhesion often complicate arthroscopic rotator cuff repair and may result in poor shoulder function [8-10].

Small rotator cuff tears are usually repairable using an arthroscopic technique, which typically produces satisfactory results. Medium rotator cuff repairs are suitable for both arthroscopic and open approaches, but there is less concern about deltoid injury due to the insignificant amount of deltoid detachment required in tears of this size. In contrast, massive rotator cuff tears are unpredictable regardless of the form of treatment, and they do not represent the most common type of pathology encountered [11,12]. Many studies have compared open and arthroscopic rotator cuff repair [1,11-17], but they have only compared the clinical outcomes and rotator cuff integrity with a non-matched arm, including all sizes of rotator cuff tears (small to massive) using a non-uniform surgical repair technique for open procedures [12,14-16]. We aimed to evaluate deltoid integrity following both open and arthroscopic repairs for large rotator cuff tear by comparing postoperative deltoid status. We hypothesized that (1) deltoid origin will change following large rotator cuff repair, and (2) open rotator cuff repairs cause more deltoid origin insults due to the re-attachment procedure required.

METHODS

This retrospective study was designed as a matched case control study that used a propensity score matching technique. It was approved by the Institutional Review Board of Asan Medical Center (IRB No. 2019-0787), and informed consent was waived due to retrospective nature of this study.

Patient Selection

We included 1,380 patients who underwent either an open or an arthroscopic rotator cuff repair between 2012 and 2016 in Asan Medical Center, Seoul, Korea. The inclusion criteria were (1) full thickness rotator cuff tear, (2) and primary repair, (3) in patients with at least one follow-up magnetic resonance imaging (MRI) scan performed 12 months after surgery, and (4) at least 18 months of clinical follow-up. The exclusion criteria were as follows: (1) incomplete medical data ($n=30$), (2) previous surgery in the affected shoulder, (3) small (<1 cm), medium (1–3 cm), or massive tear (>5 cm), (4) concurrent subscapularis tear, acromioclavicular arthritis that required concurrent distal clavicle resection, superior labral lesions that require concurrent repair, long head biceps pathology that required tenodesis, severe glenohumeral arthritis, anterior glenohumeral instability, (5) bilateral rotator cuff tears, or (6) worker's compensation case. Rotator cuff repair was performed by by (I.H.J) and (J.M.C).

Surgical Technique

Under general anesthesia, the patients were positioned in the beach-chair position and were given an interscalene block to reduce postoperative pain. Examinations under anesthesia were performed prior to the surgical procedure to assess passive range of motion (ROM).

Arthroscopic Repair Technique

A standard posterior portal was created 2 cm inferior to and 1 cm medial to the posterolateral acromion corner. The anterior portal through rotator interval was introduced using an outside-in technique. A standard diagnostic round was performed. The arthroscope was then introduced into the subacromial space to assess the acromion undersurface. An anterolateral acromioplasty was routinely performed in all patients. Afterward, a lateral portal was created under direct visualization with the help of a spinal needle; this portal later served as the main viewing portal. A bursectomy was carried out to expose the rotator cuff tear and shape. The mobility of the rotator cuff was evaluated with a retriever. The edge of the rotator cuff was refreshed and trimmed with an arthroscopic shaver and/or a punch. The size of the tear was measured mediolaterally. Greater tuberosity was then prepared with a burr for attaching the remnant tissue. The number of anchors used was dependent on the size of the rotator cuff tear and the repair configuration (single or double row). In the single-row repair configuration, the rotator cuff was routinely fixed using a bio-composite PEEK anchor (Helicoil PK 4.5 mm; Smith & Nephew, Andover, MA, USA). In the double-row repair configuration, the rotator cuff was routinely fixed with a bio-composite PEEK (polyetheretherketone) anchor in a medial row (Helicoil PK 4.5 mm, Smith & Nephew) and lateral row (Footprint Ultra PK 4.5 mm, Smith & Nephew). An attempt was always made for tensionless repair with the maximum surface coverage of the footprint at the

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greater tuberosity.

Open Repair Technique

A 5-cm skin incision was made longitudinally starting from the mid-point of one-third of the lateral margin of the acromion to the lateral border of the coracoid process. The deltoid was split longitudinally about 3–4 cm between the anterior and middle deltoid. A curvilinear incision was made to take down a small portion of the anterior deltoid, and the coracoacromial ligament was peeled off from the undersurface of the acromial spur and preserved for later reattachment. An anterolateral acromioplasty was routinely performed with an oscillating saw. Multiple non-absorbable traction No. 2-0 Mersilk (Ethicon, Cincinnati, OH, USA) sutures were placed along the edge of the torn rotator cuff to assist in mobilization of the tendon. Gentle release of adhesion and removal of any bursal hypertrophy were carried out using Mayo scissors with respect of the remnant rotator cuffs. Once adequately mobilized, the margin was converged with multiple tendon-to-tendon sutures when necessary, and the torn edge of the tendon was reattached to the greater tuberosity by No. 2-0 Ethibond (Ethicon, Cincinnati, OH, USA) in a trans-osseous, double mattress fashion (Fig. 1). The deltoid was repaired along with the coracoacromial ligament to the acromion with heavy absorbable No. 1 Vicryl (Ethicon) suture.

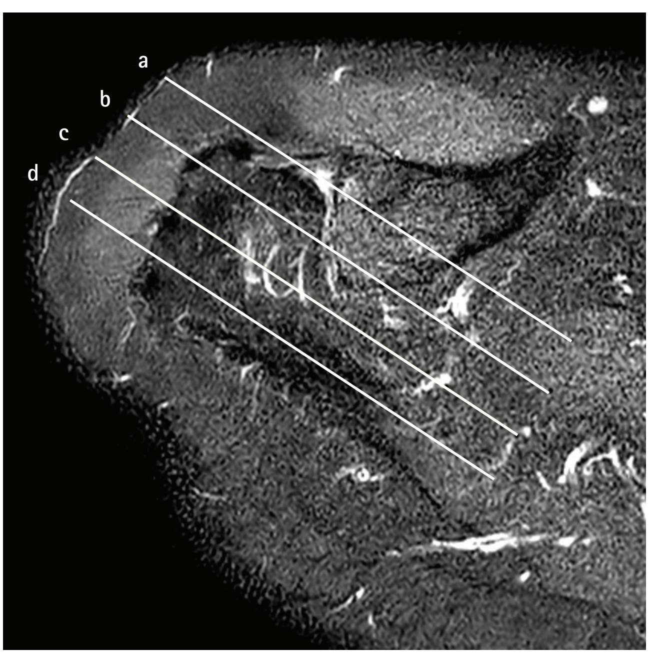

Fig. 1. Axial view of the shoulder magnetic resonance showed the region of interest for deltoid thickness measurement in four regions of interest: anterior acromion (a), anterior third (b), middle third (c), and posterior third (d) of the lateral acromion border according to scapular plane.

Postoperative Protocol

All patient arms remained in a sling for 6 weeks postoperatively, and only passive ROM was allowed during this time period. After 6 weeks, gradual full active motion was instituted, progressing to resistive strengthening, which was continued for three to 4 months. Heavy labor activities were restricted until at 6 months after surgery.

Clinical Outcome Assessment

An independent nurse practitioner documented the clinical assessment of pre-operative and postoperative parameters for (1) pain score with visual analog scale (VAS) score, (2) functional outcome with age-adjusted Constant score and American Shoulder and Elbow Surgeons (ASES) score, (3) ROM (forward elevation and external rotation) with a hand-held goniometer, and (4) muscle power (abduction and external rotator muscle strength) assessed with a myometer (Mecmesin Co., Nottingham, UK). Any complications that occurred following surgery were also recorded.

Radiological Outcome Assessment

All patients underwent radiological assessment with a 3-Tesla (3T) MRI at a minimum of one year following rotator cuff repair. The rotator cuff's integrity was evaluated using the method described by Sugaya et al. [18] The supraspinatus and infraspinatus were evaluated for any fatty infiltration according to the method of Fuchs et al. [19] The deltoid origin muscle thickness was assessed with MRI according to Gerber et al. [20] for integrity, scarring, and thickness. The deltoid origin thickness was measured in four zones: the anterior acromion and the anterior third, middle third, and posterior third at the inferior surface of the lateral acromion border according to the scapular plane (Fig. 1). Any discontinuity of any part of the deltoid origin on all sequences in sequential MRI slices was defined as a deltoid tear (Fig. 2). Scarring of the deltoid was confirmed as a high signal area on T1-weighted images with preserved integrity (Fig. 3). The postoperative thickness of the deltoid in each region of interest of the lateral acromion border was then compared to its preoperative measurement (Fig. 4). The evaluations were done independently by four shoulder-fellowship trained orthopedic surgeons (EK, JMK, HJK, DJP), and any discrepancies were resolved in a consensus meeting; if disagreement persisted, a senior shoulder surgeon who was not involved in the surgery (KHK) was consulted for the final assessment. All radiologic parameters were recorded both pre- and postoperatively.

Statistical Analysis

Sample size calculation with the a power of 90% and a 0.05 two-sid-

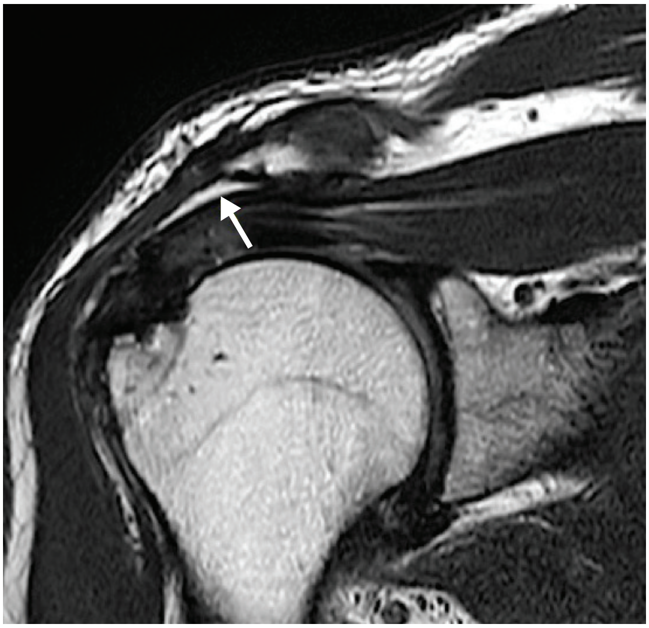

Fig. 2. Deltoid origin partial tear (arrow) 1 year after open rotator cuff repair.

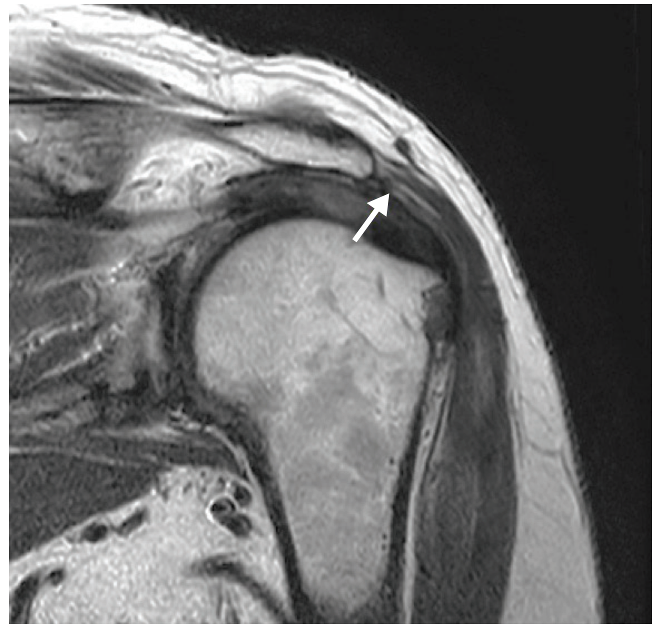

Fig. 3. Deltoid origin scarring following an open rotator cuff repair showing a high signal (arrow) at the interstitial layer of the deltoid origin.

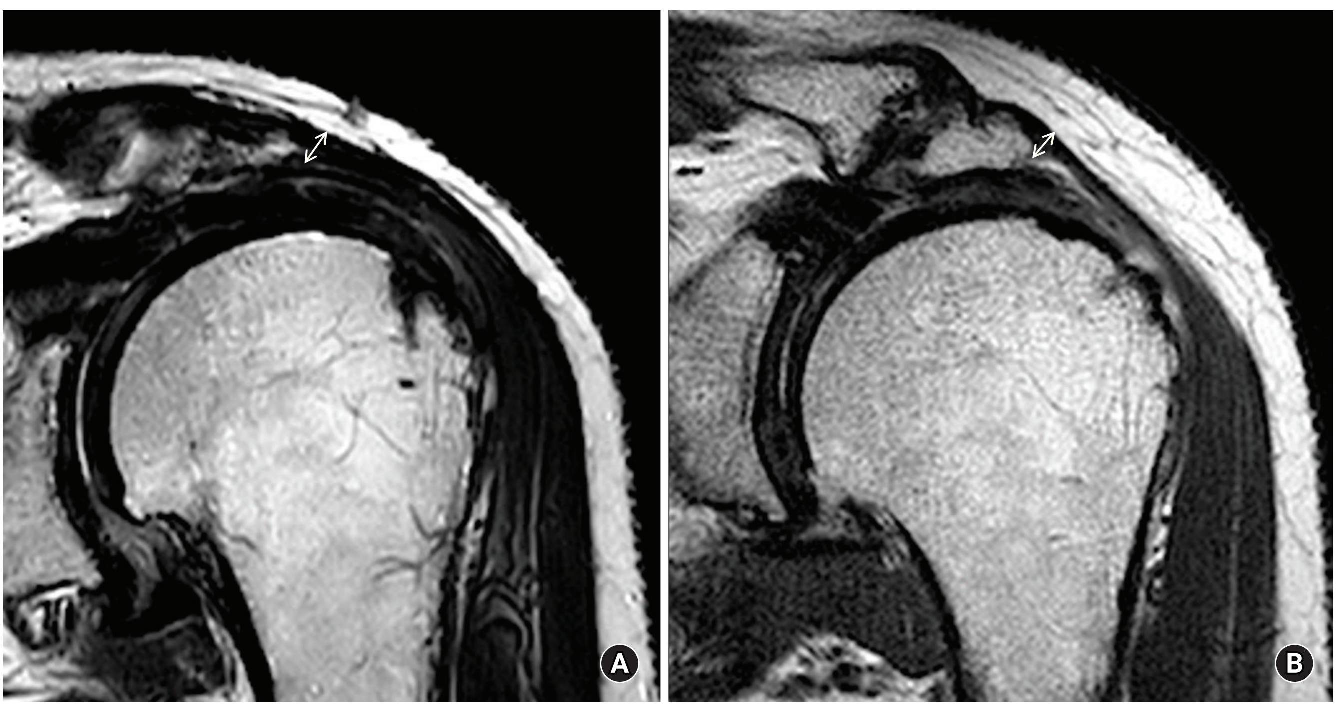

Fig. 4. (A) Measurement of the thickness of the deltoid origin (arrow) on magnetic resonance imaging (MRI) in the scapular plane prior to open rotator cuff surgery revealed the initial thickness. (B) An MRI evaluation 1 year after surgery showed a thin deltoid origin with a greater than 50% reduction in thickness (arrow) compared to the initial thickness.

ed significance level was performed with the minimum expected clinical importance difference in means of constant shoulder score for 10.4 points [21]. A minimum sample size of 47 patients in each group (including an extra 10% due to the risk of loss to follow-up) was required. The propensity score matching technique was carried out with age, sex, affected shoulder, and body mass index as covariates. A total of 1,380 cases were recruited, but 30 were excluded because of incomplete medical data. Of the remaining 1,350 pa-

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tients, 543 underwent open rotator cuff repair, while 837 underwent arthroscopic rotator cuff repair. Of the 543 open-repair patients, only 91 completed at least 18 months of clinical follow-up. Of these 91 patients, 56 had completed at least 1-year MRI and follow-up visits. The controls were the arthroscopic group that had been matched for age, sex, BMI, and affected side selected by propensity score matching (1:1 matching).

Tests for normality using the Kolmogorov-Smirnov method were applied to all datasets prior to statistical analysis. A Mann-Whitney U-test was used to compare any datasets with a skewed distribution, while an independent t-test was carried out to compare the datasets with a normal distribution. The significance level was set at $P<0.05$. Statistical analysis was performed using IBM SPSS ver. 23.0 (IBM Corp., Armonk, NY, USA) under the supervision of a biostatistician.

RESULTS

Patient Demographics and Preoperative Baseline Data

A total of 112 patients was included for analysis. The characteristics and preoperative baseline data of the open group and arthroscopic group are shown in Tables 1 and 2. There were no significant differences in demographic characteristics between these two matched groups.

Clinical Outcome Assessment

At the mean follow-up of 19.1 months, ROM, Constant score, ASES score, muscle power, and VAS were significantly improved following surgery. The arthroscopic group showed significantly better ROM ($P=0.006$) and VAS score ($P<0.001$) compared to the open group. In contrast, the open group demonstrated significantly better Constant and ASES scores ($P=0.012$ and $P=0.047$, respectively). The muscle powers for abduction and external rotation were superior in the open group, though there was no statistical difference ($P=0.068$ and $P=0.182$, respectively). No complications were seen in either group. The postoperative clinical outcomes are shown in Table 3.

Radiological Outcome Assessment

Fatty infiltration of the supraspinatus and infraspinatus showed no significant difference between the two groups. The retear rate was higher in the arthroscopic group (21.4%) compared to the open group (17.8%), though the difference was not statistically significant ($P=0.300$). No patient required revision surgery (even in the case of a cuff tendon re-tear and deltoid injury) at the final follow-up as all were in an asymptomatic state. The deltoid origin thickness was significantly greater in the arthroscopic group when measured at the anterior acromion area (6.2 ± 1.4 vs. 4.9 ± 1.1 mm, $P=0.006$), anterior third (6.3 ± 1.3 vs. 4.5 ± 0.9 mm, $P=0.005$), and middle third of the lateral acromion border (6.7 ± 1.3 vs. 4.6 ± 1.0 mm, $P=0.005$). The arthroscopic group had significantly higher intact deltoid integrity with less scarring ($P=0.04$). There were no full-thickness deltoid tears in our observations for both open and arthroscopic groups. The postoperative thickness of the deltoid insertion was significantly maintained with less than 50% reduction from its preoperative thickness in the arthroscopy group (80.7%)

Table 1. Baseline demographics for both groups

Variable	Open group (n = 56)	Arthroscopic group (n = 56)	P-value
Age (yr)	63.66 ± 7.97	61.56 ± 5.51	0.111
Sex			0.109
Female	37 (66.7)	33 (59.3)	
Male	19 (33.3)	23 (40.7)	
Affected shoulder			0.06
Right	43 (77.8)	48 (85.2)	
Left	13 (22.2)	8 (14.8)	
Body mass index (kg/m^2)			0.805
Underweight (< 18.5)	0	0	
Normal (18.5–24.9)	29 (51)	25 (44.6)	
Overweight (25.0–29.9)	27 (49)	28 (50)	
Obese class I (30.0–34.9)	0	3 (5.4)	
Obese class II (35.0–39.9)	0	0	
Obese class III (40.0)	0	0	
Comorbidity	24 (42.9)	29 (52.7)	0.302

Values are presented as mean±standard error or number (%).

Table 2. Preoperative clinical and radiologic data for both groups

Variable	Open group	Arthroscopic group	P-value[a)]
Presence of shoulder stiffness	12 (21.4)	12 (21.4)	1.000
Presence of shoulder trauma	16 (28.5)	15 (26.7)	0.569
ROM			
FE	139.63 ± 5.18	144.26 ± 3.63	0.468
ER	43.52 ± 4.12	43.15 ± 7.74	0.827
Functional score			
Constant score	54.11 ± 3.63	56.15 ± 2.75	0.657
ASES score	57.15 ± 3.91	58.63 ± 3.32	0.774
Muscle power			
Abduction	3.63 ± 0.37	2.85 ± 0.35	0.156
ER	4.05 ± 0.37	3.16 ± 0.27	0.58
Pain VAS	4.89 ± 0.35	5.59 ± 0.31	0.14
Fatty infiltration			
Supraspinatus	0.4 ± 0.65	0.78 ± 0.71	0.192
Infraspinatus	0.5 ± 0.7	0.77 ± 0.5	0.283
Deltoid muscle thickness (mm)			
At anterior acromion area	6.9 ± 0.9	7.0 ± 0.7	0.246
At anterior third of lateral acromion border	6.6 ± 0.8	6.6 ± 0.7	0.171
At middle third of lateral acromion border	6.6 ± 0.9	6.5 ± 0.8	0.264
At posterior third of lateral acromion border	6.8 ± 1.1	7.0 ± 0.8	0.289

Values are presented as number (%) or mean±standard error.
ROM, range of motion; FE, forward elevation; ER, external rotation; ASES, American Shoulder and Elbow Surgeons score; VAS, visual analog scale.
[a)]Significant level, $P<0.05$.

compared to the open group (64.1%; P = 0.04).

