CiSE

Clinics in Shoulder and Elbow

Volume
23

Number
2

June
2020

eISSN : 2288-8721

www.cisejournal.org

www.cisejournal.org

eISSN 2288-8721

CiSE
Clinics in Shoulder and Elbow

Volume 23 • Number 2 • June 2020

Aims and Scope

Clinics in Shoulder and Elbow (Clin Shoulder Elbow, CiSE; eISSN: 2288-8721) (pISSN: 2383-8337 till 2018) is an international, peer-reviewed journal and the official journal of Korean Shoulder and Elbow Society. It was first launched in 1998 (from March 1998 to June 2010: Journal of the Korean Shoulder and Elbow Society). 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 purposes 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.

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Open Access

Publisher Joo Han Oh
Editor-In-Chief Young-Kyu Kim

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Published on June 1, 2020

eISSN 2288-8721

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CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Is total elbow arthroplasty a reliable alternative treatment option for comminuted distal humerus fractures in elderly patients?

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The treatment of comminuted intra-articular distal humerus fractures is challenging in elderly patients. Open reduction and internal fixation (ORIF) in elderly patients has a high risk of complications, including poor functional outcomes, persistent pain, infection, stiffness, nonunion, ulnar neuropathy, internal fixation failure, and heterotopic ossification [1-3]. Because of poorer ORIF outcomes in osteoporotic elderly patients, there has been increasing interest in total elbow arthroplasty (TEA) as a more reliable alternative to ORIF and nonsurgical treatment.

Primary TEA for acute distal humerus fractures was first reported in 1997 by Cobb and Morrey [4]. They retrospectively reviewed the records of 20 patients (21 elbows) who had a mean age of 72 years at the time of injury. The mean duration of follow-up was 3.3 years (range, 3–10.5 years). Based on the Mayo elbow performance Score (MEPS), 15 elbows had an excellent result and five had a good result; there were inadequate data for one elbow. There were no fair or poor results. Several other studies have confirmed similar, consistently reliable results [5-7]. Prasad et al. [8] found that survivorship, with revision and definite loosening as end-points, was 89.5% at 10 years with male patients having a higher incidence of loosening and wear.

Frankle et al. [9] performed a retrospective comparison between women older than 65 who underwent ORIF (12 patients) and TEA (12 patients) for distal intra-articular humerus fractures. All fractures were Orthopedic Trauma Association (OTA) classification 13.C2 or 13.C3. After a minimum of 2 years of follow-up, there were one good and 11 excellent results based on MEPS among those treated with TEA. There were no fair or poor outcomes. On the other hand, there were four excellent, four good, one fair, and three poor results (cases that required conversion to TEA) among those treated with ORIF. McKee et al. [3] conducted a prospective, randomized, controlled trial to compare clinical outcomes in elderly patients (older than 65 years, OTA classification 13C) with displaced intra-articular, distal humerus fractures treated with ORIF (15 patients, mean age of 77 years) or primary semi-constrained TEA (25 patients, mean age of 78 years). The TEA group resulted had more predictable and improved 2-year functional outcomes than the ORIF group. The fact that 25% of fractures randomized to ORIF were not amenable to internal fixation suggests that TEA may result in decreased reoperation rates. The authors ultimately concluded that TEA is preferred over ORIF in elderly patients with complex distal humerus fractures that are not amenable to stable fixation. Dehghan et al. [10] evaluated long-term outcomes (mean follow-up period

Received: May 2, 2020 Revised: May 15, 2020 Accepted: May 15, 2020
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Financial support: None.
Conflict of interest: None.

of 12.5 years) of TEA for distal humerus fractures from a prior randomized clinical trial [3]. They concluded that TEA is an effective and reliable procedure for treatment of comminuted distal humerus fractures in elderly patients and a well-performed TEA will give them a well-functioning elbow for life. A systematic review and meta-analysis by Githens et al. [11] revealed that TEA and ORIF for the treatment of geriatric distal humerus fractures produced similar functional outcome scores and range of motion. Although there was a trend toward a higher rate of major complications and reoperation after ORIF, this was not statistically significant.

The paper titled "Comparison of open reduction and internal fixation with total elbow arthroplasty for intra-articular distal humeral fractures in older age: a retrospective study" by Lee et al. [12] in this issue of *Clinics in Shoulder and Elbow* compared the clinical and functional outcomes of ORIF (28 patients) and TEA (43 patients) in patients aged ≥65 years. At the last follow-up visit (ORIF group: mean, 31 months; TEA group: mean, 34 months), 93% (26/28 cases) of the ORIF group showed good-to-excellent results based on MEPS. On the other hand, only 35% (15/43 cases) of the TEA group showed good results. This result is interesting because it is contrary to previous reports in the literature that TEA has better or similar clinical results compared to ORIF for complex distal humeral fractures.

Throckmorton et al. [13] reported the specific failure patterns after linked semi-constrained TEA for posttraumatic arthritis. They demonstrated a 15-year survival rate of 70% with revision or resection for any reason as the end point with 68% good-to-excellent clinical results. The most common cause of early failure (failure after less than 5 years) was infection, whereas intermediate-term failure (failure after 5 to 10 years) typically was due to bushing wear. Late failure (failure after more than 10 years) was uncommon and involved component loosening or fracture. Seventy-five percent of failures occurred in patients younger than 60 years who had greater physical demands.

With regard to postoperative daily activities, TEA comes with a lifetime repetitive weight-lifting restriction of approximately 5 lb. In addition, heavy manual work, and forceful pushing and pulling activities are usually restricted. Therefore, TEA should be reserved for selected lower-demand elderly patients only; it is not an option for younger, higher-demand individuals. As the number of TEA procedures continues to increase, the revision burden will correspondingly increase [14]. The treatment of distal humerus fractures with osteoporotic and highly comminuted articular surfaces is often challenging. ORIF is the gold standard in younger patients and also should be the first-line treatment in elderly patients if osteosynthesis is possible. Therefore, TEA for the treatment of distal humerus fractures is indicated in elderly, low-demand patients and those with osteoporosis, pre-existing inflammatory arthritis, osteoarthritis, or a reduced life expectancy. It is also indicated for comminuted and nonrepairable articular surfaces, pathologic fractures, and fracture nonunion. The indications for TEA have expanded substantially in the past 10 years. Currently, acute trauma and posttraumatic arthritis of the elbow are the main indications for TEA, surpassing rheumatoid arthritis [15]. Although there are good long-term data regarding these prosthetic devices for rheumatoid arthritis, additional evidence is needed for traumatic situations because they pose a unique set of challenges and complications. Clinical evidence from long-term prospective randomized controlled studies is required to determine the feasibility of TEA in the treatment of complex distal humerus fractures in elderly patients.

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Original Article

Clin Shoulder Elbow 2020;23(2):62-70
https://doi.org/10.5397/cise.2019.00094

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Outcomes of arthroscopic capsulolabral reconstruction for anterior instability with greater than 20% glenoid bone defects: are Latarjet procedures absolutely indicated for these patients?

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Background: Recent studies have reported high rates of recurrence of shoulder instability in patients with glenoid bone defects greater than 20% after capsulolabral reconstruction. The purpose of the present study was to evaluate the failure rate of arthroscopic capsulolabral reconstruction for the treatment of anterior instability in the presence of glenoid bone deficits >20%.
Methods: Retrospective analyses were conducted among cases with anterior shoulder instability and glenoid bone defects of >20% that were treated by arthroscopic capsulolabral reconstruction with a minimum 2-year follow-up (30 cases). We included the following variables: age, bone defect size, instability severity index score (ISIS), on-/off-track assessment, incidence recurrent instability, and return to sports.
Results: The mean glenoid bone defect size was 25.8%±4.2% (range, 20.4%–37.2%), and 18 cases (60%) had defects of >25%. Bony Bankart lesions were identified in 11 cases (36.7%). Eleven cases (36.7%) had ISIS scores >6 points and 21 cases (70%) had off-track lesions. No cases of recurrent instability were identified over a mean follow-up of 39.9 months (range, 24–86 months), but a sense of subluxation was reported by three patients. Return to sports at the preinjury level was possible in 24 cases (80%), and the average satisfaction rating was 92%.
Conclusions: Arthroscopic soft tissue reconstruction was successful for treating anterior shoulder instability among patients with glenoid bone defects >20%, even enabling return to sports. Future studies should focus on determining the range of bone defect sizes that can be successfully managed by soft tissue repair.

Keywords: Glenohumeral joint; Bankart lesion; Instability; Arthroscopic soft tissue procedure

INTRODUCTION

Burkhart and De Beer [1] reported that treatment of glenohumeral joint instabilities with significant defects of the glenoid cavity by arthroscopic capsulolabral reconstruction alone had a failure rate of 67%. Thus, it is generally accepted that glenoid bone defects >20% cannot be overcome by treatment limited to arthroscopic soft tissue procedures [2-5]. More recently, the gle-

Received: March 5, 2020 Revised: April 19, 2020 Accepted: April 22, 2020
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IRB approval: Seoul National University Hospital (No. J-1705-082-855); Seoul National University Bundang Hospital (No. B-1706-402-102).
Financial support: None.
Conflict of interest: None.

noid track concept was developed while considering the combined effects of glenoid bone defects and bone defects of the humeral head (Hill-Sachs lesion) on anterior shoulder stability [6]. According to the glenoid track concept, procedure such as the Latarjet procedure are recommended for treating off-track cases, in which the glenoid and humeral head bone defects are sufficient to allow the humeral head to engage on the glenoid rim [7].

In our practice, arthroscopic capsulolabral reconstruction has remained the first-line approach for the treatment of anterior shoulder instability with glenoid bone loss in the range of 20%–30%, after careful discussions about surgical options with patients. Therefore, the purpose of the present study is to document the failure rate of arthroscopic soft tissue reconstruction for the treatment of anterior shoulder instability in patients with glenoid bone deficits >20%. We hypothesized that arthroscopic anterior soft tissue stabilization would yield clinically satisfactory outcomes with a low recurrence rate.