DISCUSSION

The current study showed that there was a difference in postoperative deltoid status between arthroscopic and open repairs of large rotator cuff tears. The deltoid origin thickness was reduced to more than 50% of its preoperative thickness in 19 of 56 patients (33.9%) who underwent open rotator cuff repair. In contrast, deltoid origin thickness was preserved within 50% of its preoperative thickness in 43 of 56 patients (76.7%) who underwent arthroscopic rotator cuff repair. The clinical outcomes for abduction muscle power were not influenced by deltoid function. The current study found that open rotator cuff repair resulted in better functional outcomes of Constant and ASES scores as measured variables. The minimal clinically important differences were a Constant score of 10.4 [22] and a range from 12 to 17 for ASES score [23]. Despite significant superiority in functional outcomes following open rotator cuff repair, the differences between groups did not exceed the smallest amount to be meaningful; therefore, this finding is disregarded and considered as comparable outcomes [24]. Open rotator cuff repair procedures for large rotator cuff tears caused more deltoid origin injury and had no significant influence on clinical outcomes due to the meticulous re-attachment procedure required. Therefore, reattachment of the deltoid origin is essential when performing open rotator cuff repair surgery.

The current study found that the incidence of deltoid origin tear following rotator cuff repair was 5.4%. However, this rate was inconsistent with previous studies because varying sizes of rotator cuff tears were included, from large to massive [25,26]. Our study focused on large-sized rotator cuff tears, so we avoided different amounts of deltoid detachment during open surgery. This approach enabled us to confirm a definitive incidence for deltoid origin tear.

The integrity of rotator cuff repair and deltoid origin reattachment procedures performed at our center were evaluated using MRI due to the unpredictability of ultrasonographic examinations [27]. The MRI evaluation was carried out 1 year following surgery with a 3T scanner in our study. We believe that both timing and MRI magnitude may play a role in evaluating deltoid origin status. A previous study obtained MRI evaluations with a 1.5-Tesla scanner 6 months after surgery [25]. We think that a longer interval between repair and MRI provides a better evaluation of the disease course, and a higher MRI magnitude increases the sensitivity,

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Table 3. Postoperative clinical and radiologic data for both groups

Variable	Open group	Arthroscopic group	P-value
ROM			
FE	151.85±0.93	158.33±2.05	0.006[a)]
ER	44.26±0.34	50.93±2.18	0.002[a)]
Functional score			
Constant score	75.93±1.88	69.59±1.53	0.012[a)]
ASES score	89.19±1.36	85.33±1.32	0.047[a)]
Muscle power (kg)			
Abduction	4.47±0.43	3.49±1.51	0.068
ER	4.47±0.36	3.92±0.18	0.182
Pain VAS	1.78±0.21	0.59±0.15	<0.001[a)]
Fatty infiltration	0.35±0.58	0.51±0.60	0.181
Supraspinatus			
Infraspinatus	0.55±0.70	0.67±0.50	0.182
Postoperative rotator cuff integrity			0.642
Sugaya type I	28 (50)	26 (47.3)	
Sugaya type II	18 (32.1)	17 (30.9)	
Sugaya type III	8 (14.3)	8 (14.5)	
Sugaya type IV	0	4 (7.3)	
Sugaya type V	2 (3.6)	0	
Deltoid origin thickness (mm)			
At anterior acromion area	4.9±1.1	6.2±1.4	0.006[a)]
At anterior third of lateral acromion border	4.5±0.9	6.3±1.3	0.005[a)]
At middle third of lateral acromion border	4.6±1.0	6.7±1.3	0.005[a)]
At posterior third of lateral acromion border	6.1±1.2	6.8±1.4	0.354
Postoperative deltoid MRI status			
Intact	38 (67.9)	40 (72.7)	0.04[a)]
Scarring	15 (26.8)	12 (21.8)	
Partial thickness tear	3 (5.4)	3 (5.4)	
Postoperative deltoid insertion thickness			0.04[a)]
<50% reduce	34 (66.1)	43 (76.7)	
>50% reduce	19 (33.9)	10 (23.3)	

Values are presented as mean±standard error or number (%).
ROM, range of motion; FE, forward elevation; ER, external rotation; ASES, American Shoulder and Elbow Surgeons score; VAS, visual analog scale.
[a)]Significant level, $P<0.05$.

which allows to detection of structural changes of deltoid origin and thus avoids underestimation of deltoid origin injury compared to an MRI scanner with a lower magnitude. This approach may explain why our findings produced a larger number of deltoid origin tears.

The deltoid origin thickness was measured regionally and was greater in the anterior acromion area and the anterior and middle thirds of the lateral acromion border area following arthroscopic rotator cuff repair. However, the deltoid thickness at the posterior third of the lateral acromion border was similar in the open and the arthroscopic groups. Standard anterolateral acromioplasty was used in all patients who underwent arthroscopic rotator cuff repair. In this technique, the amount of resection was limited to the anterior third of the lateral acromion border [28]. Therefore, the likelihood of injuring the deltoid origin will depend upon the extent of acromioplasty required. Anterolateral acromioplasty was also applied in all open rotator cuff repairs in our study. Nevertheless, we think that the extent of deltoid detachment needed to achieve cuff visualization was not consistent due to the variation in tear location and retraction level. A greater amount of deltoid origin involvement had a substantial influence upon the re-attachment procedure in open rotator cuff repair.

The current study had several strengths. First, we only included large rotator cuff tears and conducted an appropriate power analysis prior to the study. Second, a 3T MRI was used to evaluate both pre- and postoperative deltoid origin status. Third, this study ensured the inclusion of a matching case and control group by using propensity score matching to balance the clinical characteristics of the groups and therefore allow more accurate comparisons within observational studies by simulating a randomized controlled trial [29]. The matching technique, which included patient age, sex, affected site, and BMI, ensured assignment of a control patient to each case. This is a major advantage of the frequency matching technique in which the nearest neighbors are selected for each case to serve as a control despite any slight differences in the matching variable distribution. Because of potential residual confounding, regression models were also controlled for age, sex, and BMI [15-30]. Fourth, this study showed that attention should be given to the deltoid origin at the anterior acromion to the middle third of the lateral acromion border in open rotator cuff repairs since the deltoid origin is thinner in this area. Therefore, we advocate that surgeons utilize an adequate amount of the deltoid origin tendon during the reattachment procedure.

Limitations

The most significant limitation of this study is its retrospective nature. The included population was ideal for a clinical study, but it still may limit extrapolation of our findings to a general population, leading to selective bias in this study. This study also only included large tears, which limited translation of our results to all rotator cuff tear sizes. Despite these limitations, we attempted to minimize bias by excluding small, medium, and massive rotator cuff tears from our study design to provide a straightforward result. This study compared the clinical outcomes at the final follow-up visit as opposed to the postoperative timeline. MRI was used to evaluate deltoid origin status; however, the surgical repair itself may result in muscle scarring and thinning, which can lead to false positives on MRI scans. Nevertheless, despite these limitations, the accuracy provided by a 3T MRI scanner should minimize the incidence of false positives. One additional limitation was that it is difficult to blind the radiologic evaluation process due to the holes drilled in the acromion following open rotator cuff repair. Lastly, we suggest that future studies develop a better methodology to evaluate the deltoid status postoperatively.

The current study showed that there was a change in deltoid origin status following both open and arthroscopic repairs of large rotator cuff tears. Open rotator cuff repair resulted in a thinner deltoid origin, especially in the anterior acromion to the middle third of the lateral border of the acromion at the 1-year postoperative MRI evaluation. Meticulous reattachment of the deltoid origin is as essential as a proper rotator cuff repair for the open procedure.

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Primary Total Elbow Replacement for Treatment of Complex Distal Humerus Fracture: Outcomes of Short-term Follow-up

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Background: High complication rate after open reduction and internal fixation can lead to use of primary total elbow replacement (TER) in treatment of complex distal humerus fractures in elderly patients. The purpose of this study was to investigate the short-term outcomes and complications after primary TER in patients with complex distal humerus fracture.
Methods: Nine patients with acute complex distal humerus fracture were treated by primary TER using the semiconstrained Coonrad-Morrey prosthesis. The mean age of patients was 72.7 years (range, 63–85 years). Clinical and radiographic outcomes were evaluated over a mean follow-up of 29.0 months (range, 12–65 months) using visual analog scale (VAS) score for pain; Mayo elbow performance score (MEPS); Quick Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) score; and serial plain radiographs. Complications were also evaluated.
Results: At the final follow-up, mean VAS, MEPS, and Quick-DASH scores were 1.2, 80.5, and 20, respectively. The mean range of motion was 127.7° of flexion, 13.8° of extension, 73.3° of pronation, and 74.4° of supination. There was no evidence of bushing wear or high-grade implant loosening on serial plain radiographs. Three complications (33.3%) comprising two periprosthetic fractures and one ulnar neuropathy were observed.
Conclusions: Primary TER for treatment of complex distal humerus fractures in elderly patients yielded satisfactory short-term outcomes. However, surgeons should consider the high complication rate after primary TER.

Keywords: Elbow; Arthroplasty; Fracture; Complications; Total joint replacement; Clinical outcome

INTRODUCTION

Distal humerus fractures in the elderly are increasing with the aging population and are difficult to treat and challenging for orthopedic surgeons. The gold standard for treatment of displaced distal humerus fractures is open reduction and internal fixation (ORIF), along with early mobilization [1]. However, these fractures are often complicated by comminution, bone loss, intra-articular involvement, and poor bone quality. Complex distal humerus fractures in elderly patients may have inadequate internal fixation such that bony union is difficult. Successful treatment requires long-term immobilization and produces unsatisfactory clinical outcomes with complications [2]. The complication rate after ORIF for distal humerus fractures has been reported as over 35% [1,2]. The complications include fixation failure, nonunion, heterotopic ossification, ulnar neuropathy, and stiffness [1,2]. These difficulties have led to use of total elbow replacement (TER) as a primary treatment option for complex distal humerus frac-

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tures in elderly patients.

Several studies have reported that primary TER produces superior outcomes compared with ORIF and is a reasonable option for elderly patients with comminuted intra-articular distal humerus fractures [3-6]. Over the last decade, the number of displaced distal humerus fractures in elderly patients treated with TER has increased dramatically because of the aging population [7]. The advantages of TER over ORIF include early rehabilitation and satisfactory short-term outcomes. However, the disadvantages include surgeon-imposed activity restrictions and several catastrophic complications including infection, aseptic loosening, periprosthetic fracture, and potential need for revision arthroplasty [8]. With these distinct benefits and risks, it remains unclear whether TER should be a primary treatment of distal humerus fractures in elderly patients. The purpose of this study was to investigate the outcomes and complications after primary TER in patients with complex distal humerus fracture.

METHODS

This study was approved from the Institutional Review Board of Dongsan Medical Center with exemption of informed consent (IRB No. 2019-10-030).

Between 2012 and 2019, we treated 16 patients with primary TER for acute complex distal humerus fractures. Nine of 16 patients were retrospectively reviewed because six had died and one was unreachable. Inclusion criteria were (1) age older than 60 years at the time of initial trauma, (2) primary TER for acute fractures, and (3) follow-up period longer than 12 months after surgery. The decision to perform TER was based on patient age and working status, degree of comminution with intra-articular involvement, osteoporosis, and medical comorbidity.

The mean age of the patients was 72.7 years (range, 63–85 years). There were five women and four men. The mechanism of injury was slip in seven patients and fall in two patients. According to AO classification, seven patients had type C3 fracture, one had type A2 fracture, and one had type A3 fracture. One patient had an open fracture. The mean interval from initial trauma to TER was 27.8 days (range, 5–85 days) (Table 1). Three patients underwent temporary external fixation because of one open fracture, one impending compartment syndrome, and one ipsilateral proximal humerus fracture with poor condition of the soft tissue around the elbow joint. One patient with impending compartment syndrome underwent fasciotomy only.

All patients were treated using the semiconstrained Coonrad-Morrey prosthesis (Zimmer, Warsaw, IN, USA) via a triceps reflecting approach, and the ulnar nerve was transposed anteriorly. After surgery, a long-arm splint was applied in full extension to prevent wound perturbation. Passive and active motion exercises were started 2 weeks after surgery.

The mean follow-up period of patients was 29.0 months (range, 12–65 months). Clinical outcomes were assessed using the visual analog scale (VAS) score for pain; Mayo elbow performance score (MEPS); the Quick Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) score; and active range of motion (ROM) of the elbow joint. Serial plain radiographs were performed for all patients to evaluate fixation status, bushing wear, and implant loosening. The cementing technique was evaluated on immediate postopera-

Table 1. The demographic data of patients

Case	Age (yr)	Sex	Side	Injury mechanism	AO classification	Associated injury	Time to surgery (day)	Medical comorbidity	Follow-up (mo)
1	73	F	Rt	Slip down	C3		5	Hypertension	48
2	67	M	Rt	Slip down	C3	Open fracture	30	Hypertension, liver cirrhosis	44
3	71	F	Lt	Slip down	C3		18	Hypertension	23
4	70	M	Rt	Fall down	C3	Impending compartment syndrome	61	Gastric cancer, hypertension	21
5	71	M	Lt	Slip down	C3	Impending compartment syndrome	85		20
6	85	F	Lt	Slip down	A3		5	Cerebral infarction, hypertension	12
7	63	F	Rt	Slip down	C3		7	Hypertension, hypercholesterolemia	65
8	84	F	Lt	Slip down	A2		8	Dementia	15
9	71	M	Rt	Fall down	C3	Ipsilateral proximal humerus fracture	32	Diabetes mellitus, hypertension	13

F, female; M, male; Rt, right; Lt, left.

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tive radiographs for both components and was classified into three types (adequate, marginal, inadequate) as described by Morrey [9]. Bushing wear was assessed via anteroposterior radiograph at the final follow-up evaluation and was classified into three grades (normal, mild to moderate, extensive) as described by Ramsey et al. [10] Implant loosening was graded on anteroposterior and lateral radiographs according to the classification described by Morrey et al. [9] Radiolucency was graded as type 0 if the radiolucent line was less than 1 mm wide and involved less than 50% of the interface, type 1 if the radiolucent line was at least 1 mm wide and involved less than 50% of the interface, type 2 if the radiolucent line was more than 1 mm wide and involved more than 50% of the interface, type 3 if the radiolucent line was more than 2 mm wide and surrounded the entire interface, and type 4 if there was gross loosening [9].

RESULTS

At the final follow-up evaluation, the mean VAS score for pain was 1.2. Four patients had no pain, four had mild pain, and one had moderate pain. The mean MEPS was 80.5, with two excellent, five good, and two fair results. The mean Q-DASH score was 20. The mean ROM was 127.7° of flexion, 13.8° of extension, 73.3° of pronation, and 74.4° of supination (Table 2).

For the cement technique on immediate postoperative radiographs, five cases showed adequate adherence, and four cases had marginal adherence. Bushing wear was not observed on the final radiographs in all cases. According to loosening grade, there were three type 0, four type 1, and two type 2 cases on the final radiographs. Three complications (33.3%) were observed in nine patients; two patients with periprosthetic fracture around the humeral component with minor trauma were treated with ORIF and showed fair clinical results at the final follow-up. One patient had progressive ulnar neuropathy after TER and underwent adhesiolysis and decompression of the ulnar nerve at 5 months after TER.

Case 1

A 73-year-old woman (no. 1) was hospitalized for intercondylar comminuted fracture of the right distal humerus after a slip. On the 5th day after injury, we performed primary TER. At 48 months follow-up after TER, the patient had satisfactory clinical outcomes with no evidence of implant loosening (Fig. 1).

Case 2

A 63-year-old woman (no. 7) was hospitalized for intra-articular comminuted fracture of the right distal humerus after a slip. On the 7th day after injury, we performed primary TER. After surgery, the patient complained of a tingling sensation of the fourth and fifth fingers. At 5 months after surgery, we performed adhesiolysis and decompression of the ulnar nerve for progressive ulnar neuropathy with clawing deformity. At the 65-month follow-up after TER, the patient had excellent clinical outcomes with no evidence of implant loosening. Ulnar neuropathy was resolved completely (Fig. 2).

DISCUSSION

Although the number of distal humerus fractures in elderly patients has increased in the last decades, the results after ORIF in elderly patients with complex distal humerus fractures are highly variable, with many failures and poor outcomes [3-6]. Originally, TER was restricted to manage rheumatoid arthritis, posttraumatic arthritis, and fracture nonunion of the distal humerus. Recent studies have reported that primary TER for complex distal humerus fractures in elderly patients may be an alternative treatment with satisfactory outcomes [11-14]. TER involves immediate sta-

Table 2. Summary of the outcomes and complication after total elbow replacement in patients with complex distal humerus fracture

Case	Cementing technique	Bushing wear	Loosening grade	VAS score	MEPS	Q-DASH score	ROM				Complication
							Flexion	Extension	Pronation	Supination	
1	Adequate	Normal	0	0	100	12	120	10	80	80	
2	Adequate	Normal	2	3	80	23	140	0	80	80	
3	Adequate	Normal	2	4	65	19	150	0	80	80	Periprosthetic fracture
4	Marginal	Normal	0	0	80	12	120	15	70	70	
5	Marginal	Normal	1	1	80	15	105	5	70	70	
6	Marginal	Normal	1	1	80	35	145	45	60	70	
7	Adequate	Normal	0	0	100	12	150	0	80	80	Ulnar neuropathy
8	Adequate	Normal	1	0	80	25	120	30	70	70	
9	Marginal	Normal	1	2	60	27	100	20	70	70	Periprosthetic fracture

VAS, visual analog scale; MEPS, Mayo elbow performance score; Q-DASH, Quick Disabilities Of Arm, Shoulder, and Hand; ROM, range of motion.

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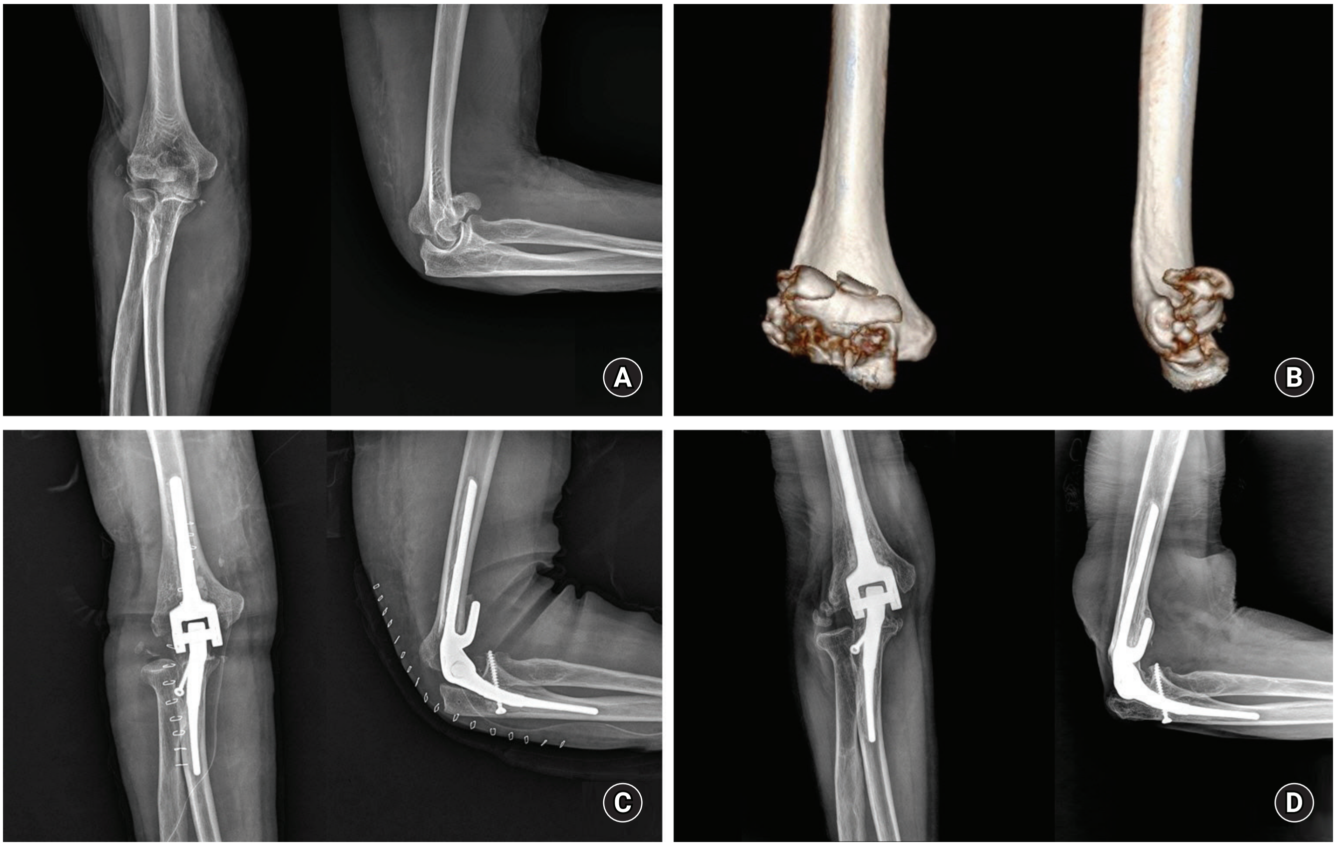

Fig. 1. (A, B) Initial radiographs and three-dimensional computed tomography images of a 73-year-old woman show an intercondylar comminuted fracture of the right distal humerus. (C) Immediate radiographs after total elbow replacement. (D) Radiographs at 48 months after surgery show no evidence of loosening with excellent clinical outcome.

bility, early mobilization, faster rehabilitation, and better short-term functional result in older low-demand patients with osteoporosis [4]. However, TER may accompany considerable postoperative complications such as infection, implant loosening, neurological problems, and periprosthetic fracture.