METHODS

This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. J-1705-082-855) and Seoul National University Bundang Hospital (IRB No. B-1706-402-102).

Study Design and Criteria

The study was conducted using a retrospective case series design. Between January 2004 and December 2015, 372 patients (261 and 111 at two institutions) underwent arthroscopic anterior capsulolabral reconstruction with or without other arthroscopic soft tissue procedures such as concomitant superior labral anterior and posterior (SLAP) repair, the remplissage procedure, and/or interval closure for anterior shoulder instability. The study group was selected by applying the following criteria: (1) glenoid bone defect >20%, calculated on preoperative computed tomography (CT) or magnetic resonance imaging (MRI) (37/372 cases), and (2) availability of follow-up data for at least 2 years postoperatively. Patients that underwent a bony procedure (e.g., Latarjet or free-bone graft), revision, concomitant rotator cuff repair, and patients with multi-directional instability or epileptic dislocation were excluded (34/372 cases). Of the 372 cases, 34 (9.9%) met our inclusion criteria. However, of these 34 cases, two were revision cases and two underwent the Latarjet procedure, and thus, these four patients were excluded. Accordingly, 30 cases constituted the study cohort.

Information about hand dominance, age at onset of shoulder instability, number of dislocations, subjective ease of dislocation, possibility of self-reduction, level of sports activity, and occupation were extracted from medical records, along with basic demographic data. Level of sport activity was dichotomized as competitive or recreational based on requirement of primary occupations. Assessments of hyperlaxity (external rotation >85° or hyperabduction of ≥20° between sides) [7] were included in the physical examination.

The definition of what constitutes a large or significant amount of bone loss is controversial, but based on recent consensus guidelines, a large defect is defined as 20%–30% loss of glenoid width and <21% loss of glenoid length [2-4]. Therefore, we set the standard at 20%. The prevalence of glenoid bone defects >20% among 372 patients that underwent arthroscopic anterior capsulolabral reconstruction was 9.9% (37/372 cases), which is lower than a previously reported rate of 12% [8]. We cautiously hypothesized that transfer bias would not be high among 9.0% of cases (3/33) lost to follow-up. The study protocol and data collection were approved by our Institutional Review Boards (IRB No. B-1706-402-102, J-1705-082-855).

Surgical Procedures and Rehabilitation

All surgical procedures were performed by two surgeons (JHO and SHK). All arthroscopic procedures were performed in the lateral decubitus position with the operated arm pulled by a traction device at ~4 kg. Generally, three portals were used for the procedure, that is, a posterior viewing portal and anteroinferior and anterosuperior portals. In cases that underwent additional SLAP repair, a trans-rotator cuff portal was used instead of the anterosuperior portal [9].

Diagnostic arthroscopy was performed prior to repair to determine the severity of glenoid bone loss and to confirm the presence of concomitant lesions. The anterior shoulder soft tissue stabilization procedure consisted of a Bankart procedure or anterior labroligamentous periosteal sleeve avulsion lesion fixation with capsular plication. For anteroinferior labral repair or anterior capsular shift, the abnormally-attached labrum or anteroinferior glenohumeral ligament was mobilized from the glenoid neck, and a 2–3 mm wide area of subchondral bone was exposed on the glenoid side for the recipient bed by removing articular cartilage using a motorized burr and curette. The capsule, together with the anterior labrum and bone fragment when present, were sutured and tacked down using three or four evenly spaced knotless suture anchors (Bioknotless; Depuy Mitek, Raynham, MA, USA or Pushlock; Arthrex, Naples, FL, USA) between 2 and 6 O'clock for the right shoulder. When present, bone fragments were always incorporated into the labral repair (Fig. 1). Incorporation of bone fragments was accomplished during capsulolabral

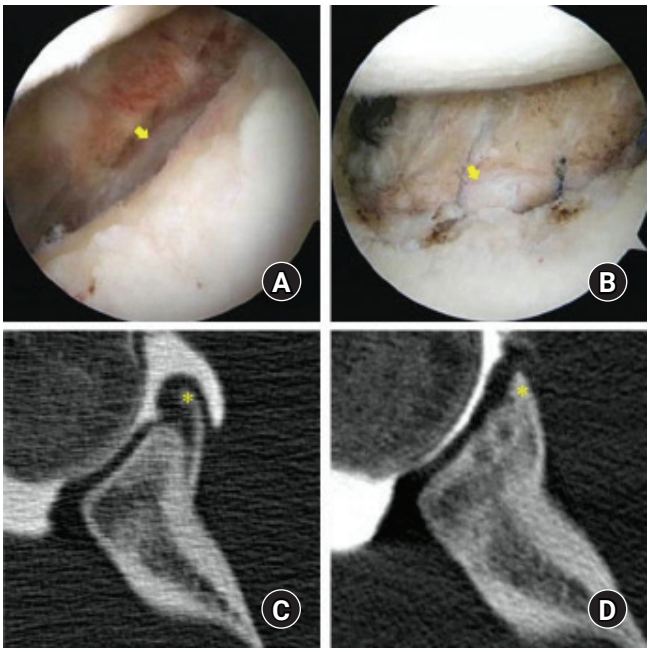

Fig. 1. Arthroscopic images in the lateral decubitus position viewed from the posterior viewing portal for the right shoulder. (A) Bankart lesion with a bone fragment (arrow) located medial to the articular surface. (B) The fragment (arrow) was reduced and incorporated into the capsulolabral repair. Comparison of preoperative and postoperative computed tomography (CT) images. (C) The bone fragment accompanying the Bankart lesion (asterisk) was visualized by preoperative CT. (D) Postoperative CT image showing healing of the fragment (asterisk) to the main glenoid rim.

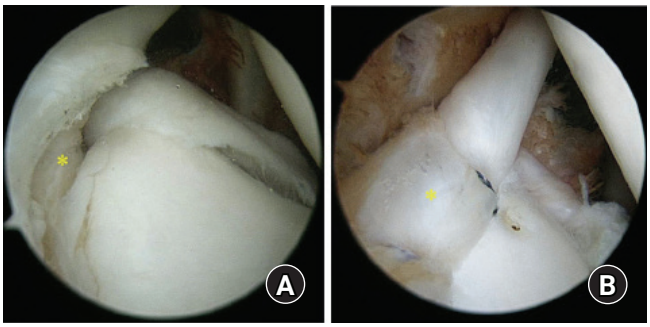

Fig. 2. (A) Arthroscope image showing a type II superior labral anterior and posterior lesion (asterisk) in conjunction with anterior labral detachment. (B) The lesion (asterisk) was repaired using two knotless suture anchors.

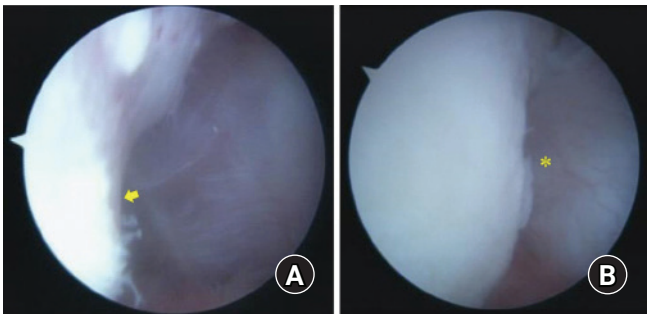

Fig. 3. (A) Arthroscope image showing a medially extended Hill-Sachs lesion (arrow) through the anterior portal. (B) The remplissage procedure was performed, and the posterior capsule was attached to the Hill-Sachs lesion (asterisk).

reconstruction without extra procedures or devices and without increasing risk or technical difficulty.

Procedures additional to anterior soft tissue reconstruction were incorporated as needed and included SLAP repair, remplissage, and/or rotator interval closure. Generally, SLAP lesions were repaired to add stability to glenohumeral joints [5], or to resolve painful instability as indicated by a positive SLAP physical test. To repair SLAP lesions, we used the trans-rotator cuff portal to achieve an appropriate angle for anchor insertion. After preparing the superior glenoid neck, and after anterior soft tissue reconstruction, one to two knotless anchors were used to repair the superior labrum (Fig. 2). To prevent postoperative external rotation limitation, the labral anterosuperior area (1 to 2 O'clock position) was not fixed.

Remplissage was used for cases with significant Hill-Sachs lesions, which are defined as large nonengaging Hill-Sachs lesions that may engage in nonfunctional positions, but not engage during functional activities. This procedure allowed overriding of the humeral head on the anterior glenoid rim even after anterior soft tissue reconstruction (Fig. 3). For this procedure, the arthroscope was switched from the posterior to the anterosuperior portal, and a cannula was placed into the posterior viewing portal. The surface of the engaging Hill-Sachs lesion was gently freshened using a bur in reverse mode while taking care to remove a minimum amount of bone surface. One or two double-loaded suture anchors were then placed at the lesion margin using a penetrating grasper passed through the tendon and posterior capsule to grasp and pull one limb of the suture. These mattress sutures were then tied, such that knots remained within the extra-articular, sub-deltoid space, and filled in the infraspinatus tendon and capsule posterior to the Hill-Sachs lesion. Additional rotator interval closure was performed using additional suture anchors in cases with definite sulcus sign when the shoulder was placed in external rotation (Fig. 4).

A standardized rehabilitation protocol was used throughout the study period. Strict immobilization in neutral shoulder rotation using an abduction pillow was maintained for 6 weeks. No motion was allowed during this period. Range of motion exercises were initiated at 6 weeks postoperatively when brace use was discontinued. Muscle-strengthening exercises, especially rotator cuff strengthening, were initiated at 3 months and continued un-

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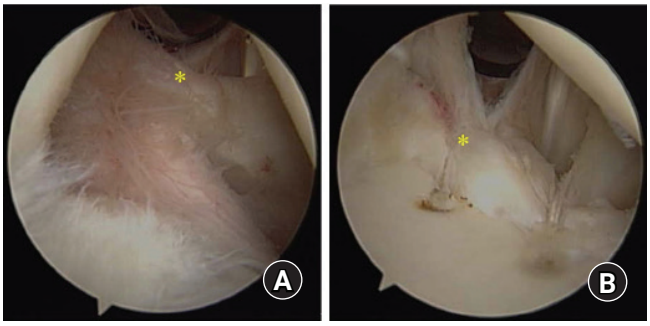

Fig. 4. (A) Arthroscope image showing a wide rotator interval (asterisk) with the shoulder in external rotation. Preoperative joint laxity tests were positive for this patient. (B) Rotator interval closure (asterisk) was performed using suture anchors.

til at least 6 months postoperatively. Return to sports was permitted at 6 months postoperatively.

Imaging Evaluation

The extent of glenoid bone loss (percentage and size in mm) were assessed using the best-fit circle method [10]. Initially, a best-fit circle was placed along the posterior and inferior margins of the glenoid in en face preoperative MRI or CT. A horizontal line was then placed through the center of the circle to extend from its posterior to anterior margins; this line represented the estimated diameter of the intact glenoid. A second horizontal line was then drawn at the same level between the anterior margin of the circle and the anterior margin of the glenoid; this line represented the amount of anterior glenoid bone loss (Fig. 5).

Hill-Sachs lesions were classified as on-track or off-track using preoperative MRI [11], and defined as the region of cortical impaction along the posterosuperior margin of the humeral head. According to the on-track/off-track technique, the glenoid track is calculated using 0.84 D–d, where D represents the diameter of the intact glenoid (mm) and d corresponds to the amount of glenoid bone loss (mm) [6]. The Hill-Sachs interval is quantified as the sum of the width of the Hill-Sachs lesion (mm) and the width of the intact bone bridge (mm) between the rotator cuff attachment and the lateral margin of the Hill-Sachs lesion. Lesions were considered to be engaging or off-track if the Hill-Sachs interval exceeded the glenoid track, and to be non-engaging or on-track if the Hill-Sachs interval was less than the glenoid track (Fig. 6). All measurements were performed on axial images at the point of largest medial lesion extent. Measures and the determination of off-track or on-track status were performed independently by two fellowship-trained shoulder surgeons(SMR, WJ, JUK) with 1 and 2 years of experience, respectively.

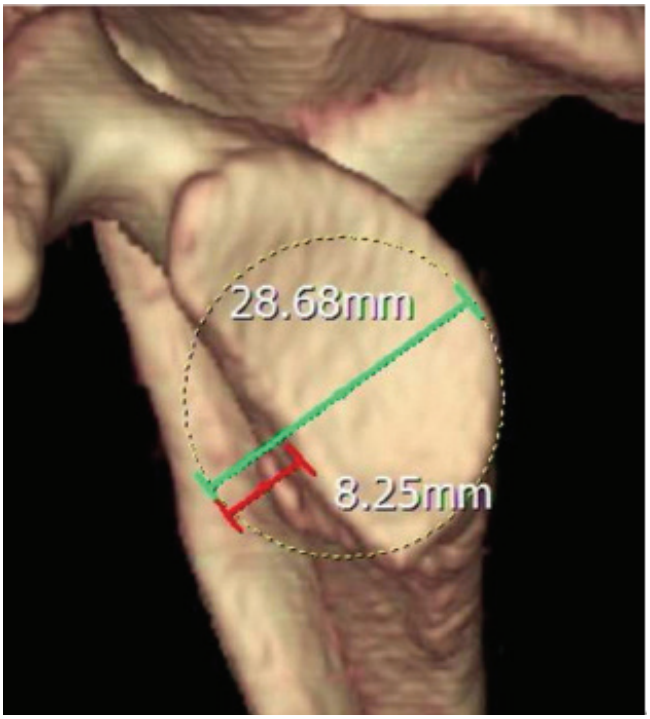

Fig. 5. En face view of a three-dimensional reconstructed CT image used to measure the extent of a glenoid bone defect. A best-fit circle was drawn and localized on the inferior part of the glenoid using the PACS (Picture Archiving and Communication System). A horizontal line (the estimated diameter of the intact glenoid, green line) was placed within the center of the circle and extended from the posterior to the anterior margin of the circle. A second horizontal line (indicating the amount of anterior glenoid bone loss, red line) was placed at that same level between the anterior margin of the circle and the anterior margin of the glenoid.

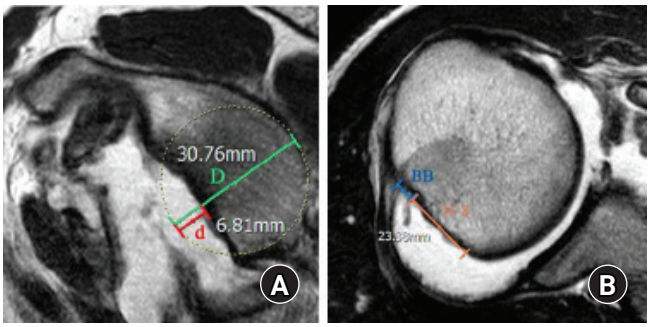

Fig. 6. (A) Sagittal T2-weighted image showing a bone defect of the anterior glenoid margin. The green line indicates the estimated intact diameter of the glenoid (D, 30.76 mm), and the red line, the amount of glenoid bone loss (d, 6.81 mm). A best-fit circle was drawn in the lower two thirds of the glenoid. A glenoid track (0.84 D–d) of 19.03 mm was calculated. (B) Axial fat-suppressed T2-weighted image showing a broad superficial Hill-Sachs lesion. The Hill-Sachs interval measured 23.38 mm (the orange line indicates the Hill-Sachs lesion [HS], and the blue line the bony bridge [BB]).

Instability Severity Index Score Evaluation

Instability severity index score (ISIS) is a 10-point scale that evaluates six preoperative factors identified as being predictive of recurrent shoulder instability [7]. The four patient-related factors included are age <20 years (2 points), involvement in competitive sports (2 points), contact or forced overhead activities (1 point), and anterior or inferior hyperlaxity (1 point), and the two radiographic factors (identified on anteroposterior views) included are visible Hill-Sachs lesion on external rotation (2 points) and loss of normal inferior glenoid contour (2 points). An ISIS score of >6 points is considered the threshold for high risk of recurrence after only capsulolabral reconstruction [7]. Two fellowship-trained shoulder surgeons with 1 and 2 years of experience, respectively performed measures independently that were not affected by the results.

Statistical Analysis

Descriptive analysis was performed using the SPSS ver. 21.0 (IBM SPSS Corp., Armonk, NY, USA). The Wilcoxon rank sum test was used to evaluate differences between preoperative and postoperative values. P-values of <0.05 were deemed significant.

RESULTS

Conservative treatment was not attempted at either institution in patients with glenoid bone loss exceeding 20%. Demographic and preoperative data are presented in Table 1. The mean age at time of surgery was 27.6±10.6 years (range, 14–57 years) and mean age at onset of shoulder instability was 23.3±9.0 years (range, 13–50 years). Mean follow-up duration was 39.9±20.1 months (range, 24–86 months). Dominant sides were involved in 17 cases (56.7%), and instability symptoms in contralateral sides were noted in seven cases (23.3%). The average number of dislocation episodes that patients reported before surgery was 13.4±11.7 (range, 1–50), and hyperlaxity was positive in 14 shoulders (46.7%) [7,12].

Table 1. Demographic and preoperative information for the study cohort (30 cases)

Variable	Value
Age at surgery (yr)	27.6±10.6 (14–57)
Age at onset of instability (yr)	23.3±9.0 (13–50)
Sex (male:female)	28:2
Number of dislocations	13.4±11.7 (1–50)
Dominant side involvement	17 (56.7)
Possibility of self-reduction	25 (83.3)
Ease of dislocation	18 (60)
Participation in competitive sports	11 (36.7)
Shoulder hyperlaxity	14 (46.7)
Bankart lesion with bone fragment	11 (36.7)

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

Mean glenoid bone defect size was 25.8%±4.2% (range, 20.4%–37.2%) and >25% in 18 (60%) cases. Bone defects were measured on CT images in 22 cases (73.3%) and on MRI in the other eight cases (26.7%). For all 30 study subjects, mean ISIS score was 5.7±2.0 (range, 2–10) and 11 (36.7%) patients had a score of >6 points. Regarding on-track/off-track Hill-Sachs lesions, 21 patients (70%) had an off-track lesion. For all study subjects, the mean diameter of best fit circles around glenoid cavity perimeters was 26.7±1.7 mm, and the mean real anteroposterior dimension of the glenoid was 19.9±1.9 mm. Mean distance between rotator cuff insertions and medial borders of Hill-Sachs lesions was 17.7±5.3 mm. Bankart lesions with bone fragments were identified in 11 cases (36.7%), and in these cases, bone fragments and capsulolabral structures were repaired using suture anchors. SLAP lesions were identified in 12 cases (40%), and repaired in eight cases; debridement only was performed in two cases and tenotomy was performed in one case. Remplissage was performed in three cases only, and rotator interval closure in three cases. On average, 4.0±1.0 anchors (range, 3–6) were used for the repair, and more anchors were used in cases of concomitant SLAP repair. Three or more anchors were used for anterior capsulolabral reconstruction.

During follow-up, no obvious dislocations occurred in any patient, but a positive sensation of subluxation was reported by three patients. Interestingly, these three patients had off-track lesions as determined preoperatively, but only one had an ISIS score of >6. Revision surgery was not required in these three cases. Twenty-four (80%) of the study subjects returned to sports at their pre-injury levels. Among all study subjects, satisfaction with surgical treatment was 9.2±0.9 (range, 7–10) determined using a 10-point visual analog scale. Preoperative and postoperative ranges of motion and American Shoulder and Elbow Surgeons Shoulder and Western Ontario Shoulder Instability Index scores are listed in Table 2. Both increased significantly at the final follow-up. In addition, external rotation at 90° abduction and internal rotation at back was improved due to loss of a sense of instability by patients. Postoperative CT arthrography was performed in 21 patients (70%), and all showed evidence of satisfactory glenoid labrum healing.