Several studies have reported short- to long-term outcomes and complication rate after TER for complex distal humerus fractures [5,6,11,12,14]. In 1997, Cobb and Morrey [12] first reported a series of 21 elderly patients who underwent primary TER for comminuted distal humerus fractures. They reported good or excellent results in 95% of patients at a mean follow-up of 3.3 years, with a reoperation rate of 5%. Lami et al. [14] reported 21 patients receiving TER for distal humerus fractures with a mean follow-up of 3.2 years, mean MEPS of 84, Q-DASH score of 32.4, mean flexion of 125°, and mean loss of extension of 22°. The complication rate was 9.5% without any revision surgery. Lee et al. [5] reported seven elderly Asian patients with distal humerus fractures treated with TER and achieved six excellent results and one good result in patients with low physical demands. The mean MEPS was 94.3 points, and mean follow-up was 24.9 months. Barco et al. [11] reported 44 TER in treatment of distal humerus fracture; patients were followed for a minimum of 10 years. The mean VAS for pain was 0.6, the mean flexion was 123°, and mean loss of extension was 24°. The mean MEPS was 90.5 points, with three patients scoring < 75 points.

Mckee et al. [2] conducted a prospective, randomized, controlled trial to compare functional outcomes, complications, and reoperation rates in elderly patients with displaced intra-articular distal humeral fractures treated with ORIF or primary semi-constrained TER. They reported that TER resulted in more predictable and improved 2-year functional outcomes compared with ORIF and may result in decreased reoperation rates (12% in TER group vs. 29% in ORIF group) [2]. Five patients randomized to ORIF were converted to TER intraoperatively because of extensive comminution and inability to obtain sufficient stability to allow early ROM [2]. Frankle et al. [3] conducted a retrospective comparison of ORIF with TER for intra-articular distal humerus fractures in 24 women aged older than 65 years. At a minimum of 2 years, TER resulted in excellent or good results in all 12 patients, with improved ROM and less physical therapy required compared with an

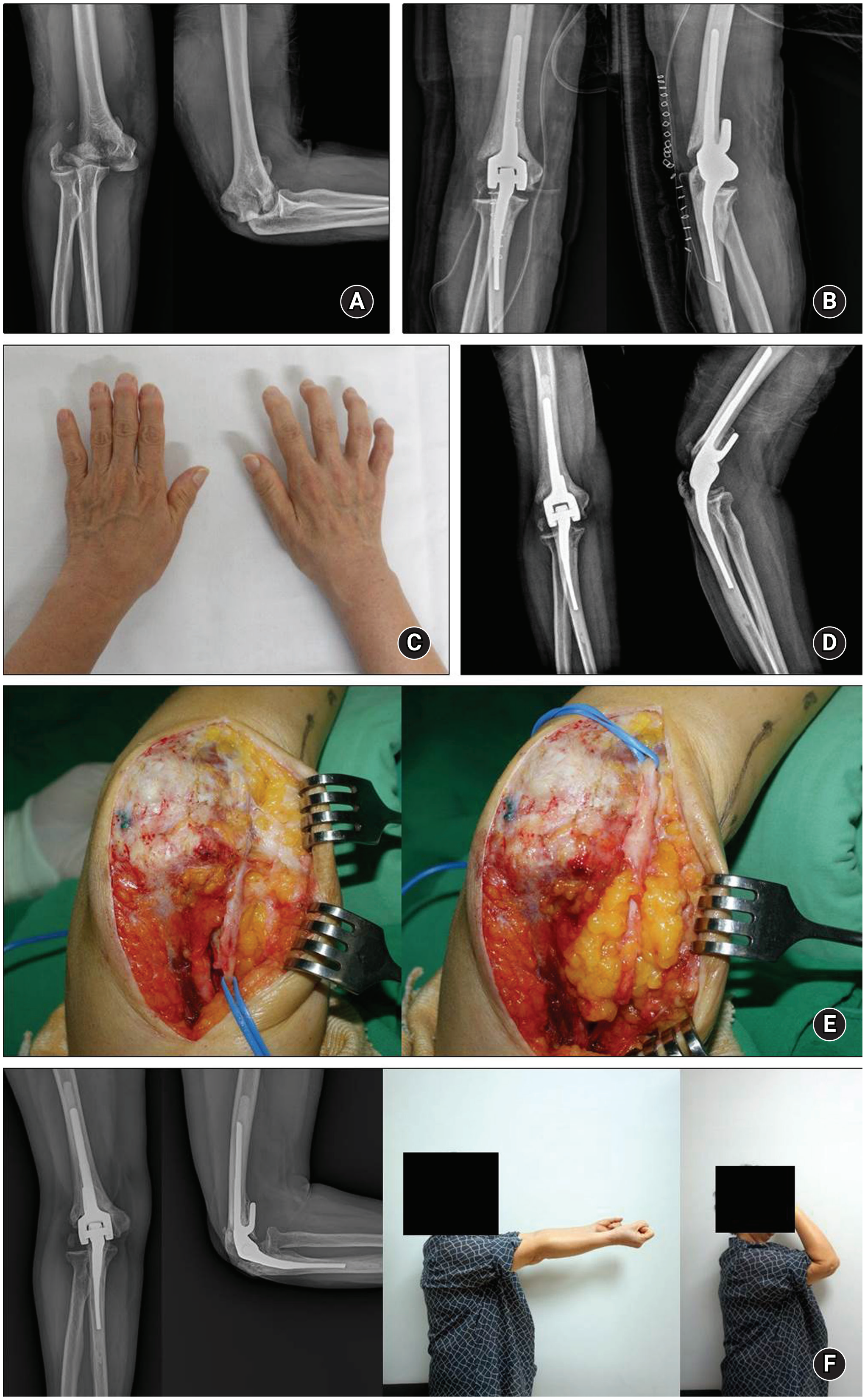

Fig. 2. (A) Initial radiographs of a 63-year-old woman show a comminuted intra-articular fracture on the right distal humerus. (B) Immediate radiographs after total elbow replacement. (C) Right fourth and fifth finger clawing deformity at 5 months after surgery. (D) Radiographs at 5 months after surgery. (E) Intraoperative findings of adhesion of the ulnar nerve. (F) Radiographs at 65 months after surgery show no evidence of loosening. Clinial photos show full elbow flexion and extension.

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ORIF group. Federer et al. [13] investigated total cost and effectiveness of TER compared to ORIF and reported that TER was slightly more cost effective than ORIF in elderly patients with acute intra-articular distal humerus fractures. In a systematic review by Githens et al. [8], 27 studies with 563 patients showed a mean follow-up after TER of 45.9 months, whereas follow-up after ORIF was 43 months. That group reported no clinically evident difference in functional outcomes as measured by ROM and functional scores [8]. Although total complications were more frequent after TER, major complications were more frequent after ORIF [8]. However, the study quality in that systematic review was generally weak. Because the optimal treatment for complex distal humerus fractures has not yet established, further prospective randomized trials are needed to assess and determine the most appropriate surgical intervention for complex distal humerus fracture.

A systematic review article by Chalidis et al. [4] reported nine clinical studies describing the results and complications of TER in 167 patients with 169 distal humerus fractures. Complications included wound infection (5.4%), ulnar nerve lesion (6.5%), reflex sympathetic dystrophy (3%), and periprosthetic fracture (1.7%). Barco et al. [11] reported a 92% survival rate for elbows without rheumatoid arthritis at both 5 and 10 years, but complication was frequent; 23 events (52%) were observed in 44 patients. Prasad and Dent [6] reported their experience of 19 TER for distal humerus fracture with a minimum 10-year follow-up. Only 53% of nonrheumatoid patients who undergo TER for distal humerus fractures survive to the 10th anniversary of their index procedure. They concluded that surgeons undertaking these procedures should be aware of the long-term revision rates and the sex difference in rates of loosening [6].

In the present study, mean VAS score, MEPS, and Quick-DASH at the mean follow-up of 29 months were 1.2, 80.5, and 20, respectively. The mean ROM was 127.7° of flexion, 13.8° of extension, 73.3° of pronation, and 74.4° of supination. Moreover, there was no evidence of bushing wear or high-grade implant loosening on serial plain radiographs. Our study demonstrated that primary TER produces satisfactory short-term functional and radiographic outcomes in patients with complex distal humerus fractures. However, we detected three complications (33.3%) in nine cases, including two periprosthetic fractures and one ulnar neuropathy that required secondary operation. The patient with progressive ulnar neuropathy recovered completely after adhesiolysis and decompression of the ulnar nerve at 5 months after TER, but two patients with periprosthetic fracture were treated with ORIF and showed unsatisfactory clinical outcomes at the final follow-up. In terms of TER indication, primary TER for complex distal humerus fractures should be selected carefully based on patient age, bone quality, comorbidities, soft tissue condition, and intra-articular comminution because of potentially considerable postoperative complications.

This study has several limitations. First, it was a retrospective study with a small number of cases. Second, the results may not be generalizable because seven (43.7%) of 16 patients died or were lost during follow-up. Third, the follow-up period was relatively short and did not allow exact radiographic results including bushing wear or implant loosening in long-term implant survival. In the future, long-term prospective studies are needed to evaluate clinical and radiographic outcomes after TER for complex distal humerus fractures.

This study revealed that primary TER for treatment of complex distal humerus fractures in elderly patients yielded satisfactory short-term outcomes. However, surgeons should consider the high complication rate after primary TER.

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Osborne-Cotterill Lesion a Forgotten Injury: Review Article and Case Report

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Osborne-Cotterill lesion is an osteochondral fracture located in the posterolateral margin of the humeral capitellum, which may be associated with a defect of the radial head after an elbow dislocation. This lesion causes instability by affecting the lateral ulnar collateral ligament over its capitellar insertion, which is associated with a residual capsular laxity, thereby leading to poor coverage of the radial head, and hence resulting in frequent dislocations. We present a 54-year-old patient, a physician who underwent trauma of the left elbow after falling from a bike and suffered a posterior dislocation fracture of the elbow. The patient subsequently presented episodes of instability, and additional work-up studies diagnosed the occurrence of Osborne-Cotterill lesion. An open reduction and internal fixation of the bony lesion was performed, with reinsertion of the lateral ligamentous complex. Three months after surgery, the patient was asymptomatic, having a flexion of 130° and extension of 0°, and resumed his daily activities without any limitation. Currently, the patient remains asymptomatic 2 years after the procedure. Elbow instability includes a large spectrum of pathological conditions that affect the biomechanics of the joint. The Osborne-Cotterill lesion is one among these conditions. It is a pathology that is often forgotten and easily overlooked. Undoubtedly, this lesion requires surgical intervention.

Keywords: Osborne-Cotterill lesion; Elbow dislocation; Fracture of the capitellum; Ligamentary injury

Rotatory instability is the most common instability of the elbow joint [1-3]. It is a condition in which the radius and the ulna rotate externally in relation to the distal humerus, allowing posterior dislocation of the radial head on the capitellum [3]. This term was coined by O'Driscoll et al. in 1991 [1]. Recurrent instability usually occurs after traumatic dislocation, and is typically associated with intra-articular fractures.

In 1966, Geoffrey Osborne and Paul Cotterill described the case of an osteochondral fracture in the posterolateral margin of the humeral capitellum, with a probability of being associated with a crater and/or shovel-like defect of the radial head [4] after an elbow dislocation, sometimes being related to nonunion of the lateral epicondyle, and caused by a disinsertion or avulsion of the lateral ulnar collateral ligament over its capitellar/humeral insertion, similar to a bony Bankart lesion. This fracture was associated with residual capsular laxity, resulting in poor coverage of the radial head, and thereby increasing instability [1,3,4]. In 1998, Faber and King [1] reported a case of recurrent dislocation of the elbow, secondary to posterolateral rotatory instability caused by an "impression fracture" of the capitellum, which can be extrapolated to a Hill Sachs lesion of the shoulder; this was very similar to what was described by Osborne-Cotterill [5]. In these studies however, the im-

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portance of the lateral ligamentous complex is not recognized, and the definition of the "Osborne-Cotterill lesion" was updated in 2008, when it was determined that there needs to be an accompanying injury of the lateral ligamentous complex [6]. At present, repair of the lateral ligamentous complex is a standard procedure to treat consistent posterolateral instability of the elbow (Fig. 1).

Literature Review

Residual posterolateral instability and, moreover, the Osborne-Cotterill lesions, are regarded as forgotten diseases subsequent to traumatic pathologies of the elbow; this can partly be explained by their low occurrence, resulting in delayed diagnosis and treatment [6]. Patients with Osborne-Cotterill lesions may present with a wide range of symptoms, ranging from vague discomfort to recurrent dislocation [3] accompanied by lateral elbow pain and a clicking noise that usually appears with physical activity, resulting in an unstable joint to external rotation with valgus and axial load. Hence, all physical examination maneuvers at the time of acquiring the medical history reproduces this mechanism, leading to radial head dislocation. It is therefore advantageous to evaluate lateral stability of the elbow under anesthesia by performing the "pivot shift" that determines the posterior dislocation of the radial head and the increase in the ulnohumeral joint space, which was observed under fluoroscopy [3].

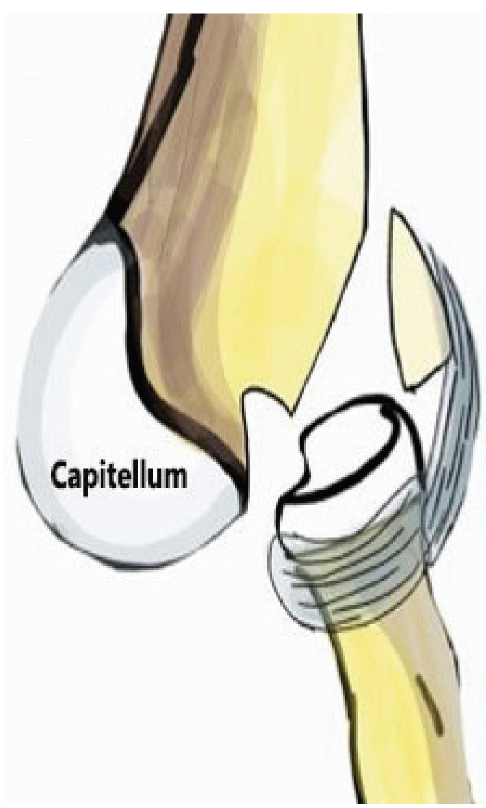

Fig. 1. The picture showing a schematic draw of the lesion.

Once the diagnosis is conjectured, the injury needs to be confirmed by imaging: anteroposterior, lateral, and oblique X-rays [5] may show an avulsion fracture of the origin or insertion of the lateral ligamentous complex, or posterior ridge of the capitellum that may or may not be associated with other lesions. The computed tomography (CT) scan of the elbow determines the extent of the lesion, and the relationship between the osseous defect of the capitellum and the radial head. The role of magnetic resonance imaging is controversial. A series of cases described report that the lateral ulnar collateral ligament can only be observed in healthy elbows of 50% of patients [3,4], indicating that the performance of magnetic resonance imaging to detect lateral ligamentous complex lesions is poor due to other interfering factors such as residual edema. The authors therefore recommend CT scan for all suspected cases of Osborne-Cotterill lesion.

In their initial description in 1966, Osborne and Cotterill recommend surgical intervention with occurrence of recurrent dislocations, or sense of permanent instability by the patient when performing daily activities. The suggested surgery was to repair the capsular and ligamentous laxity, usually present only in the lateral region, and simply repair the medial area if instability persists [4].

Other authors [5,6] have described lateral ulnar collateral ligament reconstruction using autologous graft of the palmaris longus, and occasionally with bone reconstruction using cortical bone graft to repair the defect of the capitellum. Kircher [5] reported a case in which an autologous chondrocyte implant was used for a posttraumatic defect of the capitellum, with good postoperative results and restoring ranges of motion. Schwarzkopf et al. [7] reported a case in which the patient presented with a Mason type IV fracture of the radial head, in addition to the Osborne-Cotterill lesion. Replacement of the radial head was performed after repairing the ligamentous complex, with subsequent anatomic reduction of the capitellum; the remaining defect was then filled with xenogeneic bone graft.

CASE REPORT

This study was approved by the Institutional Review Board of Fundación Santa Fé de Bogotá (IRB No. CCEI 9473-2018).

A 54-year-old physician had undergone trauma of the left elbow after a fall from a bike. Posterior dislocation of a fractured elbow was diagnosed at the emergency room. The anteroposterior X-ray revealed posterior dislocation of the elbow with osseous defect of the capitellum that was difficult to characterize, and fracture of the coronoid process. Closed reduction of the dislocation was performed, and subsequent CT scan revealed an avulsion fracture of

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the coronoid process with a 9-mm fragment gap, and a comminuted complex intra-articular fracture in the external and posterior aspect of the capitellum. An Osborne-Cotterill lesion was diagnosed a week later during the follow-up appointment (Fig. 2).

The fracture dislocation of the elbow is interpreted as a severe triad variant accompanying an Osborne Cotterill lesion, since, in spite of not having osseous defect of the radial head, there is a fracture of the capitellum affecting the joint relationship with the radial head, associated with the extensive soft tissue lesion. Since the physical examination under anesthesia revealed instability of the elbow at an extension of more than 30º and varus instability, surgical intervention was decided for the patient (Fig. 3). Using 3.0 suture anchors (Smith and Nephew, London, UK), an open reduction and internal fixation of the posterior capitellum fracture was performed by applying the posterior universal approach to the elbow. When still under reduction, the lateral ligamentous complex of the elbow was reinserted and sutured with anchors in its insertion area using double-loaded sutures. On the medial side, the coronoid process fracture was reduced and affixed using the Hotchkiss approach with reinsertion of the anterior joint capsule, applying the pull-out method (Figs. 4 and 5).

Fig. 2. Sagittal section showing a fracture of the coronoid process, type III as per the Regan and Morrey classification: more than 50% O'Driscoll affecting the sublime tubercle and fracture of the coronoid process. There is a posterolateral fracture of the capitellum in the sagittal section.

Results

The immediate postoperative radiography revealed reduction and fixation of the bone fragments (Fig. 6). Three months after surgery, the patient was asymptomatic and resumed his daily activities without any limitation, having a flexion of 130º and extension of 0. He remains asymptomatic 2 years after the surgical procedure.

DISCUSSION

The elbow instability includes a large spectrum of pathological conditions that affect the biomechanics of the joint. The Osborne-Cotterill lesion is one among these conditions. It is an often forgotten pathology and easily overlooked. Undoubtedly, this lesion requires surgical treatment.

In this case report, we describe the therapeutic approach applied for a patient having a severe triad variant: a posterior dislocation of the elbow, with a fracture of the coronoid process, and a fracture of the external and posterior aspect of the capitellum with intra-articular damage. The latter was treated as an Osborne-Cotterill lesion, performing an open reduction and internal fixation of the fracture of the posterior capitellum and ligamentous repair with 3.0 anchors. At 3 months postoperatively, the patient had complete and pain-free mobility.

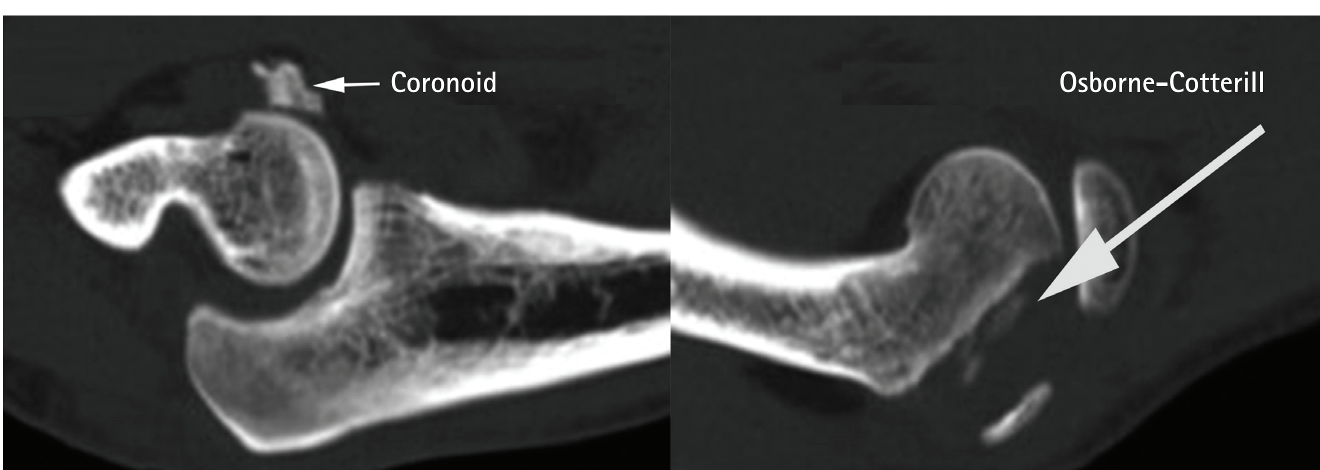

Fig. 3. Sagittal section showing a fracture of the coronoid process, type III as per the Regan and Morrey classification: more than 50% O'Driscoll affecting the sublime tubercle and fracture of the coronoid process. There is a posterolateral fracture of the capitellum in the sagittal section.

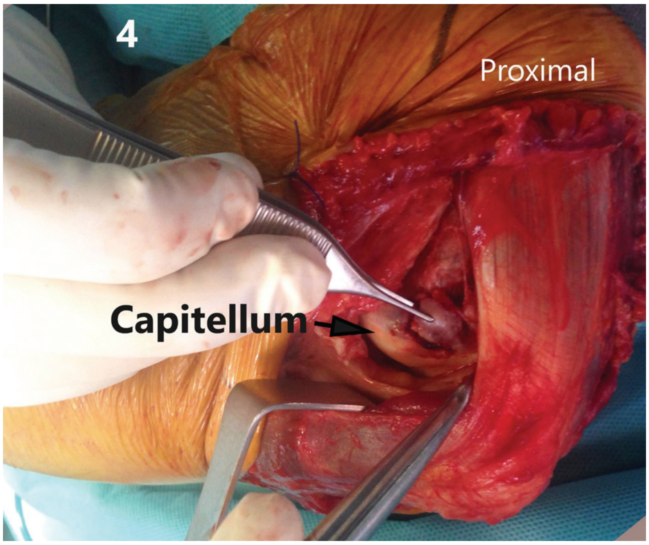

Fig. 4. The photograph showing the fracture.

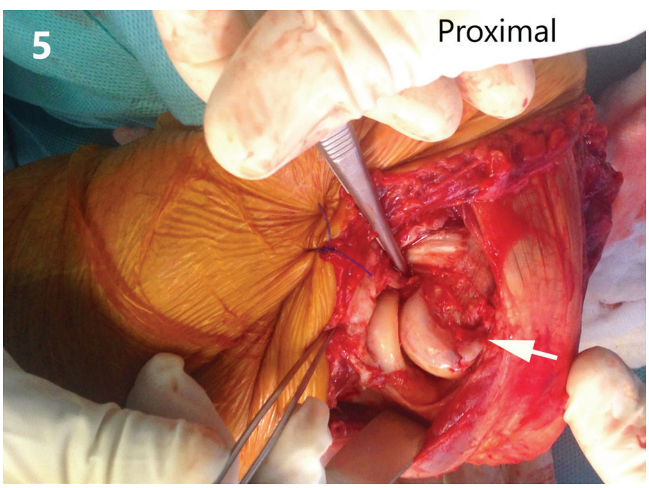

Fig. 5. The photograph showing the fracture reduced (arrow).

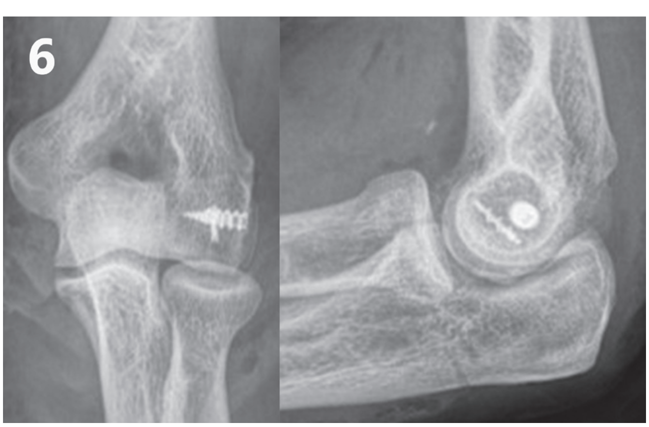

Fig. 6. Definitive postoperative radiography.

The Osborne-Cotterill lesion is an infrequent pathology, and there are few case reports in literature that range from chondral capitellar lesions to large osteochondral defects with injury of the ligamentous complex and the joint capsule. These are rarely found as isolated lesions. It is imperative to include as possible pathology during diagnosis. Since these are small bone lesions, they may be underestimated even after suspicion; however, it is crucial to understand that a large ligament injury requiring repair may possibly accompany this small bone lesion. Numerous treatment options are available, but fixing the fracture and repairing the lateral ligamentous complex should always be attempted. More biomechanical studies of the lesion need to be undertaken in order to make biomechanical studies of the lesion and to perform a classification that will provide us standardization of the treatment and an optimum therapeutic approach.

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Case Report

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Concomitant Coracoid Process Fracture with Bony Bankart Lesion Treated with the Latarjet Procedure

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Bony lesions of the glenoid and Hill-Sachs lesions are the most common injuries after a first-time traumatic shoulder dislocation. However, fracture of the coracoid process after traumatic shoulder dislocation is rare. A single, open surgical procedure could be performed by a Latarjet procedure using a fractured fragment of the coracoid process. If a fracture of the coracoid process is associated with a traumatic anterior shoulder dislocation, the Latarjet procedure may be the most appropriate surgical option.

Keywords: Shoulder dislocation; Bankart lesion; Coracoid process

A Bankart lesion is an injury of the anterior-inferior glenoid labrum of the shoulder due to anterior shoulder dislocation and bony Bankart is a Bankart lesion that includes a fracture of the anterior-inferior glenoid cavity of the scapula bone. A surgeon can consider operative treatment using either internal fixation or the Latarjet procedure when the acute glenoid rim defect is more than 5% in an active patient [1]. We present an appropriate surgical option that is suitable for patients with concomitant coracoid process fracture with bony Bankart lesions in acute traumatic shoulder dislocation.

CASE REPORT

This study was approved by the Institutional Review Board of Kyungpook National University Hospital (IRB No. KUNH 2019-07-001).

A 60-year-old man who was employed as a daily construction worker presented to the emergency department with trauma to his left shoulder and arm. He had fallen from a 3-m height while working and complained of pain in his left shoulder, wrist, and elbow. On physical examination, there was tenderness over the anterior aspect of the shoulder associated with pain-induced limitation in the range of motion. Plain radiography showed fractures of the distal radius and olecranon. An axillary lateral view of the left shoulder showed anterior subluxation of the humeral head and a Hill-Sachs lesion with a coracoid process fracture (Fig. 1). A computed tomography scan revealed a glenoid bone defect in addition to the above mentioned image findings (Fig. 2). An additional magnetic resonance imaging scan displayed not only a Hill-Sachs lesion of the humeral head and detachment of the anterior labrum with osseous involvement, but also a massive tear of the supraspinatus and infraspinatus tendons (Fig. 3).

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Conflict of interest: None.

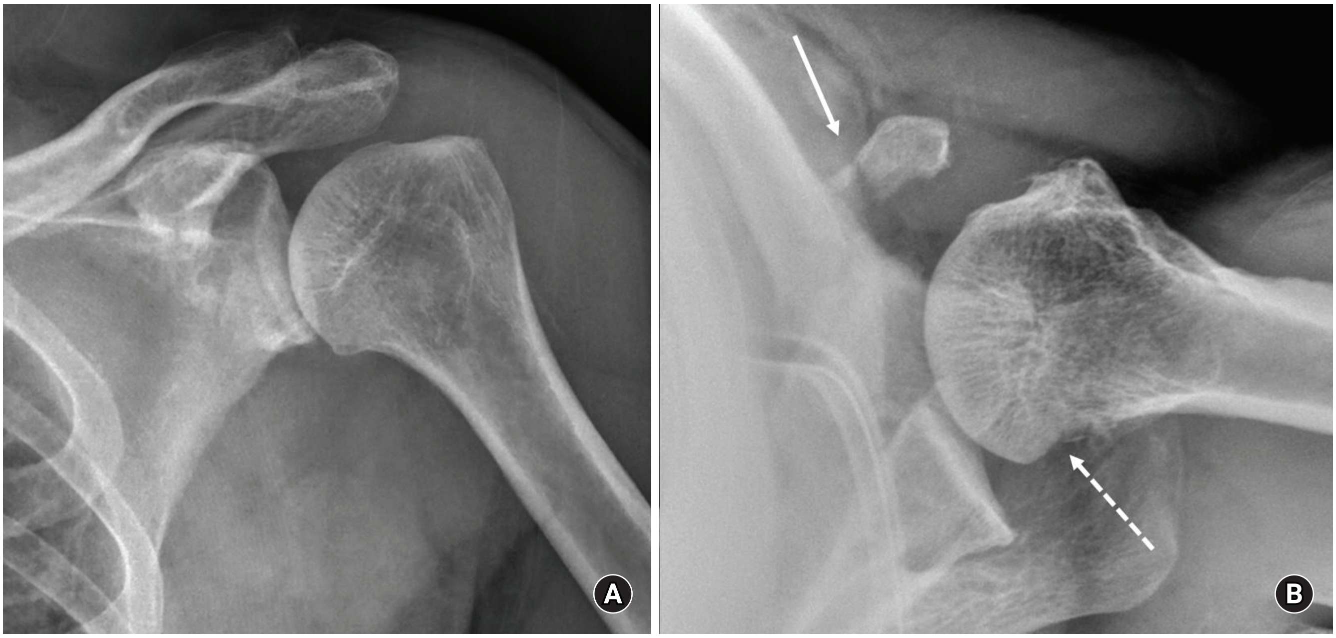

Fig. 1. Shoulder radiographs. (A) Anterior-posterior view. Humeral head inferior subluxation and abnormal coracoid process contour. (B) Axillary lateral view. Coracoid process fracture line (white arrow), Hill-Sachs lesion (white dotted arrow) and humeral head anterior subluxation.

Fig. 2. Three-dimensional computed tomography. (A) Coracoid process tip avulsion fracture (white arrow) and humeral head anterior subluxation. (B) Anterior-inferior glenoid rim fracture (white dotted arrow).

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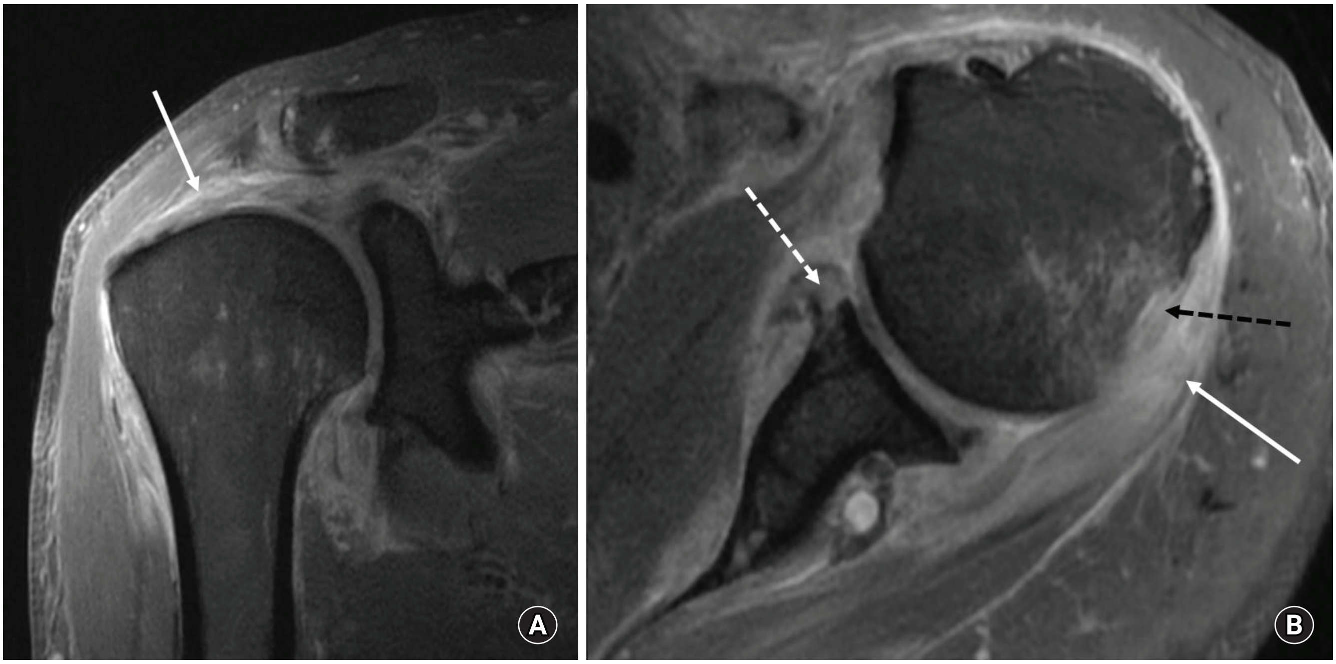

Fig. 3. Shoulder magnetic resonance imaging images. (A) Coronal view. (B) Axial view. Massive tear of supraspinatus and infraspinatus tendons (white arrows), bony Bankart lesion (white dotted arrow), Hill-Sachs lesion (black dotted arrow).

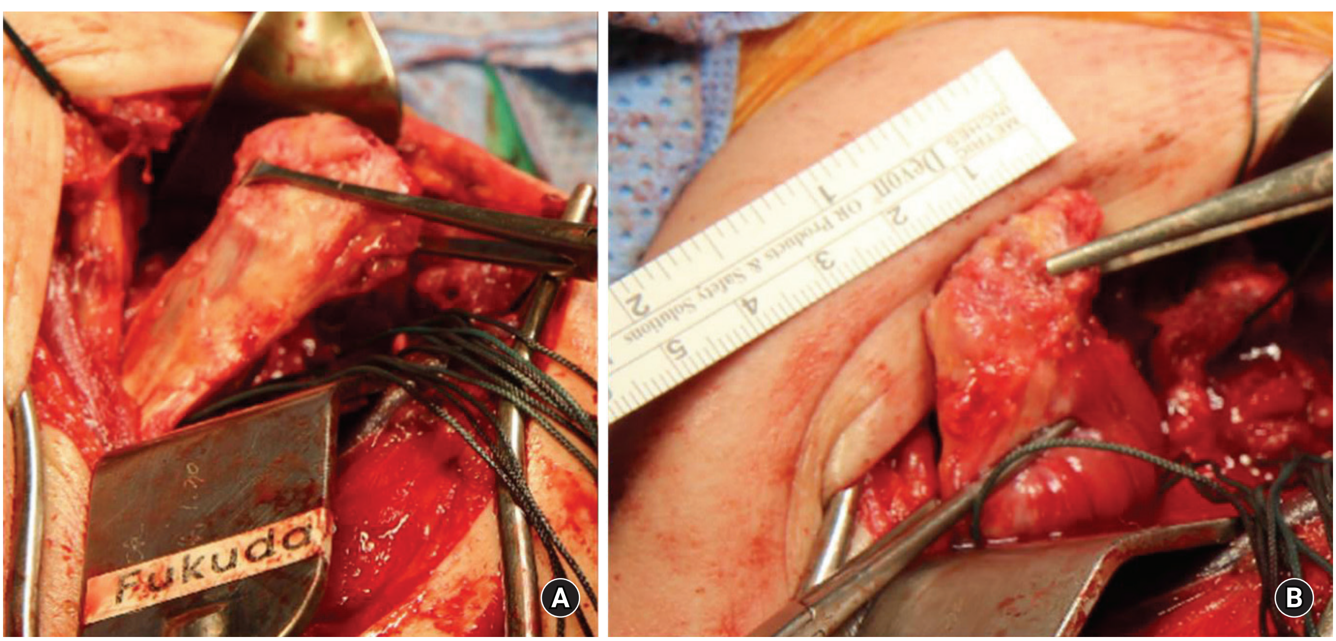

Fig. 4. (A) Identified coracoid fracture fragment and intact conjoined tendon. (B) An about 2.5-cm-sized coracoid fracture fragment.

Two days after the injury, open reduction and internal fixation were performed for olecranon and distal radius fractures. We decided to perform an open Latarjet procedure using the fractured coracoid process fragment. The operation was performed in the beach chair position. The surgical site was exposed through the deltopectoral approach. After preparation and sectioning of the clavipectoral fascia, we identified the fractured coracoid fragment (Fig. 4A). The conjoined tendons were intact and attached to the coracoid fragment. The length of the coracoid fragment was about 2.5 cm (Fig. 4B). The coracoid fragment with attached conjoined tendons was transferred to the glenoid rim following an open Latarjet procedure (Fig. 5). We used two 4.5-mm-diameter head-

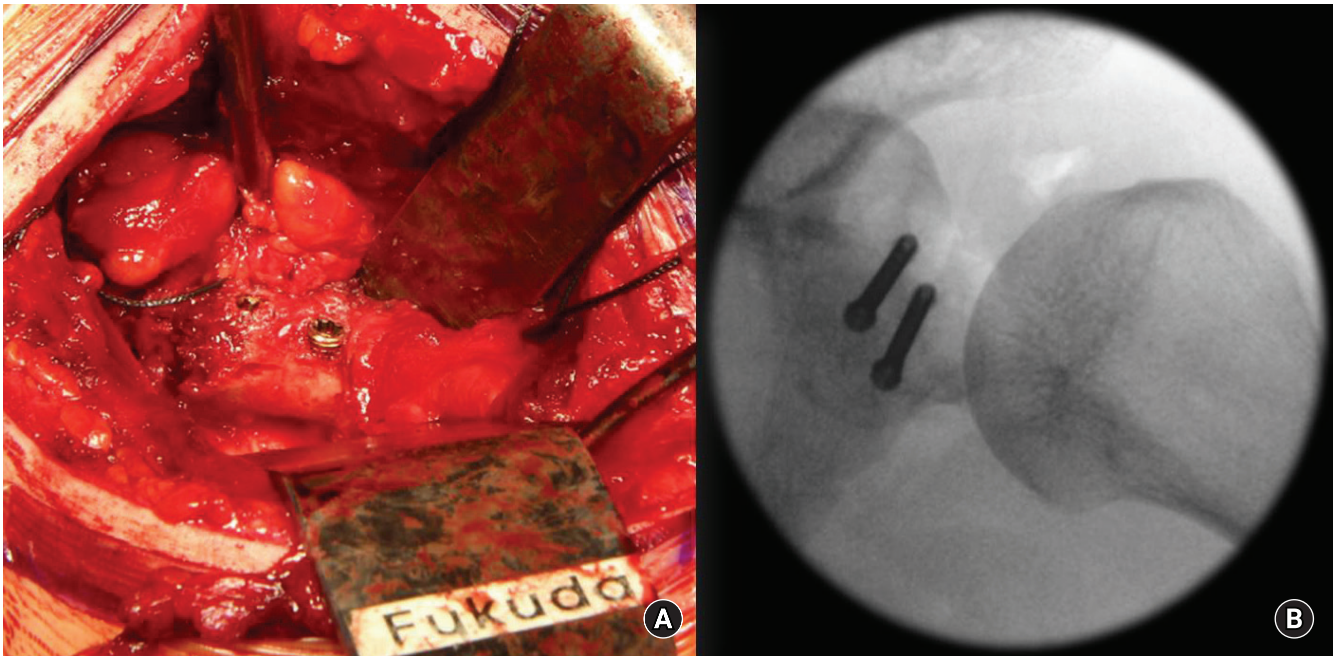

Fig. 5. (A) Transferred coracoid fragment and fixed to glenoid rim using two screws. (B) Fluoroscopic image.

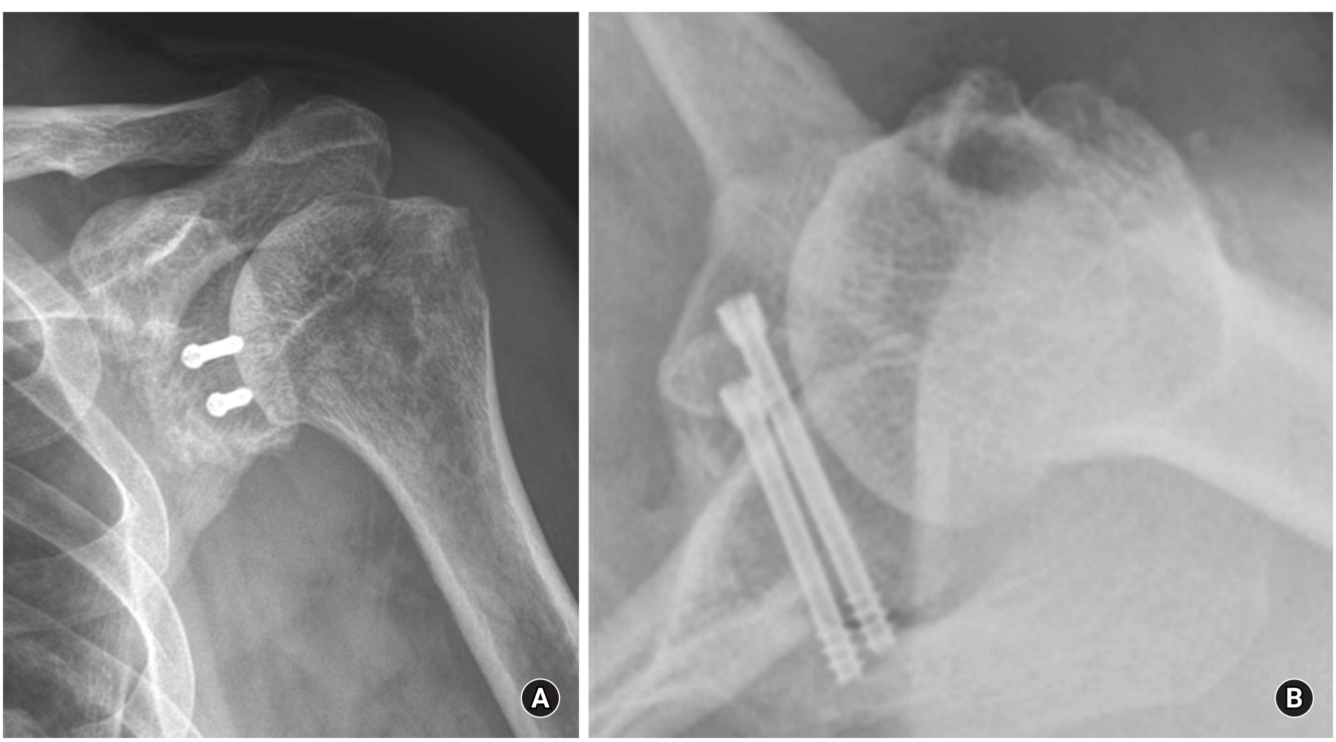

Fig. 6. Postoperative radiographs. (A) Anterior-posterior view. (B) Axillary lateral view.

less screws (length, 36 mm and 42 mm) for fixation of the coracoid fragment (Fig. 6). As the torn supraspinatus and infraspinatus tendons had relatively good status and tissue quality, we repaired the rotator cuff using a suture bridge technique without excessive tension.