DISCUSSION

This retrospective case series study demonstrates the feasibility

https://doi.org/10.5397/cise.2019.00094

Table 2. Preoperative and postoperative range of motion functional outcomes of the cohort

Outcome variable	Preoperative	Postoperative	P-value
Range of motion			
Forward flexion (°)	170±8	172±6	0.239
External rotation at side (°)	58±17	62±20	0.227
External rotation at 90° abduction (°)	82±13	91±12	0.001
Internal rotation at back*	7.6±2.5	6.8±1.4	0.029
ASES shoulder score	67.5±22.2	97.9±5.3	<0.001
WOSI	444.6±187.4	50.1±26.7	<0.001

Values are presented as mean±standard deviation.
ASES: American Shoulder and Elbow Surgeons, WOSI: Western Ontario Shoulder Instability Index.
*Internal rotation was measured by recording the vertebral level reached with the tip of the thumb. Vertebral levels were numbered serially as follows: 12 for the 12th thoracic vertebra, 13 for the 1st lumbar vertebra, 17 for the 5th lumbar vertebra, and 18 for any level below the sacral region.

of using an arthroscopic soft tissue procedure to treat anterior shoulder instability in cases with >20% glenoid defects. The definition of what constitutes a large or significant amount of bone loss is controversial, but based on recent consensus guidelines, a large defect is defined as 20%–30% loss of glenoid width and <21% loss of glenoid length [2-4]. The absence of recurrent instability among our cases is clinically relevant, as none of the 30 patients included in the sample required revision surgery and only three reported a sensation of subluxation during follow-up. Previous studies have reported recurrence rates after arthroscopic Bankart repair and capsular plication ranging from 4% to 21% and identified factors that contribute to differences in recurrence rates between studies and in variables including patient-specific characteristics, the definition of recurrence used (recurrent dislocation only or recurrent dislocation with subluxation), and follow-up duration [13,14]. Based on this information, the absence of any recurrence in our case series suggests that our soft tissue repair success rate was comparable to that of shoulder instability without bone defects, contrary to previously-reported outcomes for anterior shoulder instability with bone defects.

The presence of a glenoid bone defect in cases of anterior shoulder instability is one of the most important risk factors of recurrence [1,15]. Burkhart and De Beer [1] reported a 67% failure rate for arthroscopic Bankart repair in cases with significant bone defects, and a rate of only 4% in the absence of such defects. Boileau et al. [15] reported a 15% redislocation rate in the presence of >20% glenoid bone loss and found that this was also significantly associated with failures of soft tissue repair. Although several studies confirmed the influence of glenoid bone deficiency on the outcomes of anterior instability procedures [16,17], the critical cutoff value for bone deficiency has not been clearly determined. Recently, Ahmed et al. [18] reported that loss of >25% independently predicted failure, whereas Shin et al. [19] in a retrospective study found that a bone defect cutoff value of 17.3% best predicted recurrence after arthroscopic Bankart repair. However, Shin et al. [19] excluded Bankart lesions with bone fragments and did not provide any patient-specific information regarding sporting activity or occupation, which means that their results and ours cannot be directly compared. Kim et al. [20] reported a recurrent instability rate of 11% among patients with 20%–30% glenoid bone defects and moderate-to-low shoulder functional demands.

We agree that the Latarjet procedure and other bone graft procedures produce favorable outcomes in cases of anterior shoulder instability with significant bone loss. However, the Latarjet procedure is invasive, nonanatomic, technically demanding, and associated with considerable complications [21,22]. Although some clinicians have insisted that the Latarjet procedure is superior to Bankart repair for the treatment of anterior shoulder instability, regardless of bone defect [14], others have raised concerns regarding possible under-estimation and reporting of complications (e.g., screw problems, bone resorption, and later osteoarthritic changes) associated with the Latarjet procedure [23]. In fact, a recent systematic review reported a complication rate of 30% for the Latarjet procedure and recurrent dislocation and reoperation rates of 2.9% and 7%, respectively [23].

The recently-proposed glenoid track concept considers contributions of bone defects of the glenoid and head of the humerus to the biomechanics of anterior shoulder instability. Considering that 21 of our cases (70%) were off-track lesions, the rate of recurrent instability should theoretically have been higher, despite the fact we used only soft tissue repair rather than the bony procedure recommended for such cumbersome cases. However, on-track/off-track assessment considers only the rolling motion of the head of the humerus on the glenoid cavity as determined by static MRI [6], whereas this rolling motion is actually accompanied by a gliding motion during shoulder movement. As a result of this combined motion, during arm elevation in external rota-

tion, the point of contact of the humeral head on the glenoid migrates from an inferior region to a superocentral-posterior region while the glenoid contact shifts posteriorly [24]. Given this posterior displacement of the head of the humerus, which would be increased by anterior capsulolabral reconstruction, the anterior glenoid rim and Hill-Sachs lesion may not contact each other, despite preoperative imaging findings of an off-track lesion. In addition, the importance of proprioception recovery after anterior stabilization needs to be considered, given that position sense and detection of movement should be equivalent to those of the uninvolved shoulder at 1 year after surgery [25]. From a clinical perspective, the ISIS scoring system was developed to predict failure of soft tissue repair, based on patient-related and radiographic characteristics, whereby a score >5 out of 10 is associated with a 70% risk of recurrent instability following arthroscopic anterior stabilization [6]. In a population-based study, an ISIS score of ≤6 points was associated with a 10% risk of recurrent instability after arthroscopic stabilization, and a score of >6 points was associated with a 70% risk. Those authors recommended open procedures, such as the Latarjet procedure, for cases with scores >6 points. In the present study, 11 cases (36.7%) had ISIS scores of >6 points.

The low rate of recurrence observed in the present study can be explained as follows. First, for the 11 cases (36.7%) with Bankart lesions and bone fragments, we incorporated fragment repair with the capsulolabral structure, and thus, when fragments healed, the sizes of glenoid bone defects were effectively reduced. Satisfactory results for bone fragment defect repair during arthroscopic capsulolabral reconstruction have been reported previously, even when those studies did not address larger bone defects [16,26]. In cases of attritional bone loss, defined as glenoid bone defects without bony fragments, outcomes of soft tissue repair are not as predictable [16], although the outcomes of such cases were clinically satisfactory in the present study. Second, we completely immobilized operated shoulders for 6 weeks, and even forbade pendulum motion, passive exercise, and return to sports activity during this period. Furthermore, before returning to sports activities, patients were instructed to perform extensive rotator cuff strengthening exercises that commenced 3 months after surgery and continued until at least 6 months postoperatively. Extensive rotator cuff strengthening exercise started with isometric exercises with resisted contraction for internal and external rotation, and then added isotonic shoulder strengthening with rubber bands. Somewhat surprisingly, no guideline studies have evaluated the effects of different postoperative rehabilitation protocols on the results of shoulder instability surgery. Nevertheless, the conservative rehabilitation protocol that we adopted could have affected our results. Third, three or more anchors were used in all cases to stabilize anterior capsulolabral structure, as the use of less than three anchors has been shown to be a risk factor of recurrence [15].

The reliability and validity of glenoid bone defect identification and Hill-Sachs lesion measurements must also be considered. Direct visual measurement during arthroscopic surgery provides the most reliable data in most cases, but in 48% of cases, bare bone is not well visualized. Moreover, referencing a bone defect to the center of the glenoid is possible in only about 37% of cases, as the referencing landmark is eccentrically located in the other 63% [27]. To overcome these issues, the use of three-dimensional (3D) CT is recommended as the gold standard to measure glenoid bone loss, as 3D CT measurements have been reported to be well correlated with arthroscopic measurements and to have high reliability based on cadaveric measurements [28]. In our case series, glenoid bone loss was measured using MRI in several cases, due to the absence of 3D CT images. Although 3D CT is considered the gold standard, glenoid bone loss can be accurately measured on MRI using the circle method, which has been shown to compare favorably with 3D CT and CT measurements [29]. Recently introduced on-track/off-track measurements hold promise as feasible clinical measures of bone loss, but are currently limited with respect to the measurement of Hill-Sachs deficits and by the ambiguous measurement guidelines provided in the original publication describing their use [30].

The importance of the effects of glenoid bone defects on anterior shoulder stability is being increasingly recognized, and this recognition has expanded the use of the Latarjet procedure. Although the Latarjet procedure does provide definite shoulder stability in patients with glenoid bone defects, we contend that anterior capsulolabral reconstruction is probably sufficient in the majority of cases. Sometimes, over-treatment is more problematic than under-treatment since the former is more invasive and associated with higher complication rates. Therefore, we suggest that selection of the best surgical strategy should be an individualized decision based on careful discussion with the patient, rather than being based solely on objective considerations of bone defect size.

This study has several limitations that require consideration. First, it is inherently limited by its retrospective case series design, the small number of cases included, and by the lack of a control group. A retrospective, case controlled study would have been more relevant, but at the two involved institutions, soft tissue procedures are used as first-line treatments for anterior instability even in patients with >20% glenoid bone loss. Furthermore, it should be noted that >20% loss of glenoid contour in

https://doi.org/10.5397/cise.2019.00094

cases of anterior shoulder instability is relatively uncommon; the rate of occurrence was only 9.9% in our case series. Second, our incorporation of additional procedures was not standardized. Most frequently, anterior instability was accompanied by a SLAP lesion (43.8% of cases). However, SLAP repair was performed in only nine of these cases, while debridement was performed in four cases and tenotomy in the remaining case. Remplissage and rotator interval closure were performed in three cases each. For SLAP repairs, the superior labrum was repaired to relieve symptoms and to add shoulder stability [31]. Therefore, debridement and tenotomy were performed for cases in which extents of injury to labrum and biceps tendon were deemed insufficient to warrant full SLAP repair. Remplissage and rotator interval closure were performed at the surgeon's discretion. We were not able to evaluate whether adding these procedures enhanced shoulder stability. As previously mentioned, bone defects were measured using preoperative MRI in nine cases rather than using 3D CT images, which is the recommended gold standard [29].

This retrospective case series analysis of 30 cases of anterior shoulder instability with glenoid bone defects exceeding 20% indicates that the use of arthroscopic soft tissue repair is feasible and provides clinically favorable outcomes, even in a sporting population. This finding is important when one considers the invasive nature of the Latarjet procedure and its high rate of associated complications. Future studies should focus on determining the size range of bone defects that can be successfully managed by soft tissue repair.

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https://doi.org/10.5397/cise.2019.00094

Original Article

Clin Shoulder Elbow 2020;23(2):71-79
https://doi.org/10.5397/cise.2020.00122

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Difference in glenoid retroversion between two-dimensional axial computed tomography and three-dimensional reconstructed images

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Background: The glenoid version of the shoulder joint correlates with the stability of the glenohumeral joint and the clinical results of total shoulder arthroplasty. We sought to analyze and compare the glenoid version measured by traditional axial two-dimensional (2D) computed tomography (CT) and three-dimensional (3D) reconstructed images at different levels.

Methods: A total of 30 cases, including 15 male and 15 female patients, who underwent 3D shoulder CT imaging was randomly selected and matched by sex consecutively at one hospital. The angular difference between the scapular body axis and 2D CT slice axis was measured. The glenoid version was assessed at three levels (midpoint, upper one-third, and center of the lower circle of the glenoid) using Friedman's method in the axial plane with 2D CT images and at the same level of three different transverse planes using a 3D reconstructed image.

Results: The mean difference between the scapular body axis on the 3D reconstructed image and the 2D CT slice axis was 38.4°. At the level of the midpoint of the glenoid, the measurements were 1.7°±4.9° on the 2D CT images and −1.8°±4.1° in the 3D reconstructed image. At the level of the center of the lower circle, the measurements were 2.7°±5.2° on the 2D CT images and −0.5°±4.8° in the 3D reconstructed image. A statistically significant difference was found between the 2D CT and 3D reconstructed images at all three levels.

Conclusions: The glenoid version is measured differently between axial 2D CT and 3D reconstructed images at three levels. Use of 3D reconstructed imaging can provide a more accurate glenoid version profile relative to 2D CT. The glenoid version is measured differently at different levels.

Keywords: Shoulder; Scapula; Bone retroversion; Multidetector computed tomography; Three dimensional

INTRODUCTION

The glenoid version of the shoulder joint is correlated with the stability of the glenohumeral joint and clinical results of total shoulder arthroplasty [1-3]. The glenoid version is of interest in shoulder joint pathologies. Posterior instability of the shoulder joint is reported to be associated with increased retroversion of the glenoid [4,5]. Bone loss of the glenoid affects the glenoid version, resulting in changes in contact pressure in the glenohumeral joint [6-8]. Also, it is important to evaluate the glenoid inclination before conducting shoulder arthroplasty, since an altered glenoid inclination due to the glenoid component may facilitate

Received: March 17, 2020 Revised: May 6, 2020 Accepted: May 7, 2020
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Financial support: None.
Conflict of interest: None.

biomechanical changes in the glenohumeral joint, resulting in different wear patterns of the glenoid component [8-11].

The glenoid version is reported from 2° anteversion to 9° retroversion and varies among individuals and races [7]. Under the aid of a scapula-holding device, the glenoid version was measured with a goniometer in several cadaveric studies [7,12,13]. In image studies, the measurement method described by Friedman et al. [6] is mainly used and adopts a line positioned between the medial border of the scapula to the center of the glenoid as a reference line for the scapular axis. Although various methods of measuring the glenoid version have been discussed, methods involving computed tomography (CT) scans, mostly axial two-dimensional (2D) CT images, are preferred and known to be more accurate than those incorporating measurements of plain radiograph images [14]. Recently, reports suggesting new methods of measuring the glenoid version with magnetic resonance imaging (MRI) are comparable to those using CT scans [15,16].

However, the measurement process may be affected by patient posture in a variety of ways, such as if the scapular position is not aligned with the axis of the CT scanner. There is a report suggesting that scapular rotation in the coronal and sagittal planes will affect the variation of the measured glenoid version, highlighting in particular that 0.42° of anteversion was gained with 1° of scapular abduction in the coronal plane [17]. Discrepancies between the actual glenoid version and the scans can be attributed to changes in scapula posture.

There are image software programs that offer the capacity for three-dimensional (3D) reconstruction based on 2D CT images. Using these programs, it is possible to measure and analyze the reconstructed image by freely rotating the image in 3D. Moreover, it is possible to print models using 3D printing technology [18]. In a 3D reconstructed image, the transverse plane of the glenoid can be decided at various levels. The transverse plane obtained on 3D reconstructed scans is not altered by the position of the CT scanner or scapula or by the patient's posture.

Our hypothesis was that differences exist between the glenoid version measured with axial 2D CT and 3D reconstructed imaging, respectively. This thought arose from the discrepancy between the axis of the CT scanner and the scapula position, which can be changed by patient posture. Therefore, the purpose of this study was to analyze and compare the glenoid version measured with traditional axial 2D CT and with 3D reconstructed imaging, respectively.

METHODS

This study was approved by the Institutional Review Board of Eunpyeong St. Mary's Hospital (IRB No. PIRB-20200305-005).

Patient Enrollment

A total of 30 cases, including 15 male and 15 female patients, who underwent shoulder 3D CT was consecutively selected and matched by sex at one hospital. Patients with glenoid fracture, previous shoulder operation, deformity due to severe glenoid wear or erosion, or poor CT scan quality were excluded. The mean age of male patients was 52.5 years (range, 28–72 years) and that of female patients was 64.0 years (range, 22–84 years).

Three-Dimensional Reconstruction Protocol

Shoulder 3D CT (Optima CT 660; GE Healthcare, Chicago, IL, USA) scans were collected with the patient in the supine position. A free open-source software program, ITK snap (version 3.4.0; United States National Institute of Biomedical Imaging and Bioengineering, Bethesda, MD, USA) [19], was used for reconstructing 2D CT images into 3D images (Fig. 1). Meshmixer (version 3.0; Autodesk Inc., San Rafael, CA, USA), a free open-source software program, was used to rotate and edit the 3D reconstructed images (Fig. 2).

A scapular coronal plane as a reference plane, based on the method introduced by Kwon et al. [13], was achieved by connecting three reference points (i.e., inferior tip of the scapular body, medial pole of the scapula, and center of the glenoid surface). The area orthogonal to this plane was defined as the transverse scapular plane (Fig. 3).

Measuring the Angle between the 2D Axial CT Scan and Scapular Coronal Plane

The glenoid version can be measured ideally when the 2D CT slice axis is orthogonal to the scapular body axis. The 2D CT slice axis was established by use of the scout image function in a PACS (picture archiving and communication) system (Marosis M-view version 5.4; Marotech, Seoul, Korea). We checked for an angular difference between the scapular body axis and the actual 2D CT slice axis (Fig. 4).

Measuring the Glenoid Version with 2D Axial CT

The glenoid version was measured at three levels, including the upper one-third of the glenoid, midpoint of the glenoid, and center of the lower circle of the glenoid. A center point bisecting the anatomical glenoid axis (i.e., at the midpoint of the glenoid) was chosen because it represents the base plate position in anatomical total shoulder arthroplasty. The center of the lower circle of the glenoid was chosen because it is the center peg hole of the base plate for reverse total shoulder arthroplasty. On axial 2D CT scans