Two years after surgery, the patient obtained improvement of shoulder function and range of motion. He had no limitation of daily activities. Recurrent anterior dislocation did not occur during

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the follow-up period. At the final follow-up visit, the clinical outcomes were assessed using visual analog scale, 2/10; Simple Shoulder Test, 10/12; University of California at Los Angeles Shoulder Score, 31/35; and Constant score, 86/100.

DISCUSSION

Bony lesions of the glenoid and Hill-Sachs lesions are the most common injuries after a first-time traumatic shoulder dislocation [2-6]. However, fracture of the coracoid process after traumatic shoulder dislocation is rare (0.8%–2%) [7,8]. Generally, an acute glenoid rim defect caused by first-time shoulder dislocation can be treated operatively using a bone graft when the glenoid defect is larger than 25% [9]. A surgeon can consider operative treatment using either internal fixation or the Latarjet procedure when the acute glenoid rim defect is larger than 5% in an active patient [1]. A type II coracoid process fracture can be treated conservatively, but some studies report that a coracoid pseudoarthrosis can occur when there is a concomitant anterior shoulder dislocation [10]. A few cases of shoulder dislocations with a simultaneous fracture of the coracoid process have been previously reported in the literature [11]. Ogawa et al. [12,13] classified fractures of the coracoid process into two types based on the coracoclavicular ligaments. They recommended surgical treatment in type I fractures (fractures proximal to the coracoclavicular ligaments). Type II fractures (fractures distal to the coracoclavicular ligaments) can be treated conservatively. However, Kälicke et al. [10] reported that a coracoid pseudoarthrosis could be caused by tension of the conjoined tendons in an anterior shoulder dislocation with a concomitant type II coracoid fracture. Therefore, surgical treatment should be considered to prevent pseudoarthrosis or nonunion in type II fractures with displacement greater than 5 mm.

The mechanism of injury in our case probably resulted from direct trauma of the dislocated humeral head against the glenoid rim and coracoid process. The fracture of the coracoid process was type II, and the fractured fragment measured about 2.5 cm. The glenoid bone defect was 15% by Sugaya's method [14], and anterior subluxation of the humeral head was sustained in more than 50% of the glenoid [15,16]. A defect involving more than 20% to 25% of the glenoid bone has historically been considered critical bone loss causing a recurrent anterior shoulder dislocation. Therefore, a Latarjet procedure or bone graft from the iliac bone is a surgical option for a severe glenoid bone defect. The treatment choice in cases involving borderline defects of the glenoid (15%–20%) is controversial and left to the surgeon's preference [17]. In the case of an isolated coracoid process fracture treated surgically, screw fixation, plate fixation, or tension band wiring are considered as treatment methods [12,18].

To treat glenoid bone loss in a first-time shoulder dislocation concomitant with a coracoid process fracture and a rotator cuff tear, like the present case, by one-time surgery, the Latarjet procedure can be an ideal option for solving all the problems in one step. The Latarjet procedure has a sling effect caused by the conjoined tendons as well as bony augmentation of the glenoid rim using the coracoid process, and it is used for cases of failed anterior shoulder instability or a large bony defect of the glenoid. But, in the case of an elderly patient with poor rotator cuff function, surgeons must carefully consider the treatment options, because the Latarjet procedure may compromise further surgeries, like reverse total shoulder arthroplasty for irreparable massive rotator cuff tear. The previous literature reported only one case where the Latarjet procedure was performed in a patient with chronic recurrent anterior shoulder instability with a fracture of the coracoid process [19]. The present report described the first case of Latarjet procedure in an acute concomitant bony Bankart lesion with a coracoid process fracture.

We reported a surgical method that can solve concomitant lesions by a one-time operation. If a fracture of the coracoid process is associated with a traumatic anterior shoulder dislocation, the Latarjet procedure may be the most appropriate surgical option.

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Case Report

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Arthroscopic Excision of Heterotopic Ossification in the Supraspinatus Muscle

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Heterotopic ossification is formation of bone in atypical extra-skeletal tissues and usually occurs spontaneously or following neurologic injury with unknown cause. We report a 46-year-old female with right shoulder pain and restricted range of motion (ROM) for 3 months without history of trauma. Magnetic resonance imaging (MRI) showed a lesion within the rotator cuff supraglenoid. Excisional biopsy from a previous institution revealed a heterotopic ossificans (HO). Following repeat MRI and bone scan, histopathology from arthroscopic resection confirmed an HO. The patient demonstrated improved pain and ROM at follow-up. Idiopathic HO rarely occurs in the shoulder joint, and resection of HO should be delayed until maturation of the lesion to avoid recurrence. The current case showed that arthroscopic HO resection provides an excellent surgical view to ensure complete lesion removal and minimize soft tissue damage at the supraglenoid area. Furthermore, the minimally invasive procedure of arthroscopy may reduce rehabilitation time and facilitate early return to work.

Keywords: Supraspinatus; Heterotopic ossification; Arthroscopy

Heterotopic ossification (HO) is formation of bone in atypical extra-skeletal tissues and usually occurs spontaneously or following neurologic injury resulting from insult to the spinal cord, closed head injury, and burns [1]. Little has been reported regarding idiopathic HO of the shoulder joint. We report a 46-year-old woman with idiopathic HO in the supraspinatus muscle treated with an arthroscopic excision procedure.

CASE REPORT

This study was approved by the Institutional Review Board of Asan Medical Center (IRB No. 2019-0736).

A 46-year-old female presented with right shoulder pain that was aggravated by activity and relieved by oral analgesics and who had no history of trauma for the previous 6 months. Three months previously, she had been treated for the same complaint at another hospital, where arthroscopic biopsy revealed HO.

Physical examination revealed a healed scar from previous arthroscopic biopsy. Preoperative range of motion (ROM) for forward elevation was 110° (active) and 150° (passive). Shoulder abduction was 110° (active) and 150° (passive). External rotation at 90° abduction was not affected, while internal rotation at 90° abduction was decreased to 50° for active motion. Skin color and temperature were unremarkable. Muscle strength grade was 5 of 5

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for the supraspinatus in external rotation and the subscapularis. The Hawkins impingement test was positive. Laboratory examination demonstrated elevated serum alkaline phosphatase (299 IU/L), elevated C-reactive protein (7.1 mg/dL), and elevated erythrocyte sedimentation rate (36 mm/hr).

Plain shoulder radiographs showed a radiopaque lesion in the subacromial space (Fig. 1A), and magnetic resonance imaging (MRI) showed a soft tissue mass at the subacromial space with an intact rotator cuff tendon. MRI was repeated, and computed tomography (CT) scan and bone scan were obtained. CT scan with three-dimensional reconstruction showed an irregularly-shaped ossification lesion at the dorsal aspect of the coracoid process (Fig. 1B), extending from the supraglenoid tubercle to the coracoid base. Compared with that on the initial plain radiograph, the size of the ossification lesion was increased. The T2-weighted MRI images in coronal oblique and sagittal projections showed a heterogenous soft tissue mass at the rotator interval occupying the subacromial space with supraspinatus tendinosis (Fig. 1C). The rotator cuff tendon was intact, with tendinosis at the supraspinatus. Bone scintigraphy using Technetium-99m (Tcm-methylene diphosphonate) showed a hot spot at the right shoulder, with greater density at the anterior site (Fig. 1D).

For arthroscopic excision, the patient was placed in the beach-chair position under general anesthesia with addition of an interscalene block to reduce postoperative pain. The glenohumeral joint was located within the normal limit following a standard diagnostic arthroscopic round. Rotator interval release was performed from the glenohumeral joint to provide a safety margin for release of the ossified lesion due to the proximity to the supraspinatus tendon. Afterward, a standard direct lateral portal was estab-

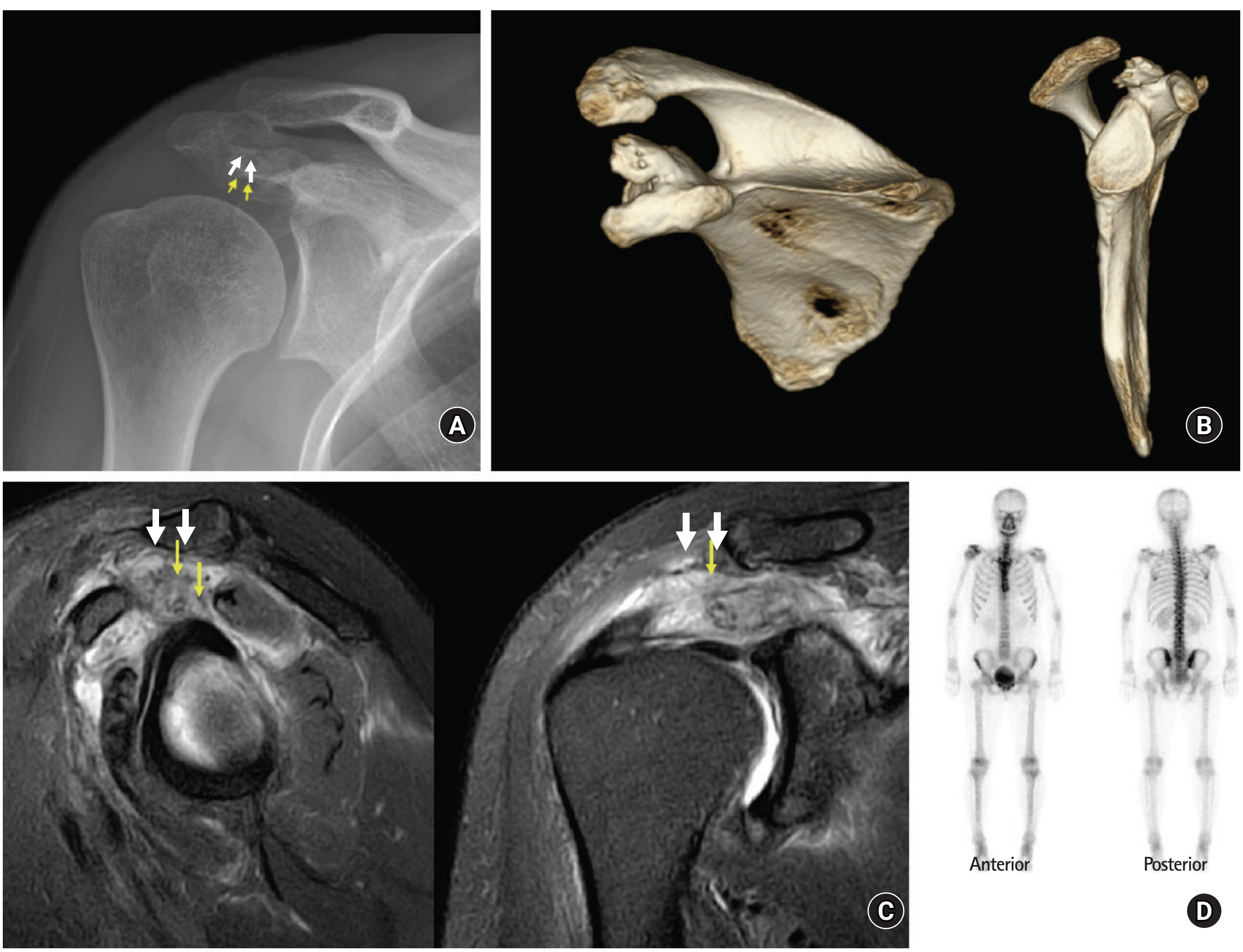

Fig. 1. (A) Diagnostic imaging shows a radio-opaque lesion (arrows) at the subacromial space on plain X-ray. (B) An irregularly-shaped ossification lesion at the dorsal aspect of the coracoid process measuring 7 mm (mediolateral)×5 mm (proximodistal) on three-dimensional computed tomography scan. (C) A heterogeneous soft tissue mass (arrows) at the rotator interval occupying the subacromial space on T2-weighted magnetic resonance imaging scan. (D) Hot uptake with greater density at the anterior site on bone-scan.

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lished under the direct vision technique and served as the main viewing portal. Standard anterolateral subacromial decompression was performed following placement of the lateral portal. Ossified tissue with a stalk was connected to the coracoid base (Fig. 2A). Soft tissue release was meticulously performed with radiofrequency ablator and arthroscopic shaver while taking care not to damage the rotator cuff tendon and muscle (Fig. 2B). Resection of the calcified tissue was performed with the defragmentation technique and an arthroscopic burr. The subscapularis muscle remained intact at the end of procedure (Fig. 2C). The resected HO was sent to pathology, and the final report confirmed heterotopic ossification (Fig. 3).

The patient was discharged on postoperative day two with an arm sling and instructions to exercise as tolerated to increase ROM. A regular follow-up visit 2 weeks after surgery revealed complete pain relief with full ROM. The patient received celecoxib 100 mg (two times daily) for 1 month postoperatively to prevent recurrence of HO. Follow-up plain shoulder radiograph showed absence of the previous lesion (Fig. 4A), and a follow-up CT scan performed 2 months later also showed absence of an ossified lesion in the rotator interval and coracoid base (Fig. 4B).

DISCUSSION

The literature describes HO in the shoulder joint associated with events such as head injury, spinal cord injury, severe burns, and postoperative events [2]. However, a report of HO in the shoulder joint without direct trauma is rare. In the current case, the patient's medical history did not reveal any HO risk factors, suggesting an idiopathic type of HO. In a case series of 892 patients treated with acromioplasty and distal clavicle resection, Berg and Ciullo [2] reported 5 % with ectopic bone formation, including sites like the subacromial space, acromioclavicular joint, coracoacromial ligament, and coracoclavicular ligament, and approximately 3.2% of

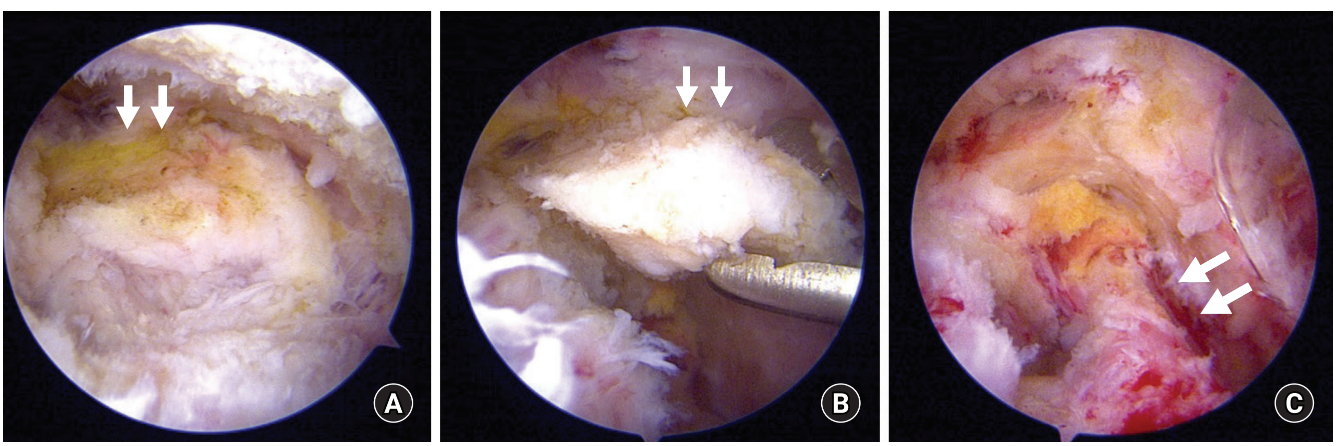

Fig. 2. Arthroscopic view of the right shoulder from the direct lateral portal shows the ossification lesion (arrows) at the acromion undersurface (A), for which soft tissue release was performed for isolation (B). (C) The subscapularis (arrows) was intact following HO excision.

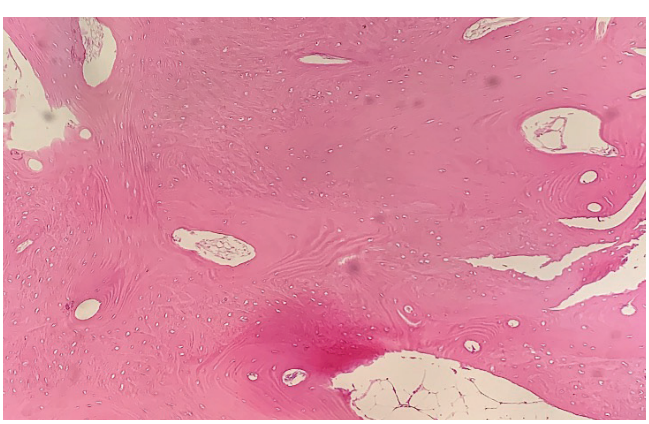

Fig. 3. Histological examination with H&E staining shows mature trabecular bone (×40).

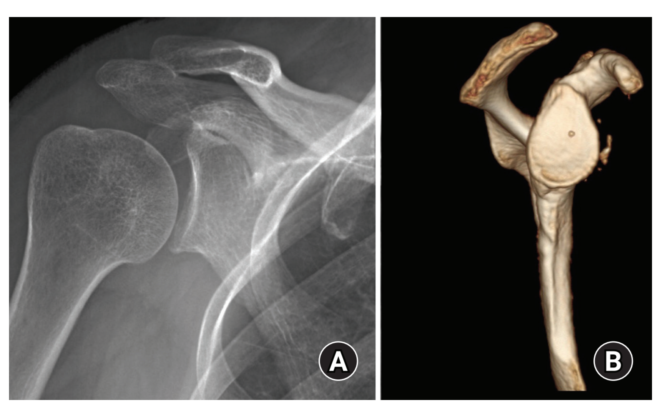

Fig. 4. Follow-up imaging shows no recurrence with absence of the ossification lesion at the previous location on both plain shoulder radiograph (A) and computed tomography scan (B).

them were symptomatic [2].

HO is usually asymptomatic [2]. When it is extensive, it may manifest by decreased ROM, localized pain and inflammation of the involved joint, and even bony ankylosis. The process of HO formation begins within days to weeks after the inciting event. However, it can only be seen on a radiograph 4 weeks after onset. Three-phase bone scintigraphy is the most sensitive imaging modality for early detection of HO, and lesions can be seen as early as 2.5 weeks after injury. Activity on delayed bone scans usually peaks a few months after injury and progressively decreases to normal in a 6- to 12-month period; hence, the classic suggestion is to wait at least 1 year before bone resection [3,4]. Considering the timing for surgical intervention, the definition of complete bony maturation remains inconclusive [3]. Although timing is an important consideration, surgical intervention should be considered when there is lack of functional improvement despite conservative treatment [3,5]. One study of the hip joint recommended early surgical excision, as preservation of the tissue planes may help in differentiating ectopic ossifications from normal bone at the site of recent trauma or intervention [6]. Hence, in the present case, early surgical removal of HO was performed due to significant functional deterioration of the shoulder joint and anticipation of clear margin HO resection with intact tissue planes. CT and MRI can provide highly detailed anatomic representations of late-stage HO, but they cannot detect the early stages [7].

Posttraumatic HO typically is located inferomedial to the joint [8]. In contrast, the present case demonstrated idiopathic HO in the supraglenoid area. Classically, post-operative HO has been classified by anatomic location [2], including lesions located in the acromion or coracoacromial ligament (A lesion), such as demonstrated in the current case, and around the clavicle or coracoclavicular ligament (C lesion). Furthermore, additional subtypes were created for lesions that occur in the supraspinatus outlet ("o") or in the acromioclavicular interval ("i"). The HO lesion in the current case was classified as A-o type due to its location at the coracoacromial ligament and occupying the outlet space, which we think caused extrinsic impingement of the supraspinatus outlet.

Recurrence is a known complication following surgical excision of a calcific deposit of the shoulder, with an incidence between 16% and 18% [9]. Most recurrence results from incomplete bone removal from a periosteal remnant [2]. Therefore, arthroscopic removal is beneficial for providing an excellent view during the resection procedure, which may lower the recurrence risk. Previous studies recommend a timetable for surgical intervention only for post-traumatic HO [1]. Timing of surgical intervention is key to successful HO surgical treatment and based on maturation of the lesion prior to surgical intervention.

Idiopathic HO is rare around the shoulder. CT and MRI may provide anatomic location and surgical margins, and bone-scan may confirm maturation state. Arthroscopic HO removal may provide an excellent surgical view to ensure complete surgical resection and minimize soft tissue damage, enabling early return to work.

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Concise Review

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Comparison of Ulnar Collateral Ligament Reconstruction Techniques in the Elbow of Sports Players

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Ulnar collateral ligament injuries have been increasingly common in overhead throwing athletes. Ulnar collateral ligament reconstruction is the current gold standard for managing ulnar collateral ligament insufficiency, and numerous reconstruction techniques have been described. Although good clinical outcomes have been reported regarding return to sports, there are still several technical issues including exposure, graft selection and fixation, and ulnar nerve management. This review article summarizes a variety of surgical techniques of ulnar collateral ligament reconstructions and compares clinical outcomes and biomechanics.

Keywords: Elbow; Ulnar collateral ligament; Reconstructive surgical procedures

INTRODUCTION

The ulnar collateral ligament (UCL) of the elbow is the primary restraint to valgus stress and is an important structure to overhead throwing athletes. Since the first description of UCL rupture in javelin throwers [1], interest in UCL injuries has increased due to both the epidemic of injury among patients involved in throwing sports and media interest in professional overhead throwing athletes.

Since Dr. Jobe first performed UCL reconstruction (UCLR) in 1974, and published his experience in 1986 [2], UCLR has been a popular treatment for insufficient UCL. There have been many modification and advancements in surgical techniques, and optimal UCLR continues to be a topic of debate. Despite use of various techniques of UCLR for UCL injuries, studies reviewing surgical techniques from the traditional to currently existing or new methods are lacking. The purpose of this review was to address surgical techniques of UCLR by summarizing and comparing clinical outcomes and biomechanics.

SURGICAL TECHNIQUES

Original Jobe Technique

The first successful UCLR was performed by Frank Jobe (Kerlan-Jobe Orthopedic Clinic, Inglewood, CA, USA) on Los Angeles Dodgers pitcher Tommy John in 1974. After surgery, John resumed pitching at his pre-injury level. Jobe et al. [2] published their initial results in a population of baseball pitchers and javelin throwers in 1986. The original technique utilized the palmaris longus tendon or plantaris tendon as an autograft and required detachment of the flexor-pronator musculature at its origin and sub-

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muscular transposition of the ulnar nerve. At the humeral origin of the UCL, two tunnels were created in a "V" configuration through the posterior cortex to configure the graft in a figure-8 fashion. Two drill holes in the ulna and three in the medial epicondyle were made with a 3.2-mm drill bit (Fig. 1).

This series reported a 63% success rate (10 of 16 patients), as defined by return to preinjury or better level of participation in athletic activity. However, it was also associated with a 32% complication rate, primarily related to postoperative ulnar neuropathy. A later study by Conway et al. [3] of 56 UCLR cases with a mean 6.3 years of follow-up showed 68% excellent outcomes in which the patient was able to compete at the same or higher level as before the injury for > 12 months.

Modified Jobe Technique

Due to the high rate of ulnar nerve complications, Jobe modified his technique using a muscle splitting approach without detaching the flexor-pronator, no ulnar nerve transposition, and larger humeral tunnel through the anterior cortex. He reported better outcomes, with 5% of patients experiencing transient ulnar nerve symptoms and 93% showing an excellent result [4].

Andrews et al. [5] and Andrews and Timmerman [6] also used the Jobe technique, except with subcutaneous ulnar nerve transposition and combined arthroscopy. Exposure of the UCL was achieved with elevation of the flexor-pronator mass, and a humeral tunnel was made with a 3.5-mm drill bit to create a Y-shaped tunnel configuration. Another study from the same institution showed excellent results in 81% of 78 baseball players who underwent UCRL [7]. In the largest series on UCLR to date, Cain et al. [8] reported on 1,281 patients treated with this technique. Among the 733 individuals with reconstruction, 83% had excellent results and 16% developed transient ulnar nerve paresthesia, with most of these cases resolving within 6 weeks. Arthroscopic debridement of olecranon osteophytes was the most common additional surgery in 7.2% of patients. This modified technique was called the Andrews technique or the American Sports Medicine Institute (ASMI) modification.

Docking Technique

David Altchek developed the docking technique and reported results of the first 36 patients treated with this technique in 2002 [9]. Key elements of the docking technique included a muscle-splitting approach without routine transposition of the ulnar nerve, routine arthroscopic assessment, treatment of associated lesions, and docking the two ends of the tendon graft into a single humeral tunnel (Fig. 2). Rohrbough et al. [9] first described the docking technique and provided significant improvement of technical issues such as graft fixation and tensioning of the previous technique. They raised several concerns about the previous Jobe technique, which included the large drill holes within the limited area of the epicondyle, the difficulty in holding tension on the graft during fixation, and the strength of tendon fixation.

The ulnar tunnel is created in the same manner as in the Jobe technique. The humeral tunnel is created with a single inferior tunnel and two small superior exit tunnels, creating a Y-shaped tunnel. A 4.5-mm drill or burr is used to create a socket in the center of the footprint to a depth of 15 mm. and two 1.5-mm sockets that converge to the single 4.5-mm socket are drilled. The two 1.5-mm sockets should be just anterior to the medial intermuscular septum and at least 5 to 10 mm apart (Fig. 3) [10,11]. Dodson et al.

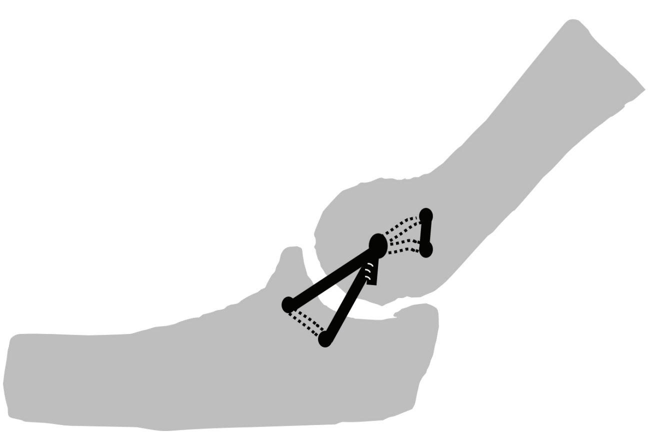

Fig. 1. Illustration of the original Jobe technique. A free tendon graft is pulled through the ulnar and humeral tunnel and forms a figure-8. It is then put under tension and sutured to itself.

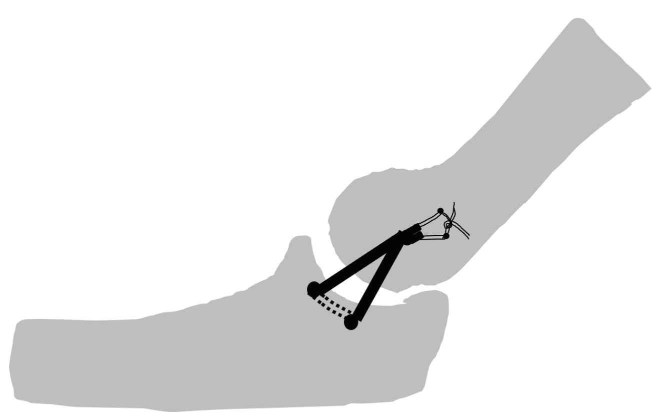

Fig. 2. Illustration of the docking technique. Two ulnar tunnels and a single humeral tunnel are created, followed by two small exit holes. Sutures of both limbs from the ulnar tunnel are tied over the humeral bony bridge.

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[11] reported that 90% of patients were able to return to their preinjury level of activity after UCLR with the docking technique.

MODIFIED DOCKING TECHNIQUE

Paletta and Wright [12] reported a case series using further modification of the docking technique using a four-strand palmaris longus graft, and 23 of 25 participants (92%) were able to return to their preinjury levels of competition. Koh et al. [13] modified the docking technique using a three-strand construct with a double anterior bundle and a single posterior bundle. Bower et al. [14] described another three-strand docking technique with excess graft sutured to the anterior band, while tension was maintained on the excess graft. McGraw et al. [15] and Donohue et al. [16,17] reported a novel docking plus technique that used four strands of the palmaris longus tendon.

David Altchek and Neal ElAttrache for Tommy John (DANE TJ) Technique

In 2006, Conway [18] described a new procedure, the DANE TJ technique. This technique utilizes a combination of fixation techniques of docking fixation on the humeral side and interference screw fixation on the ulnar side (Table 1, Fig. 4). He preferred a gracilis tendon as autograft and used an interference screw (4.75-, 5.5-, 6.0-mm diameter) for ulnar side fixation. This technique originated from a biomechanical study using interference screws [18]. Ahmad et al. [19] demonstrated that the load to failure strength was 90% of that of the native ligament when the tendon graft was locked to the interference screw with sutures. The DANE TJ technique may be valuable when the sublime tubercle is compromised or a revision surgery is required. However, graft trauma from screw-graft-tunnel mismatch and proximal ulnar fracture is concerning. In addition, another biomechanical study showed that interference screw fixation did not provide sufficient fixation [20]. Dine et al. [21] reported excellent results in 86% of 22 athletes treated with this technique.

Repair with or without an Internal Brace Augmentation

Despite good clinical outcomes after UCLR, patients require a long recovery time prior to return to sports (RTS), which is a challenge for high-demand athletes. In addition, UCL injuries vary in degree, from partial tears to chronic complete tear. These observations imply that repair is an option for some athletes. Although initial data on UCL repair demonstrated poor outcomes, recent studies showed promising results in symptomatic UCL injury to the proximal or distal end of the ligament. Savoie et al. [22] reported 93%

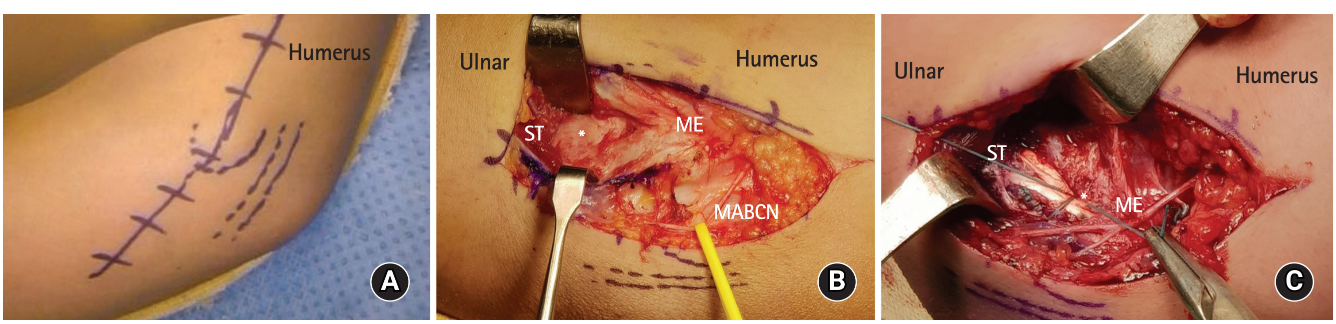

Fig. 3. (A) The skin incision is 8 cm centered over the medical epicondyle. (B) Longitudinal splitting of the flexor pronator muscle exposes an ulnar collateral ligament (asterisk). (C) When the docking suture is tied, the tension on the graft may be supported with a yolk stitch (asterisk). ST, sublime tubercle; ME, medial epicondyle; MABCN, medial antebrachial cutaneous nerve.

Table 1. Three UCL reconstruction techniques and their differences

Technique	Inventor	Year published	FPM approach	Graft configuration	Ulnar preparation fixation	Humeral preparation fixation	Ulnar nerve treatment
Jobe [2]	Frank Jobe	1986	Transection	Figure-8	Tunnel None	Tunnel Suture to tendon	Submuscular transposition
Docking [9]	David Altchek	2002	Split	Triangle	Tunnel None	Socket Suture over bridge	Only if symptomatic
DANE TJ [18]	David Altchek, Neal ElAttrache	2006	Split	Linear	Socket Interference screw	Socket Docking over bridge	Only if symptomatic

UCL, ulnar collateral ligament; FPM, flexor pronator muscle; DANE TJ, David Altchek and Neal ElAttrache for Tommy John.

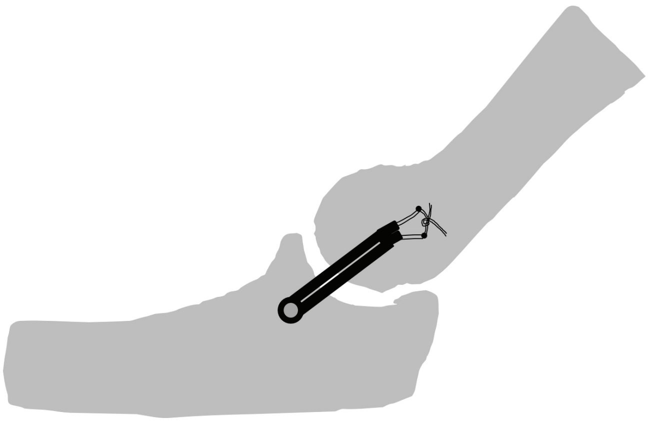

Fig. 4. Illustration of the David Altchek and Neal ElAttrache for Tommy John (DANE TJ) technique. This technique utilizes a combination of fixation techniques. On the ulnar side, an interference screw is fixed with a single drill hole; on the humeral side, docking fixation is used.

good to excellent results, and 97% of patients RTS after repair using suture anchors with arthroscopic assistance.

Alternative Technique

Hechtman et al. [23] described a hybrid technique that uses an ulnar osseous tunnel and suture anchor fixation on the humerus and reported that their method closely reproduced the normal anatomy without any marked difference in reconstruction strength compared with traditional bone tunnels. Savoie et al. [24] and Hurt et al. [25] reported the short-term outcomes of 116 patients who underwent UCLR with hamstring allograft. Myeroff et al. [26] and Acevedo et al. [27] described UCLR using cortical buttons on humeral and ulnar fixation that create a single tunnel. This technique may offer an alternative solution to bony insufficiency in revision surgery.

BIOMECHANICAL STUDIES

There have been biomechanical studies comparing the native UCL with reconstructive UCL and UCLR techniques for clinical applications. As in native elbow, the valgus stability of UCLR elbow can vary with flexion angle [28]. Mullen et al. [29] found that UCLR with Jobe technique had stability similar to the native UCL at flexion angles of 30°–90°. However, Ciccotti et al. [30] showed that UCLR with modified Jobe and docking technique provided valgus stability at flexion angles >90°. Paletta et al. [31] compared stability of UCLR with that of the Jobe technique with a four-strand docking technique and concluded that the docking technique can provide greater initial stability. Ahmad et al. [19] evaluated the stability of interference screw fixation and found the average ultimate moment of UCLR with interference screw was 95% of that of native UCL. However, Armstrong et al. [20] performed a biomechanical comparison of native ligament strength, the docking and Jobe techniques, interference screw fixation, and reconstruction with an Endobutton and concluded that UCLR with either the docking technique or Endobutton may be the best option biomechanically. The authors also expressed concerns over graft rupture with interference screw fixation. McAdams et al. [32] compared cyclical valgus stability of the docking technique and interference screw fixation. Valgus stability was greater with interference screw fixation at early cycles, but no difference was found at 1,000 cycles. The tension slide technique involves a single ulnar bone tunnel with a tendon graft attached to a cortical button and use of interference screw. In a cadaveric study, biomechanical results showed superiority of strength and stiffness of ulnar fixation with the bone tunnel technique [33].

Recently, several biomechanical studies have evaluated valgus stability of an internal brace combined with UCRL or repair [34-38]. Most studies demonstrated augmentation with an internal brace providing stability similar to that of the docking technique or more resistance to the valgus load. These results support use of repair or reconstruction with an internal brace technique for UCL insufficient patients. One systemic review about biomechanical testing with UCLR showed that the most common mode of failure following UCLR in a laboratory setting was suture failure. While failure of the graft represented 27% and bone tunnel fracture was 14% of the failure, suture failure was much higher at 51% [24].

SPORTS PERFORMANCE OUTCOMES

Jobe and various modifications and biomechanical studies have demonstrated that UCLR can appropriately restore elbow stability and provide superior outcomes in UCL insufficient athletes. However, while athletes who underwent UCLR can RTS, players who return to pre-injury level are not numerous. Erickson et al. [39] evaluated the performance of 179 major league baseball (MLB) pitchers on RTS and found that they pitched fewer innings in a season and had fewer wins and losses per season compared to before surgery. Furthermore, Jiang and Leland [40] and Lansdown and Feeley [41] reported small, but statistically significant, decreases in velocity of fastball and changeup pitches thrown by pitchers who return to MLB after UCLR from pre-injury to post-injury years [42]. In addition, there is increase in number of UCLR revisions among primary UCLR athletes, and performance and longevity after revision surgery decrease [46] (Table 2).

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Table 2. Summary of clinical outcomes of UCLR

Study	UCLR technique	No. of cases	Mean follow-up	Rate of RTS (%)	Complication
Jobe et al. (1986) [2]	Jobe	16	51 mo	63	3 (Reop)
Azar et al. (2000) [7]	ASMI	78	35 mo	79	8 (4 Donor site, 2 reop, 1 infection, 1 UN)
Thompson et al. (2001) [4]	Modified Jobe	33	2 yr	100	5% UN
Rohrbough et al. (2002) [9]	Docking	36	3.3 yr	92	2 (1 Hematoma, 1 UN)
Dodson et al. (2006) [11]	Docking	100	36 mo	96	3 (2 UN, 1 stiffness)
Dine et al. (2007) [21]	DANE TJ	22	35.9 mo	86	4 (2 UN, 2 stiffness)
Cain et al. (2010) [8]	ASMI	743	38.4 mo	83	1 48 (121 UN, 55 reop for osteophyte)
Hechtman et al. (2011) [23]	Hybrid	34	6.9 yr	85	1 (UN)
Dugas et al. (2012) [43]	ASMI	120	> 2 yr	87.5	42 (25 UN, 8 reop)
Savoie et al. (2013) [24]	Jobe, docking	116	39 mo	95	7 (3 UN, 2 wound, 1 med epicondylar fracture, 1 tendon tear)
Erickson et al. (2016) [44]	Docking, double docking	188	60 mo	94.1	10 (reop)
Myeroff et al. (2018) [26]	Cortical button	23	42.7 mo	82.6	1 Failure
Donohue et al. (2019) [16]	Docking plus	324	> 24 mo	90.9	28 UN, 8 retear, 18 reop
Dugas at al. (2019) [45]	Repair with internal brace	111	> 12 mo	92	5 (3 UN, 1 heterotopic bone, 1 retear)

UCLR, ulnar collateral ligament reconstruction; RTS, return to sports; Reop, reoperation; ASMI, American Sports Medicine Institute; UN, ulnar neuropathy; DANE TJ, David Altchek and Neal ElAttrache for Tommy John.

CONCLUSION

Since the first UCLR surgery in 1974, several modifications and new techniques for UCL injuries for athletes have been proposed. The Jobe technique and modified Jobe technique, docking technique and modified docking technique, and DANE TJ technique have been most often used for UCLR surgery. Clinical studies have reported successful outcomes and a high rate of RTS in overhead throwing athletes. Several modifications including flexor pronator muscle splitting approach and minimal handling of the ulnar nerve might improve outcomes. Newer fixation techniques such as augmentation with an internal brace may allow a faster RTS. Finally, with the perception of lower performance after surgery, efforts are needed to focus on education and injury prevention.

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Surgical Options for Failed Rotator Cuff Repair, except Arthroplasty: Review of Current Methods

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Although the prevalence of rotator cuff tears is dependent on the size, 11% to 94% of patients experience retear or healing failure after rotator cuff repair. Treatment of patients with failed rotator cuff repair ranges widely, from conservative treatment to arthroplasty. This review article attempts to summarize the most recent and relevant surgical options for failed rotator cuff repair patients, and the outcomes of each treatment, except arthroplasty.

Keywords: Rotator cuff; Tendon transfers; Arthroscopic surgery; Subacromial impingement syndrome; Reconstructive surgical procedures

INTRODUCTION

Different studies have reported the rate of rotator cuff retear, in patients who underwent rotator cuff repair, to be between 11% and 94% [1-9]. Although the risk factors for retear are not clear, previous studies suggest older [4,10], preoperative big tear size [11,12], advanced degree of muscular atrophy [12], advanced degree of fatty infiltration [11,12], massive retraction of tendon [12,13], higher critical shoulder angle [14], lower acromiohumeral distance (AHD) [14], high tendon tension after repair, and inappropriate postoperative rehabilitation [12] as the major factors for failure of the rotator cuff repair. Management of patients with retear varies from conservative treatment to arthroplasty. This study attempts to summarize the reported results for surgical methods applied for treating rotator cuff retear, except arthroplasty.