https://doi.org/10.5397/cise.2020.00122

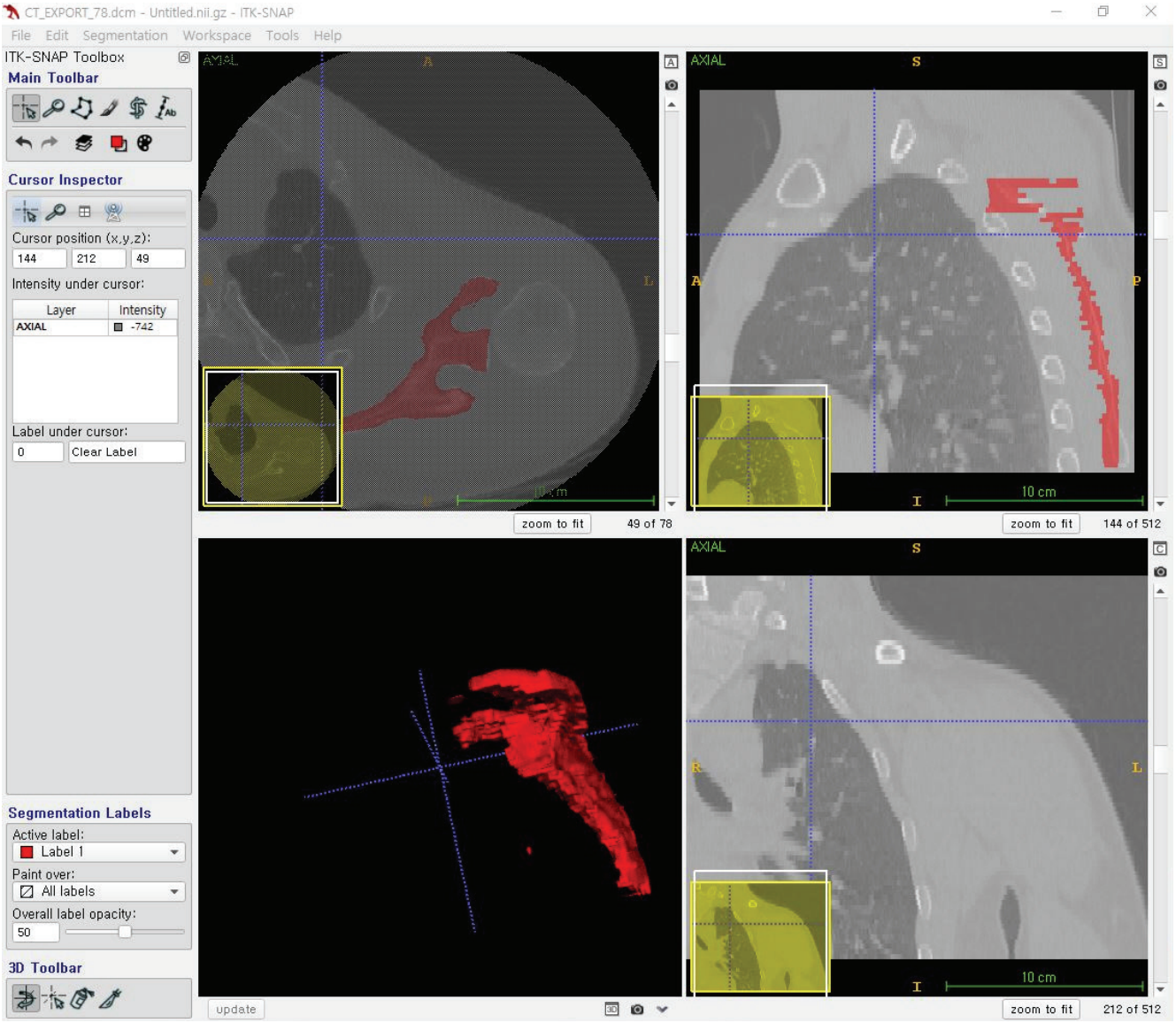

Fig. 1. ITK SNAP (version 3.4.0) was used for reconfiguring computed tomography axial images into the three-dimensional structure image.

of these three levels, the glenoid version was measured (Fig. 5). The measuring method developed by Friedman et al. [6] was adopted at each level [20].

Measuring the Glenoid Version Using 3D Reconstructed Imaging

Here, a 3D reconstructed image was sliced along the transverse scapular plane orthogonal to the scapular coronal plane. The axial 3D slice was taken at the same three levels as those chosen for assessment on the 2D CT scans (Fig. 6).

Statistical Analysis

Measured glenoid versions were compared between the 2D CT scans and the 3D reconstructed image at each of the three levels. The IBM SPSS ver. 24.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. The Kolmogorov-Smirnov test was used for normal distribution assessments of all measurements. A paired t-test and the signed rank-test were used to compare the glenoid version between the data from 2D CT scans and 3D reconstructed images, respectively. An analysis of variance and the Kruskal-Wallis test were chosen to compare the glenoid version between the 2D CT images and 3D reconstructed image at each level. Significance levels for all analyses were set at $P < 0.05$.

RESULTS

The mean angle between the 2D CT slice axis and the scapular body axis on the 3D reconstructed image was 38.4°. The mean

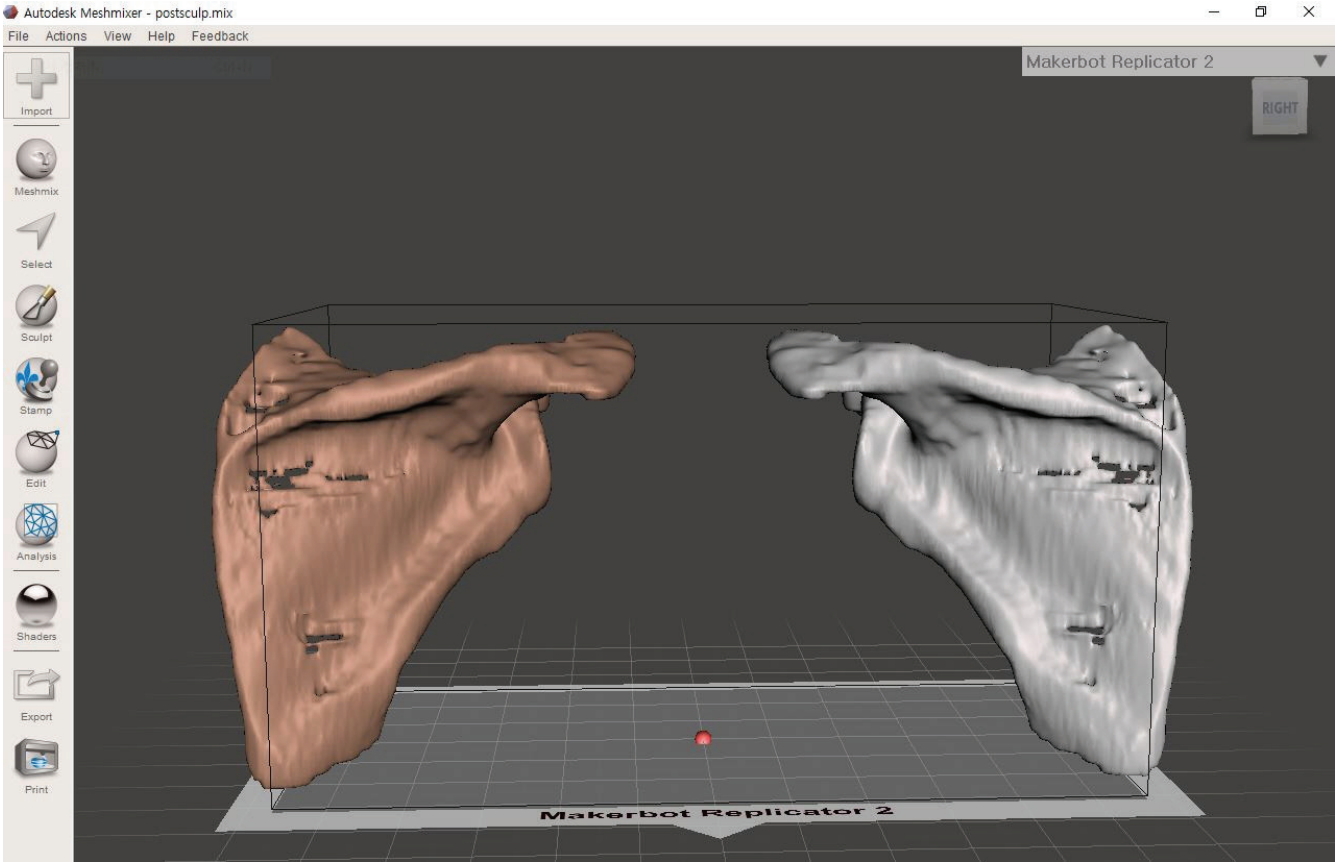

Fig. 2. Meshmixer (version 3.0) was used to edit and rotate the three-dimensional reconstructed image.

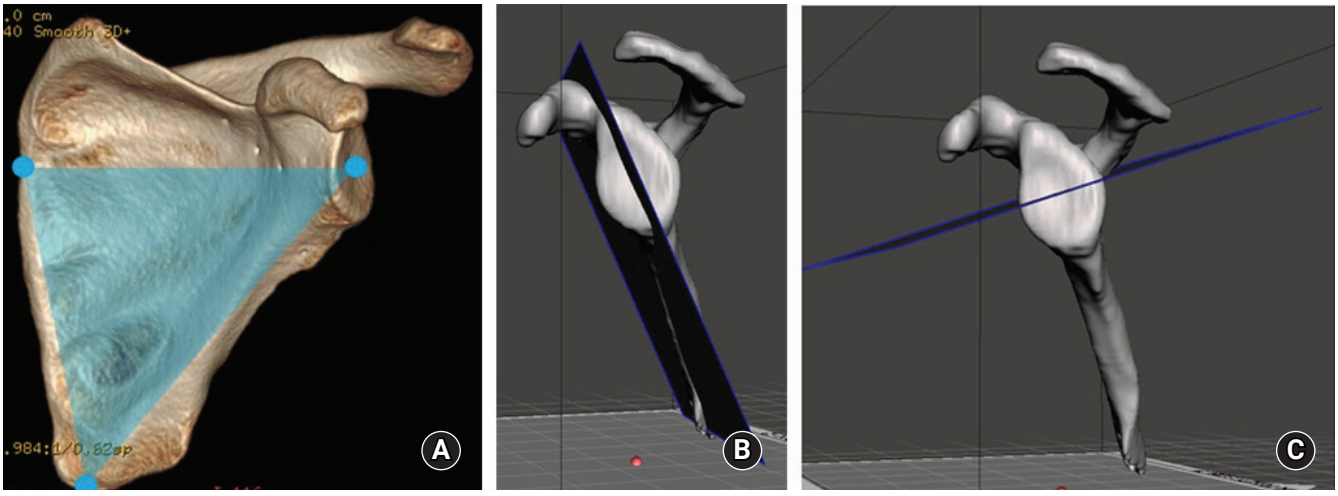

Fig. 3. Scapular plane. (A) The scapular coronal plate, as the reference plane, was defined by connecting the inferior tip of the scapular body, medial pole of the scapula, and the midpoint of the glenoid surface. (B) The scapular coronal plane was demonstrated on the three-dimensional constructed image with the Meshmixer software. (C) The transverse scapular plane was marked orthogonally to the scapular coronal plane.

glenoid version measured at the level of the upper one-third of the glenoid was −3.6° ± 4.5° on the 2D CT images and −4.5° ± 5.7° on the 3D reconstructed image. At the level of the glenoid center, the glenoid version was measured as 1.7° ± 4.9° on the 2D CT images and −1.8° ± 4.1° on the 3D reconstructed image. Finally, the mean glenoid version measured at the level of the center of the lower circle of the glenoid was 2.7° ± 5.2° on the 2D CT images and −0.5 ± 4.8° on the 3D reconstructed image. A statisti-

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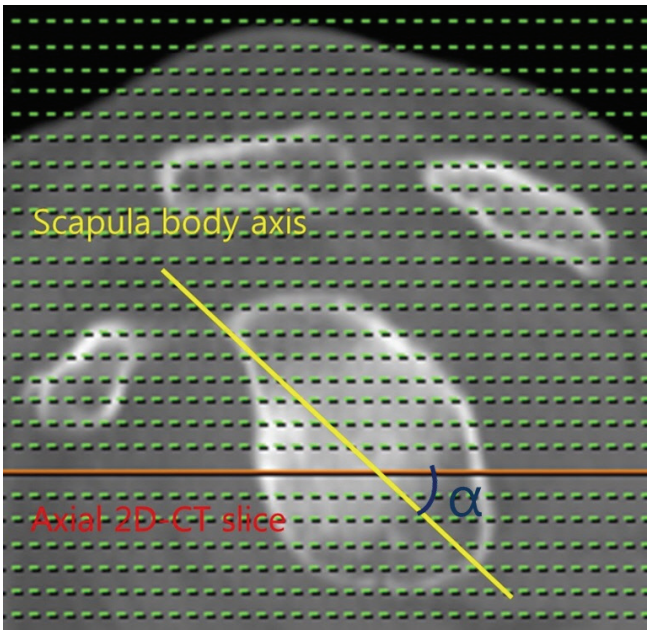

Fig. 4. The angle between the axis of a standard axial two-dimensional computed tomography (2D CT) scan (orange line) and the scapula body axis (yellow line) was measured.

cally significant difference was found between the glenoid version measured on the 2D CT images and 3D reconstructed image at all three levels (P = 0.003, P = 0.000, and P = 0.000, respectively) (Table 1).