INDICATIONS

There exists an uncertainty whether all patients with retear require revision surgery. Previous studies have shown that there is no correlation between the presence of retear and functional improvement [1,15]. Recently, however, several reports determined a significant correlation between integrity of the repaired tendon and functional improvement [16,17]. In addition, few studies have correlated increase in strength and recovery of function with cuff healing. Hence, the correlation with overall outcomes of the patient who underwent rotator cuff repair and cuff healing is still debatable [2,18]. It is therefore important to define the group of patients who require revision surgery, from among the failed rotator cuff repair patients. Previous studies suggest the following factors as having promising outcomes after reoperation: male [19], preoperative abduction above 90° [19], preoperative forward flexion above

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90° [20], intact deltoid origin [20], good-quality rotator cuff tissue [20], only one prior procedure [20], increased AHD [21], the absence of glenohumeral arthritis [21], degenerative retear [21], and visual analog scale less than 5 [22]. However, some studies report that age and number of previous surgeries do not affect the outcome of revision surgery; hence, these two factors remain uncertain [19,23]. The authors of this review have determined the following factors for revision surgery: age <65 years, and confirmation of retear by sonography, computed tomography arthrography, or magnetic resonance imaging (MRI). Moreover, we also consider the patient's compliance, as well as their working and activity level.

CLASSIFICATIONS

The most commonly used classification of retear is the one suggested by Sugaya et al. [24] in 2005. In this study, the Sugaya et al.'s classification [24] divided the radiologic integrity of repaired cuff into five categories. Of these, type 4 and 5 are considered as retear in most papers. Type 4 is presence of a minor discontinuity in only one or two slices on both oblique coronal and sagittal images, suggesting a small full-thickness tear; type 5 is the presence of a major discontinuity observed in more than two slices on both oblique coronal and sagittal images, suggesting a medium or large full-thickness tear.

Among the several classification systems, the classification system proposed by Cho et al. [25] has important implications for predicting reparability. They divided the retear into two types, according to the presence of remnant tissue. The authors infer that type 2 retear, a medial row failure, has low reparability. In many studies, type 2 retear (or medial row failure) is significantly higher in rotator cuff repair using either the double row technique or the suture bridge technique [26].

Another classification system is based on the anatomical deficiency of the retear patient. The authors emphasize that the following six types of anatomical deficiencies should be considered in revision surgery: (1) failure of tendon healing, (2) poor tendon quality, (3) fatty infiltration/atrophy, (4) retear medial to the medial row of fixation, (5) bone defects in the greater tuberosity after anchor removal, or perianchor cyst formation, and (6) bony and tendinous insufficiency [27].

SURGICAL PROCEDURES

Revision Repair

Revision repair is the first surgical procedure considered in revision surgery of a retear. Lo and Burkhart [28] presented a technique and outcomes of an arthroscopic revision repair in a case series of 14 patients. The authors emphasized a careful release technique when the torn tendon is difficult to identify due to medial retraction and fibrotic adhesion to adherent tissue during revision repair. In addition, tissues in non-anatomical areas are perplexing, but the authors claim that tendons can be dissected with careful manipulation. Compared to the preoperative state, patients in this study showed functional improvement. Several other studies have also reported alleviation of pain and functional improvement after revision repair. In 1992, Bigliani et al. [29] reported outcomes of 31 patients who underwent rotator cuff revision repair: 25 patients (81%) reported pain relief, but 14 patients (45%) had persistent weakness. Results of 20 patients who underwent rotator cuff revision repair were reported by Ma et al. [30]: 15 patients (75%) reported pain relief, and the average forward flexion improved from 80° preoperatively to 127° postoperatively; 12 patients (60%) reported no functional problems or minor limitations after surgery, and 11 patients (55%) reported overall satisfaction with the surgical results.

However, a study comparing the results of revision repair with the results of primary repair did not show favorable outcomes of revision repair for all factors. Shamsudin et al. [17] retrospectively compared patients with primary repair and revision surgery. In revision surgery, the rerupture rate at 2-year follow-up was 40%, which was significantly higher than that of primary repair (21%). Moreover, revision surgery patients showed significantly inferior results than primary repair patients when considering postoperative pain, range of motion and strength. The authors reason that this could be because primary surgery inhibits microcirculation, and revision surgery is applied to repair already degenerated and weakened tendons.

Thorough subacromial decompression during revision repair is important in patients where acromiohumeral impingement is the primary cause of pain. Acromioplasty as a method of subacromial decompression was first described in 1995 by Rockwood et al. [31]. They performed acromioplasty in 50 irreparable cuff tear patients, and reported good outcomes in pain relief and restoration of active range of motion. Subacromial decompression is advantageous due to ease of execution by arthroscopy, and a recent report states that there is further pain reduction by additional tenotomy of the biceps long head [32]. Another method of subacromial decompression, tuberoplasty was first described in 2002 [33]. Arthroscopic tuberoplasty methods were first introduced in 2004 under the name "reversed arthroscopic subacromial decompression method" [34]. However, since acromioplasty and tuberoplasty surgery alone are unable to halt the progression of rotator cuff tear arthropathy and its associated osteoarthritis, their application in young retear patients is limited and can be considered only for pain relief purposes [35].

Rotator cuff partial repair is a possible option for reducing pain and restoring function [36,37]. In 1994, the biomechanical "suspension bridge system" concept was introduced, and rotator cuff partial repair was first reported [37]. Since then, many authors have insisted that the rotator cuff cable can be restored by partial repair alone, with successful restoration of force-couple of the glenohumeral joint [38,39]. The following protocol is followed for partial repair. After sufficient tissue relaxation, chondroplasty is performed to medialize the footprint, by suturing the infraspinatus in the medialized footprint and suturing the long head of the biceps together. When performing partial repair, since complete cover of the superior portion is not possible, the anterior rotator cuff muscle group and the posterior rotator cuff muscle group must be firmly attached to the humeral head to ensure recovery of the force-couple [40]. Reports for partial repair outcomes are varied [41,42]. Most previous studies report pain relief and improved range of motion subsequent to partial repair, thereby supporting the theory that partial repair is appropriate for irreparable cuff tear patients. A recently published systematic review article on partial repair stated that there are methodological issues in the design of the study on rotator cuff partial repair published so far, such as selection bias, [43] and hence argued that it is too early to draw conclusions on the usefulness of this procedure.

There is another way to medialize the footprint for revision repair. Shifting the anatomic insertion of the rotator cuff to the medial side of the cartilage of the humeral head can be achieved if the torn tendon does not reduce to footprint even after sufficient intra-articular release of the tendon-capsular interface or extra-articular release of the tendon-bursal interface. There is a concern that the moment arm in abduction of medialized torn tendon may be shortened. However, previous biomechanical studies have reported no effect on the shoulder biomechanics during medialization of 3–10 mm [44,45]. Recently, Kim et al. [46] reported the results of medialization in 35 patients, wherein the range of motion and clinical scores were improved.

The double interval slide technique is another method applied to accomplish revision repair. In 2004, Lo and Burkhart [47] were the first to perform repair using the interval slide technique, in patients with massive and retracted cuff tears. Of the nine patients, six were subjected to single interval slide, and three patients underwent double interval slide repair. Single interval slide refers to the technique of repairing tendons after sufficient release of the rotator interval between supraspinatus and subscapularis to the coracoid process base. The double interval slide was introduced as a technique of releasing the base of the scapular spine between supraspinatus and infraspinatus, in addition to the single interval slide. Patients included in this study showed improved strength and range of motion compared to preoperative values. However, some recent research has questioned the usefulness of interval slide technique. In 2013, Kim et al. [48] divided 41 patients with large-to-massive contracted rotator cuff tears into two groups: one group was subjected to partial repair with marginal convergence, whereas the second group underwent double interval slide repair. No functional difference was observed at 2-year follow-up in both groups, and retear rate was observed in 20 of the 22 patients who underwent a double interval slide (91%), which was significantly higher than the partial repair with the marginal convergence group.

Muscle Advancement

It is well known that the original footprint cover is important for rotator cuff repair [49,50]. However, it is also known that retear increases significantly when excessive tension is applied to the repaired tendon for footprint cover [51]. Accordingly, many attempts have been made to reduce the tension of repaired cuff tendons. In 1965, Debeyre et al. [52] first introduced a technique to reduce tension during repair by elevating the supraspinatus from the supraspinatus fossa. Many authors have reported good results by following this method for tension-free repair [49,53].

In the muscle advancement technique, an approximately 4-cm incision is applied first at the medial side of the scapular spine, followed by detachment of the trapezius from the scapular spine. Supraspinatus and infraspinatus located under the detached trapezius are elevated from the scapula body and lateralized about 2 cm in order to cover the footprint of the humerus head (Figs. 1 and 2).

Recently, Yokoya et al. [49] published a comparative study of the muscle advancement technique. In this study, the authors performed a prospective comparative study of 47 chronic massive ro-

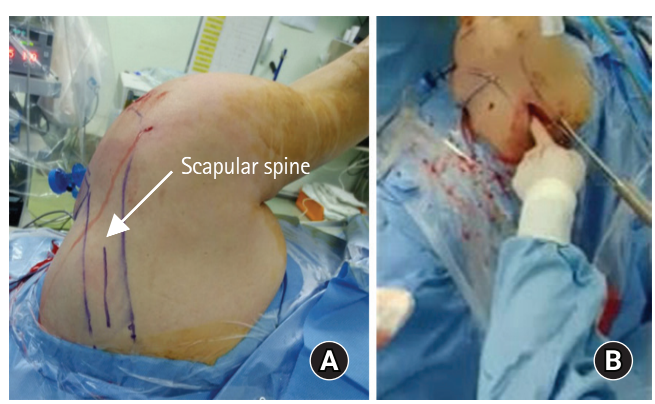

Fig. 1. (A) Surface anatomy for advancement. The part drawn in blue is the scapular spine. (B) Intraoperative procedure of advancement. About 5-cm incision to detach trapezius and to elevate supraspinatus and infraspinatus from its fossa.

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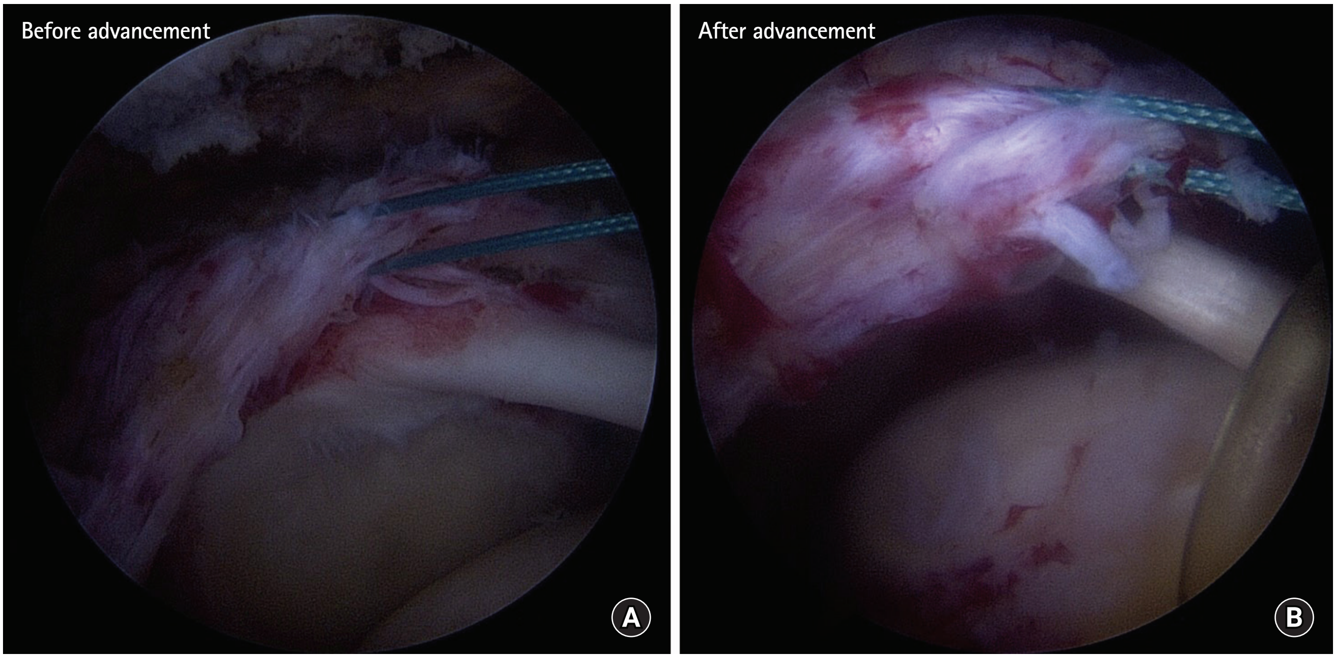

Fig. 2. (A) Arthroscopic views before (A) and after (B) muscle advancement technique.

tator cuff tear patients: 21 patients underwent transosseous equivalent (TOE) repair only, whereas 26 patients were subjected to TOE with muscle advancement. No difference was observed in the clinical score between groups, but the muscle advancement group showed significant improvement in abduction muscle strength and acromiohumeral interval compared to the TOE only group. Furthermore, the muscle advancement group reported lower retear rate, at 23.1% versus 52.4%.

The muscle advancement technique has the advantage of covering the original footprint tension freely, but it is not an all-arthroscopic technique, and the excessive advancement during muscle advancement can lead to suprascapular nerve palsy [54]. Therefore, when performing muscle advancement technique, it is recommended to simultaneously cut the transverse scapular ligament arthroscopically for suprascapular nerve release introduced by Lafosse et al. [49,55].

Patch Graft: Bridging Technique

Patch graft interposition (bridging) techniques are applied for retracted, irreparable, and chronic rotator cuff tears in retear patients. The graft interposition technique was first introduced in 1978. In the first study, the authors used a freeze-dried allograft tendon to link the retracted rotator cuff with a greater tuberosity of humeral head, and reported good results such as pain relief [56]. However, another author group questioned the promising result of graft interposition using freeze-dried allograft tendon, and reported contradictory results. The authors reported that only two patients had functional improvement subsequent to the same procedure performed on seven patients included in the study [57]. Based on this research, numerous studies have been undertaken to overcome the problem of graft materials. Achilles tendon, tensor fascia latae, quadriceps femoris, and patellar tendon as allografts have been attempted, and the long head of biceps and fascia lata as autografts were also tried to link the cuff and footprint. New biomaterials such as polyester (Dacron), Gore-Tex, Teflon, and carbon fiber have been developed and are currently being actively researched [58-60]. Among the various trials, xenograft is practically not being used due to the significantly higher rerupture rate and severe inflammatory reaction [61].

There is only one randomized study of bridging techniques to date. In the study, 48 patients were divided into two groups. The control group underwent simple partial repair, and the treatment group underwent autograft bridging. Both showed significant functional improvement. However, the rerupture rate of infraspinatus (the rate of retear of the graft group) was significantly lower in the graft group (autograft vs. simple repair: 8.3% vs. 41.7%, respectively). In addition, functional improvement in the rerupture group was lower than the non-retear group, and the author emphasized the usefulness of the patch graft [62]. A recently published meta-study argued that it was impulsive to conclude the usefulness of this procedure since there was only one high-level randomization study of the bridging technique mentioned above [63].

Patch Graft: Augmentation

The patch augmentation technique is considered when the cuff tendon of a retear reaches the medial margin of the footprint but is unable to cover the entire footprint (Fig. 3). Bond et al. [64] reported arthroscopic patch augmentation and its outcomes for the first time in 2008. They reported significant functional improvement and pain reduction in 16 massive tear patients, and follow-up MRI in 13 patients confirmed full recovery of the footprint. In 2015, Lenart et al. [65] reported the results of patients who underwent footprint augmentation using poly-l-lactide graft. This study reported significant functional improvement during the follow-up period, similar to the previous studies; however, retear was observed in 62% patients, thereby making it difficult to establish the stability of this procedure.

In 2017, a systematic review compared and presented bridging and augmentation techniques with patch graft. Based on the results of 12 studies included in this study, the overall healing rate of patch augmentation is 64% and the overall healing rate of bridging is 77.9%. Furthermore, a significant alleviation was observed in the degree of pain in patients who underwent the bridging technique. The authors thereby concluded that bridging is a better option than augmentation in irreparable cuff patients [66].

Superior Capsular Reconstruction

In 2013, reverse total shoulder arthroplasty was not permitted in Japan due to the medical insurance system. It is hypothesized that glenohumeral capsules are important for the superior displacement of the humeral head due to defects of the rotator cuff, in situations where other treatments for massive, irreparable or retear cuff are required. Based on this hypothesis, an arthroscopic method of reconstructing the capsule using autologous tensor fascia lata was developed [67]. This superior capsular reconstruction has the advantage of being an arthroscopic technique as well as an open approach. Superior capsular reconstruction is performed as follows. Acromioplasty is first performed to reduce the graft tendon and acromion impingement, followed by repairing the infraspinatus and subscapularis to the footprint. The graft is fixed bilaterally on the medial side of the superior tubercle of the glenoid and to the outside of the greater tuberosity of the humerus. Good long-term results were obtained with graft thickness greater than 6–8 mm (Fig. 4).

A cadaver study reported the upward stability of the glenohumeral joint provided by superior capsular reconstruction [68]. In this study, the authors contended that superior capsular reconstruction completely restores the superior stability of the glenohumeral joint, and improved results could be expected compared to

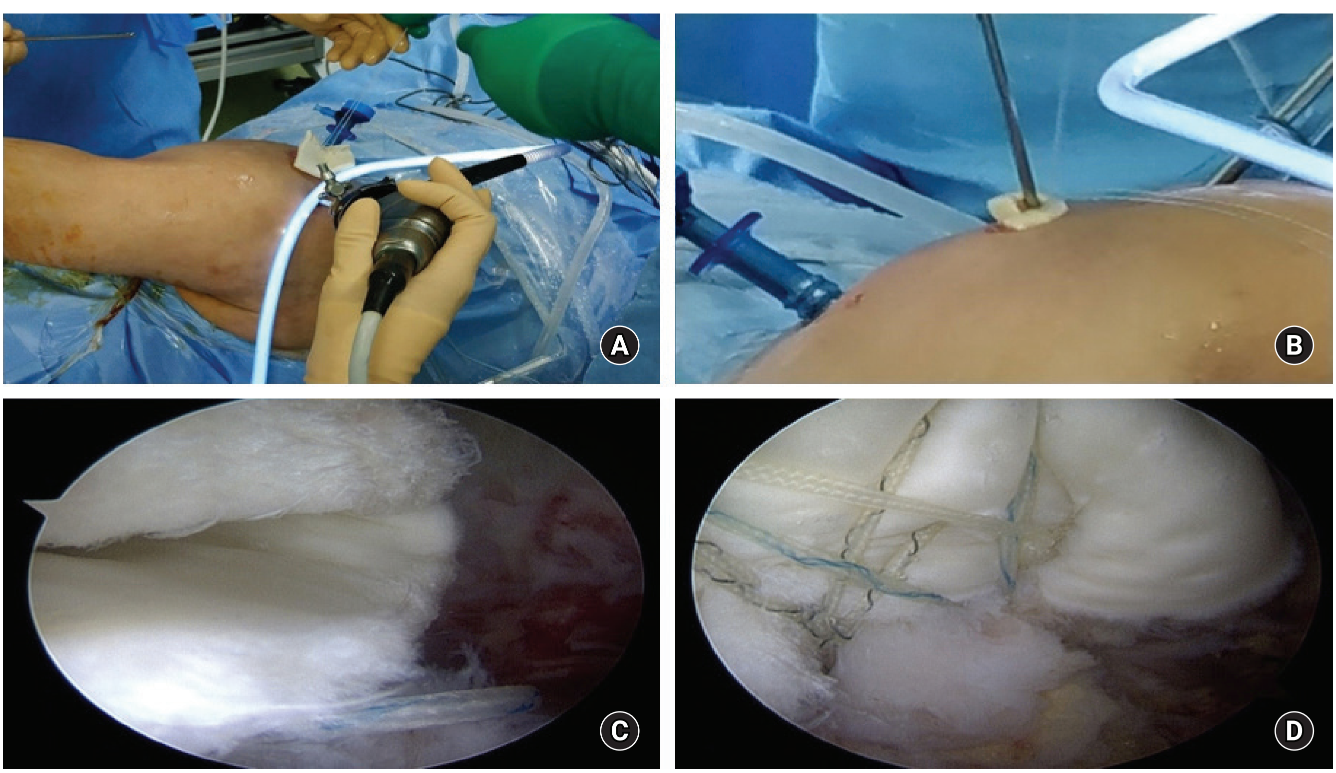

Fig. 3. (A, B) Photographs representing the procedure of arthroscopic allograft dermal patch augmentation. (C) Arthroscopic view entering allograft dermal patch. (D) Arthroscopic view after repair with patch augmentation.