Considering results of the same modality, a statistical difference was found among the three levels between 2D CT scans (P = 0.000) and 3D reconstructed images (P = 0.007). During a multiple comparison test, a statistical difference was found between the upper one-third of the glenoid and the midpoint of the glenoid (P = 0.000) and between the upper one-third and the center of the lower circle of the glenoid (P = 0.000) on the 2D CT images. During a multiple comparison test of the 3D reconstructed image, a statistical difference was found between the upper one-third of the glenoid and the center of the lower circle of the glenoid (P = 0.006). All angles were measured by two orthopedic surgeons (HK and HSS) independently. The interclass correlation coefficient was greater than 0.9.

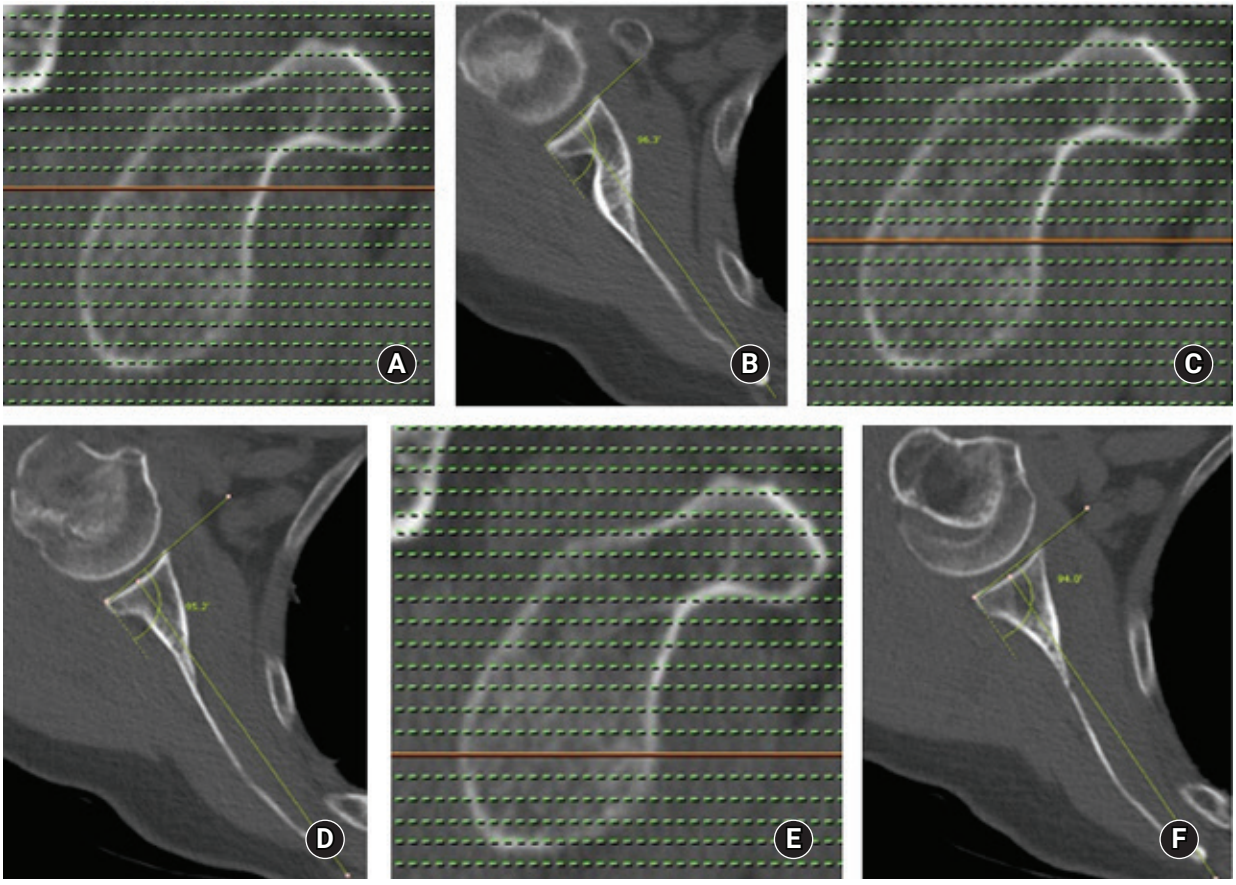

Fig. 5. The glenoid version as measured on an axial two-dimensional computed tomography scan. (A) The level of measurement at the upper one-third of the glenoid. (B) The glenoid version at the upper one-third of the glenoid. (C) The level of measurement at the center of the glenoid. (D) The glenoid version at the center of the glenoid. (E) The level at the center of the lower plane. (F) The glenoid version at the center of the lower circle of the glenoid.

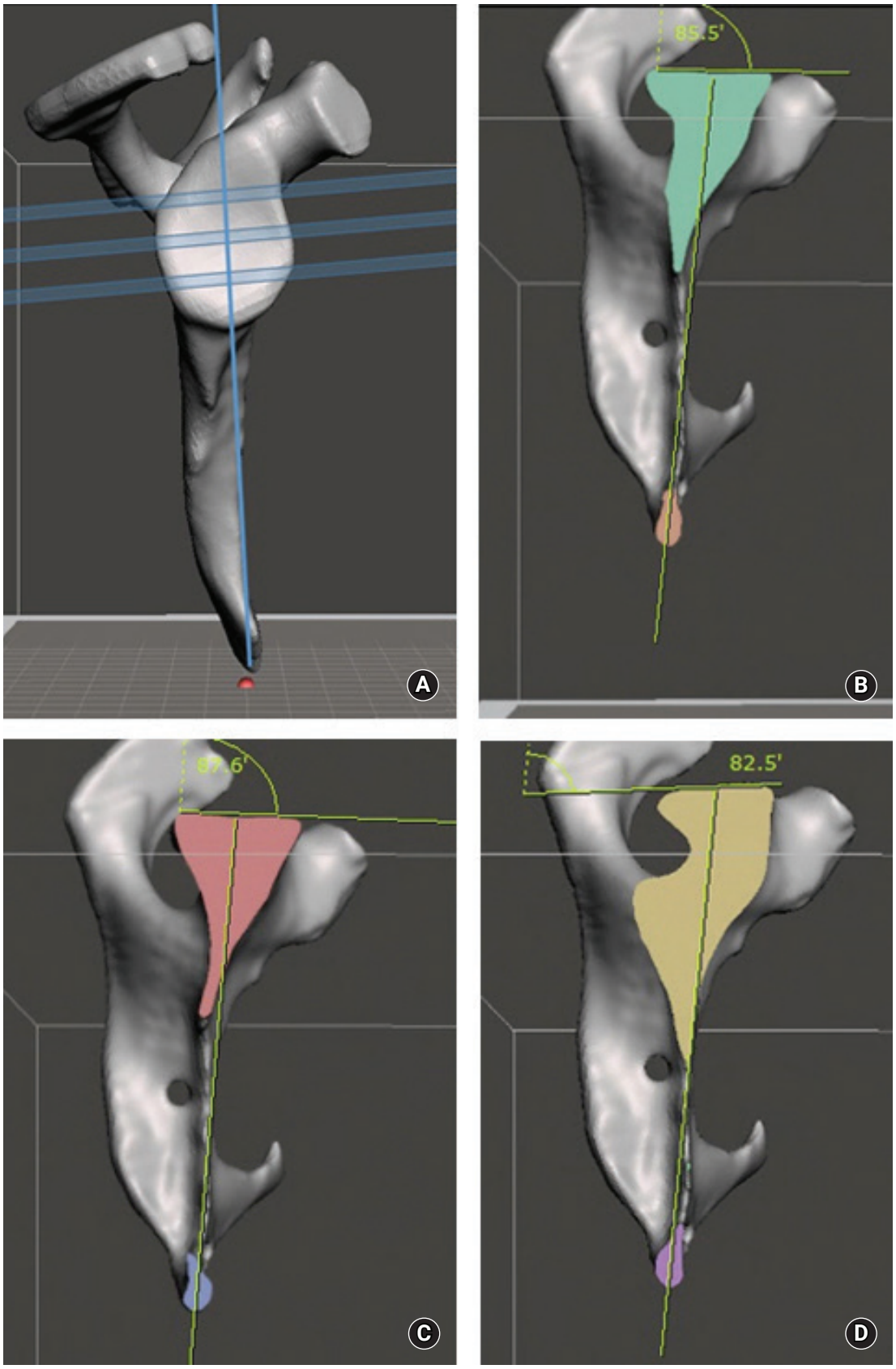

Fig. 6. The glenoid version as measured on the three-dimensional (3D) reconstructed image. (A) The 3D reconstructed image showing three transverse planes. (B) The glenoid version as assessed at the upper one-third transverse plane. (C) The glenoid version as assessed at the center of the glenoid. (D) The glenoid version as assessed at the center of the lower circle of the glenoid.