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partial repair using interposition patch graft. The same authors also reported the results of superior capsular reconstruction clinical studies. The average follow-up period of 24 cases was 34 months. The forward elevation improved from 84° to 148° and the external rotation improved from 26° to 40°. AHD increased from 4.6 mm to 8.7 mm, and the American Shoulder and Elbow Surgeons scores were also significantly increased. Recently, the results of superior capsular reconstructions using synthetic patches (Arthrex Inc., Naples, FL, USA) or allograft skin tendons have been reported in consideration of morbidity of donor sites [59]. Moreover, there have been a number of favorable results for superior capsular reconstruction [68,69]. However, there is still doubt regarding the efficacy and long-term outcomes of superior capsular reconstruction; this technique has been reported in nearly 40% of reoperations in studies by authors other than those who developed superior capsular reconstruction [70,71]. There is also a debate on the difference in failure rate depending on whether the graft material is autograft or allograft. Of the various superior capsular reconstruction studies included in the systematic review published by Sochacki et al. [72] in 2019, the failure rate of the study using autograft is only 5% (5/100), but the failure rate of studies using allograft ranges from 3% (3/88) to 80% (4/5).

Tendon Transfer: Latissimus Dorsi

Tendon transfer is a good option for irreparable failed rotator cuff repair patients. Muscles commonly used for tendon transfer include latissimus dorsi (LD), pectoralis major (PM), and lower trapezius (LT) [73,74]. Since the LD transfer is intended to restore the posterior force-couple of the shoulder, LD transfer requires consideration in rupture of the rotator cuff, including posterior part of supraspinatus and infraspinatus and teres minor. In this procedure, the LD is detached from the lesser tuberosity of the humeral head (the original insertion site), and subsequently moved to the rear of the humerus and reattached to the greater tuberosity. This altered muscle vector changes LD orientation from internal rotator to external rotator. Authors who presented the results of LD transfer emphasized the abnormality of the subscapular muscle as a prerequisite for LD transfer, and warned that the outcomes of this technique may be inferior if the subscapular muscle is abnormal [75]. To predict a good prognosis for LD transfer, the authors do not recommended LD transfer in patients with eccentric humeral head position, patients with Hamada grade 4 or 5 glenohumeral osteoarthritis, and those with pseudoparalysis. In recent biomechanical experiments, LD transfer showed good results in the range of motion and stability of the glenohumeral joint; however, it was indicated that problems such as an "overcompensation phenomenon"

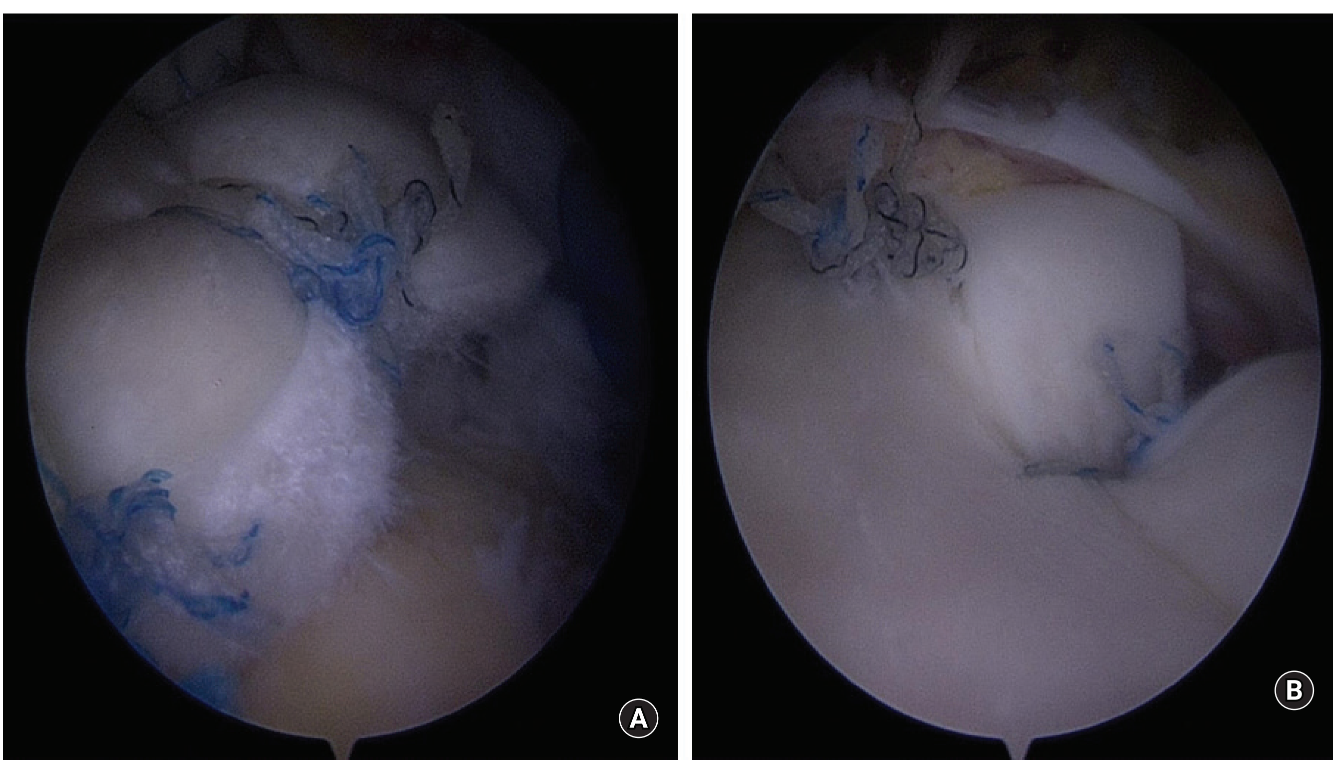

Fig. 4. Arthroscopic views of humeral footprint (A) and superior glenoid (B) after superior capsular reconstruction.

can occur in the 60º abduction position. An “overcompensation phenomenon” refers to an event wherein the contact pressure of the glenohumeral joint inevitably increases after LD transfer in patients with massive irreparable rotator cuff tears, whose force-couple disappears with simultaneous reduction in the glenohumeral joint contact peak pressure. This is the basis for negative results such as osteoarthritis, in long-term follow-ups [76]. Nevertheless, many authors report an improvement of the joint range of motion through LD transfer [77,78].

The recently introduced arthroscopic LD transfer has reported good results, and research on how the transferred LD actually works for active external rotation has continued [79]. Some authors performed electromyography on patients 1 year after LD transfer to determine if the actual LD was activated during external rotation. Indeed, by confirming the activation of the transferred LD, they reasoned that LD transfer did not merely restore force coupling by maintaining shoulder stability but also recovers the external rotation strength [80]. However, another study disputed that LD transfer merely affects the centralizing of the glenohumeral joint resulting in a functional recovery, and not being converted to external rotator cuff. Therefore, the conclusion on this issue remains debatable [81].

In 2010, Valenti et al. [82] reported results of LD transfer as a revision surgery. Of the 25 patients included in the study, eight patients had revision surgery with LD transfer, and 17 patients had primary surgery with LD transfer. Both groups showed significant functional improvement and joint range of motion improvement compared to the preoperative condition, with no statistical difference between the groups. However, there was a significant difference in patient satisfaction: 84% of primary patients reported satisfaction, as against only 50% satisfied patients after revision surgery.

Tendon Transfer: Pectoralis Major

As opposed to LD transfer, PM transfer can be considered in patients with anterior muscle rupture of the rotator cuff surrounding the shoulder. This technique was first introduced in 1997 by Wirth and Rockwood [83] and many authors have subsequently reported good results [84,85]. Several surgical techniques for PM transfer have been introduced, such as transferring the entire PM, transferring the clavicular insertion only, or transferring the sternal side only. Surgical techniques can also be distinguished by the harvested path of the PM, which passes under or above the conjoined tendon and reattaches to the lesser tuberosity of the humeral head. Recently, some authors reported a comparison of the PM transfer paths, and argued that the biomechanical reattachment of PM under the conjoined tendon gave better outcomes [86]. PM transfer may be an available option in relatively young revision patients, but it is difficult to operate and has risks which include injury complications of the musculocutaneous nerve.

Tendon Transfer: Lower Trapezius

LT transfer was first introduced as a salvage procedure for patients with brachial plexus injury [87], and is now also performed in irreparable rotator cuff tear patients [88]. LT transfer is performed to restore the posterior force-couple of the shoulder, similar to the LD transfer described above, a prerequisite being an intact scapula muscle.

LT transfer has the following advantages over LD transfer. First, LD is an internal rotator, whereas LT is a muscle that is originally activated during external rotation of the shoulder, which makes it easier to rehabilitate the shoulder motion even after tendon transfer. It is also advantageous that the muscle contraction vector after transfer to greater tuberosity is almost similar to the original vector. However, since the tendon excursion is short, it is possible to attach the greater tuberosity only by bridging, such as autograft fascia lata or allograft Achilles tendon. Reddy et al. [89] recently published a study comparing the biomechanics of LT transfer and LD transfer using three-dimensional images. In this study, the LT showed overall better results than LD transfer due to stronger abduction moment arm.

Subacromial Balloon Spacer

Since 2012, some authors have reported on the use and results of biodegradable subacromial spacers in the treatment of irreparable rotator cuff tears [90-92]. This spacer is located between the acromion and humeral heads; when the deltoid muscle contracts, this spacer assists the humeral head to remain within the glenohumeral joint instead of upward displacement during shoulder forward flexion, abduction, and external rotation. These spacers are made of copolymer poly-L-lactide-co-e-caprolactone, allowing for survival of more than 12 months in the body, which helps restore the force-couple of the glenohumeral joint.

This balloon spacer can be inserted using a usual arthroscopic approach. After arthroscopic debridement, the gap between the acromion and the glenoid is measured; subsequently, a spacer of appropriate size is selected and inserted. It needs to be emphasized that this procedure can be used in the absence of injuries of the subscapularis, whereas patients with arthritis, having allergic reactions to external implants, and patients with existing infections are not indications.

Various authors have reported good results of this technique [93,94]. In 2019, Moon et al. [95] published a systematic review of seven previously published studies. Complications were reported in only six cases (3%) of the 204 shoulders included in this study,

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and most of the patients showed satisfactory results during 2–3-year follow-up. However, lack of high-level randomization studies on the use of balloon spacers requires further research.

AUTHOR'S PREFERRED METHODS

Surgery is primarily performed when the activity level and symptoms match, taking into account the age of the patient. If the patient condition requires surgery but does not correspond to the indication of reverse total shoulder arthroplasty, we first consider revision repair. If complete revision repair is not possible after sufficient tissue release, muscle advancement technique is considered. Superior capsular reconstruction is considered if the tendon quality is not good. Muscle transfer is considered as the last resort because it is at the expense of other muscles.

CONCLUSION

Surgical treatment of a failed rotator cuff repair patient is a challenging area. It is important to select the correct patients that require surgical intervention, and various surgical treatments need to be considered depending on the physical needs of the patient and condition of the retear or unhealed tendon.

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CiSE
Clinics in Shoulder and Elbow

Instructions to authors

Enacted from June 1, 2009
Revised on December 31, 2010
June 1, 2013
March 1, 2014
May 13, 2014
September 1, 2017
March 1, 2019
December 1, 2019

1. AIMS AND SCOPE

CiSE is an international, peer-reviewed journal and the official journal of Korean Shoulder and Elbow Society. It was first launched in 1998. It is published quarterly in the first day of March, June, September, and December, with articles in English, and has been published as an online-only journal since 2019.

The purpose of CiSE are: first to contribute in the management and education of shoulder and elbow topics; second, to share latest scientific informations among international societies; and finally to promote communications on shoulder/elbow problems and patient care. It can cover all fields of clinical and basic researches in shoulder and elbow.

Manuscripts submitted to CiSE should be prepared according to the following instructions. CiSE follows the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (http://www.icmje.org/icmje-recommendations.pdf) from the International Committee of Medical Journal Editors (ICMJE).

2. RESEARCH AND PUBLICATION ETHICS

The journal adheres to the guidelines and best practices published by professional organizations, including ICMJE Recommendations and the Principles of Transparency and Best Practice in Scholarly Publishing (joint statement by the Committee on Publication Ethics [COPE], Directory of Open Access Journals [DOAJ], World Association of Medical Editors [WAME], and Open Access Scholarly Publishers Association [OASPA]; https://doaj.org/bestpractice). Further, all processes of handling research and publication misconduct shall follow the applicable COPE flowchart (https://publicationethics.org/resources/flowcharts).

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Clinical research should be conducted in accordance with the World Medical Association's Declaration of Helsinki (https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/). Clinical studies that do not meet the Helsinki Declaration will not be considered for publication. For human subjects, identifiable information, such as patients' names, initials, hospital numbers, dates of birth, and other protected health care information, should not be disclosed. For animal subjects, research should be performed based on the National or Institutional Guide for the Care and Use of Laboratory Animals. The ethical treatment of all experimental animals should be maintained.

Statement of Informed Consent and Institutional Approval

Copies of written informed consent should be kept for studies on human subjects. Clinical studies with human subjects should provide a certificate, an agreement, or the approval by the Institutional Review Board (IRB) of the author's affiliated institution. For research with animal subjects, studies should be approved by an Institutional Animal Care and Use Committee (IACUC). If necessary, the editor or reviewers may request copies of these documents to resolve questions regarding IRB/IACUC approval and study conduct.

Conflict of Interest Statement

The author is responsible for disclosing any financial support or benefit that might affect the content of the manuscript or might cause a conflict of interest. When submitting the manuscript, the author must attach the letter of conflict of interest statement (http://cisejournal.org/authors/copyright_transfer_agreement.php). Examples of potential conflicts of interest are financial support from or connections to companies, political pressure from interest groups, and academically related issues. In particular, all sources of funding applicable to the study should be explicitly stated.

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The Editorial Board will continuously work to monitor and safeguard publication ethics: guidelines for retracting articles; maintenance of the integrity of academic records; preclusion of business needs from compromising intellectual and ethical standards; publishing corrections, clarifications, retractions, and apologies when needed; and excluding plagiarized and fraudulent data. The editors maintain the following responsibilities: responsibility and authority to reject and accept articles; avoid any conflict of interest with respect to articles they reject or accept; promote the publication of corrections or retractions when errors are found; and preserve the anonymity of reviewers.

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4. SUBMISSION AND PEER-REVIEW PROCESS

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All manuscripts should be submitted online via the journal's website (https://submit.cisejournal.org/) by the corresponding author. Once you have logged into your account, the online system will lead you through the submission process in a stepwise orderly process. Submission instructions are available at the website. All articles submitted to the journal must comply with these instructions. Failure to do so will result in the return of the manuscript and possible delay in publication.

Peer Review Process

All papers, including those invited by the Editor, are subject to peer review. Manuscripts will be peer-reviewed by two accredited experts in the shoulder and elbow with one additional review by prominent member from our editorial board. CiSE's average turnaround time from submission to decision is 4 weeks. The editor is responsible for the final decision whether the manuscript is accepted or rejected.

- The journal uses a double-blind peer review process: the reviewers do not know the identity of the authors, and vice versa.
- Decision letter will be sent to corresponding author via registered e-mail. Reviewers can request authors to revise the content. The corresponding author must indicate the modifications made in their item-by-item response to the reviewers' comments. Failure to resubmit the revised manuscript within 4 weeks of the editorial decision is regarded as a withdrawal.
- The editorial committee has the right to revise the manuscript without the authors' consent, unless the revision substantially affects the original content.
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Appeals of Decisions

Any appeal against an editorial decision must be made within 2 weeks of the date of the decision letter. Authors who wish to appeal a decision should contact the Editor-in-Chief, explaining in detail the reasons for the appeal. All appeals will be discussed with at least one other associate editor. If consensus cannot be reached thereby, an appeal will be discussed at a full editorial meeting. The process of handling complaints and appeals follows the guidelines of COPE available from (https://publicationethics.org/appeals). CiSE does not consider second appeals.

5. MANUSCRIPT PREPARATION

Authors are required to submit their manuscripts after reading the following instructions. Any manuscript that does not conform to the following requirements will be considered inappropriate and may be returned.

General Requirements

- All manuscripts should be written in English.
- The manuscript must be written using Microsoft Word and saved as ".doc" or ".docx" file format. The font size must be 12 points. The body text must be left aligned, double spaced, and presented in one column. The left, right, and bottom margins must be 3 cm, but the top margin must be 3.5 cm.
- The page numbers must be indicated in Arabic numerals in the middle of the bottom margin, starting from the abstract page.
- Neither the authors' names nor their affiliations should appear on the manuscript pages.
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- The names and locations (city, state, and country only) of manufacturers of equipment and non-generic drugs should be given.
- Authors should express all measurements in conventional units using International System (SI) units.
- P-value from statistical testing is expressed as capital P.

Reporting Guidelines for Specific Study Designs

For specific study designs, such as randomized control studies, studies of diagnostic accuracy, meta-analyses, observational studies, and non-randomized studies, authors are encouraged to consult the reporting guidelines relevant to their specific research design. A good source of reporting guidelines is the EQUATOR Network (https://www.equator-network.org/) and NLM (https://www.nlm.nih.gov/services/research_report_guide.html).

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- Review Articles should focus on a specific topic. Format of a review article is not limited. Publication of these articles will be decided upon by the Editorial Board.
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The Aabstract should not exceed 200 words, and must be written as one unstructured paragraph. Authors are warned that these have a high rejection rate.

- Technical Notes should not exceed 1,500 words. The abstract should be an unstructured summary not exceeding 150 words. The body of these manuscripts should consist of introduction, technique, discussion, references, and figure legends and tables (if applicable). References should not exceed 10. A maximum of 3 figures and 1 table are allowed.
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- All sources of funding applicable to the study should be stated here explicitly.

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Each paper should start with an abstract not exceeding 250 words. The abstract should state the background, methods, results, and conclusions in each paragraph in a brief and coherent manner. Relevant numerical data should be included. Under the abstract, keywords should be inserted (maximum 5 words). Authors are recommended to use the MeSH database to find Medical Subject Heading Terms at http://www.nlm.nih.gov/mesh/meshhome.html. The abstract should be structured into the following sections.
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- Results: The most important study results and analysis should be presented in a logical manner with specific experimental data.
- Conclusions: The conclusions derived from the results should be described in one to two sentences, and must match the study objective.

Guidelines for the Main Body

- All articles using clinical samples or data and those involving animals must include information on the IRB/IACUC approval or waiver and informed consent. An example is shown below. "We conducted this study in compliance with the principles of the Declaration of Helsinki. The study's protocol was reviewed and approved by the Institutional Review Board of OO (IRB no. OO). Written informed consent was obtained / Informed consent was waived."
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- Results: This section should include detailed reports on the data obtained during the study. All data in the text must be presented in a consistent manner throughout the manuscript. All issues which the authors brought up in the method section need to be in result section. Also it is preferred that data to be in figures or table rather than long list of numbers. Instead, numbers should be in tables or figures with key comment on the findings.
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uous set of numbers: "Kim et al. [2,8,9] insisted…" and "However, Park et al. [11–14] showed opposing research results."

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Figures and Figure Legends

Figures should be cited in the text and are numbered using Arabic numbers in the order of their citation (e.g., Fig. 1). Figures are not embedded within the text. Each figure should be submitted as an individual file. Location of figure legends begins at the next page after last table. Every figure has its own legend. Abbreviation and additional information for any clarification should be described within each figure legend. Figure files are submitted in EPS, TIFF, or PDF formats. Requirement for minimum resolutions are dependent on figure types. For line drawings, 1,200 dpi are required. For grey color works (i.e., picture of gel or blots), 600 dpi are required. For color or half-tone artworks, 300 dpi are required. The files are named by the figure number.

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- Papers containing unclear photographic prints may be rejected.
- Remove any writing that could identify a patient.
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References

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- Other types of references not described below should follow ICMJE Recommendations (https://www.nlm.nih.gov/bsd/uniform_requirements.html).
- Examples of references are as follows:

Journal article

1. Kim IB, Kim EY, Lim KP, Heo KS, Does the use of injectable atelocollagen during arthroscopic rotator cuff repair improve clinical and structural outcomes? Clin Shoulder Elbow 2019;22: 183-9.
2. Kovacevic D, Fox AJ, Bedi A, et al. Calcium-phosphate matrix with or without TGF-β3 improves tendon-bone healing after rotator cuff repair. Am J Sports Med 2011;39:811-9.
3. Nord KD, Masterson JP, Mauck BM. Superior labrum anterior posterior (SLAP) repair using the Neviaser portal. Arthroscopy 2004;20 Suppl 2:129-33.
4. Rohner E, Jacob B, Bohle S, et al. Sodium hypochlorite is more effective than chlorhexidine for eradication of bacterial biofilm of staphylococci and Pseudomonas aeruginosa. Knee Surg Sports Traumatol Arthrosc 2020 Feb 7 [Epub]. https://doi.org/10.1007/s00167-020-05887-9

Book & book chapter

5. Iannotti JP, Williams Jr GR. Disorders of the shoulder: diagnosis & management. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2007. p. 66-80
6. Provencher MP, LeClere LE, Van Thiel GS, et al. Posterior instability of the shoulder. In: Angelo RL, Esch JC, Ryu RK, eds. AANA advanced arthroscopy the shoulder. Philadelphia, PA: Saunders; 2010. p. 115-23.

Website

7. American Cancer Society. Cancer facts & figures 2020 [Internet]. Atlanta, GA: American Cancer Society; c2020 [cited 2020

Feb 5]. Available from: https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2020.html.

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Final Version

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