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Table 1. Mean glenoid version on the 2D CT images and 3D reconstructed image (minus value represents retroversion)

Level of the glenoid	2D CT	3D reconstruction	P-value*
Upper one-third (°)	−3.6±4.5	−4.5±5.7	0.003
Center (°)	1.7±4.9	−1.8±4.1	0
Center of the lower circle (°)	2.7±5.2	−0.5±4.8	0
P-value†	0	0.007	

Values are presented as mean±standard deviation.
2D: two-dimensional, CT: computed tomography, 3D: three-dimensional.
*Paired t-test. †Analysis of variance.

DISCUSSION

In this study, there was a significant difference in glenoid version between measurements collected from routine axial 2D CT scans and a 3D reconstructed image at three levels of the glenoid. Thus, the glenoid version could be different depending on the level of measurement and whether 2D axial CT scans or a 3D reconstructed image is assessed. Restoring the glenoid version anatomically is important when performing shoulder arthroplasty since it affects the clinical results [21,22]. It is known that the possibility of loosening increases when the glenoid component is inserted in a retroversion position of more than 10° [8,23]. To restore the glenoid version accurately, it is important to measure and analyze the glenoid version preoperatively.

In most of the available reports in the literature, the glenoid version was measured on axial 2D CT scans. In the study by Nyffeler et al. [14], which compared the glenoid version as measured in the axillary view of a plain radiograph and an axial 2D CT scan image, the glenoid version was measured more accurately on the CT image. However, there could be a discrepancy depending on the position of the CT scanner and the patient's scapula when the image was taken [24]. In the present study, the mean angle between the 2D CT slice axis and the scapular body axis on the 3D reconstructed image was 38.4°.

To overcome this discrepancy, Kwon et al. [13] measured the glenoid version on 3D reconstructed images of cadaveric scapulae and suggested that measuring the glenoid version on a 3D reconstructed image obtained from CT scans could accurately reflect the actual glenoid version measured in cadavers. Considering these reports, the authors [13] doubted whether there would be any measurement difference between those taken from axial 2D CT images and those from a 3D reconstructed image. Also, if a difference was found, the 3D reconstructed image would likely be a preferable image type in the clinical field.

Considering that ideal glenoid version can be achieved when the superoinferior axis of glenoid—that is, the coronal plane of the scapula—is orthogonal to the axis of a 2D CT scanner, this study suggested that it is not easy to match this axis in real-world clinical circumstances. Patients may experience difficulties maintaining the necessary position due to pain, anxiety, medical comorbidities, or body habitus. Technicians might face challenges in positioning patients in the right position due to variations among patients' spine curvatures or the anterior tilt of the glenoid itself. As a result, the scanning process may proceed without proper perception of the patient position, which would make it difficult to obtain an accurate scapula axis and which can lead to inaccurate measurements of the glenoid version. Indeed, a difference of 38.4°, which is quite a large variation from 90°, was observed in this study.

The glenoid version is mostly measured on axial 2D CT scans. To assess the difference of the glenoid version measured at different levels, the glenoid version was measured not only at the midpoint of the glenoid, but at levels superior and inferior to the center of the glenoid. From this, it was revealed that the glenoid version was different depending on the level at which measurements are performed. Lewis and Armstrong [25] reported different glenoid version measurements in a different series of glenoid heights collected from 3D CT scans. The tilting angle of the glenoid was also reported to be different in five planes in a 3D image study that adopted MRI by Inui et al. [15]. Furthermore, the glenoid surface itself possesses the shape of a superior-to-inferior spiraling twist [15,26]. In this study, a statistically significant difference was found between 2D CT scan images and a 3D reconstructed image at all three levels assessed. This suggests that, by measuring with a 3D reconstructed image, more accurate measurements can be obtained. Also, this study showed an approximately 4° difference between measurements at the upper one-third and center of the lower circle of the glenoid. A report by Inui et al. [15] showed the tendency for an increase in retroversion when measurements were conducted superiorly, although the measurement level was different from that in this study.

This study had some limitations. The sample size of each group was relatively small. Because glenoids with deformities were excluded from this study, more studies should be completed to validate our measurement method in patients with arthritis or other defects of the glenoid. However, by measuring the glenoid version on the 3D reconstructed image, no effect of patient positioning was apparent, which is a strength of this research.

In this study, by accurately selecting the transverse planes on the 3D reconstructed image, comparison with axial 2D CT images was possible. This study has significant value to facilitate clini-

cal improvement given the availability of easy access to the 3D reconstruction program. Also, it is meaningful that the angular difference between the scapular body axis and 2D CT slice axis was analyzed. In this investigation, the glenoid version was measured differently between axial 2D CT scans and a 3D reconstructed image at three levels. The 3D reconstructed image provided more accurate glenoid version data relative to the 2D CT scans. Finally, the glenoid version is measured differently at different levels.

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Original Article

Clin Shoulder Elbow 2020;23(2):80-85
https://doi.org/10.5397/cise.2020.00066

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Clinical outcome of ultrasound-guided atelocollagen injection for patients with partial rotator cuff tear in an outpatient clinic: a preliminary study

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Background: Atelocollagen has been studied for restoration of rotator cuff tendon. In this study, we attempted to evaluate the clinical outcome of ultrasound-guided atelocollagen injection in an outpatient clinic for patients with partial rotator cuff tear.
Methods: We recruited 42 outpatients who visited our hospital from May 2019 to September 2019. Atelocollagen injection was performed in patients with partial rotator cuff tear diagnosed by magnetic resonance imaging and ultrasound. American Shoulder and Elbow Surgeons (ASES), Constant, Korean Shoulder Score (KSS) and Simple Shoulder Test (SST) scores, and range of motion were assessed before injection and after 2 months. Statistically, we analyzed the clinical results using the Wilcoxon signed-rank test.
Results: Finally, 15 patients were enrolled for analysis. There was no significant difference between pre- and post-injection in terms of range of motion, ASES (57.0 vs. 60.4), Constant (56.4 vs. 58.9), KSS (64.6 vs. 68.5), and pain-visual analog scale (4.2 vs. 3.7), except function-visual analog scale (F-VAS; 6.3 vs. 7.1) and SST (6.6 vs. 6.9). A significant difference was found in SST (P=0.046) and F-VAS (P=0.009). According to the ultrasound results at 2 months, we found hyperechoic materials in three of seven patients. The most common complication of atelocollagen injection was post-injection pain (53%, 8/15).
Conclusions: Ultrasound-guided atelocollagen injection for partial rotator cuff tear showed no significant change in terms of clinical outcomes, except for F-vas and SST score. Tendon regeneration was not clear due to the remnants of atelocollagen present at 2-month follow-up ultrasound. There seems to be alarming post-injection pain for 2 to 3 days in the patients who received atelocollagen injection in an outpatient clinic.

Keywords: Atelocollagen; Partial rotator cuff tear; Ultrasound-guided injection; Preliminary study

INTRODUCTION

Partial thickness rotator cuff tear, which can be divided into bursal side tear, intra-tendinous tear, and articular side tear, has been reported to be more common and painful than full thickness tear with a prevalence rate ranging from 13% to 32% in the adult population [1-3]. Previous studies have shown that 80% of partial rotator cuff tears deteriorate or progress to full thickness rupture through conservative treatment [4]. Thus, for regeneration of rotator cuff tear, numerus strategies such as platelet-rich plasma and tissue engineering have been proposed.

Atelocollagen, which is obtained from bovine dermis, is central to one of the treatment strategies. Atelocollagen has favorable properties, including that it does not readily dissolve in the living

Received: February 8, 2020 Revised: March 17, 2020 Accepted: March 17, 2020
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Financial support: None.
Conflict of interest: None.

body and offers low immunogenicity [5]. Therefore, it had been used as a scaffold of cellular proliferation with chondrocyte and mesenchymal stem cells embedded within its matrix [6,7]. In 2017, Suh et al. [8] demonstrated that patch-type atelocollagen can enhance the healing of rotator cuff tear in a rabbit model. However, to the best of our knowledge, there has been no study analyzing the clinical outcome of ultrasound-guided atelocollagen (gel-type) injection in an outpatient clinic. Therefore, in this preliminary study, we attempted to determine clinical outcomes of atelocollagen injection for patients with partial rotator cuff tear and complications observed during 2 months of follow-up.

METHODS

Patient Selection

This study was approved by the Institutional Review Board of Samsung Medical Center (IRB No. 2020-01-039-001), and informed consent was exempted because of the retrospective study design. We performed a chart review on prospectively collected data from 42 patients who underwent gel-type atelocollagen (Tendoregen; Phammode, Seoul, Korea) injection for partial rotator cuff tear. From May 2019 to September 2019, we performed ultrasound-guided atelocollagen injection in patients with partial rotator cuff tear. The inclusion criteria were (1) age 30 to 70 years, (2) articular-side, bursal-side, or intra-tendinous tear diagnosed by magnetic resonance imaging (MRI; n = 12) or ultrasound (n = 3), and (3) agreed to nonsurgical treatment with atelocollagen. The exclusion criteria were (1) frozen shoulder, (2) follow-up loss at 2 months, (3) previous steroid injection within 3 months, (4) past medical history of allergic reactions or hypersensitivity on collagen, and (5) previous shoulder surgery. In addition, the initial 10 patients were excluded to avoid technical bias. We divided patients into three groups according to location of partial rotator cuff tear: (1) articular-side tear, (2) intra-tendinous tear, and (3) bursal-side tear (Fig. 1).

Procedures

Ultrasound-guided atelocollagen injection procedures were carried out by three orthopaedic surgeons who underwent fellowship training in the shoulder. The atelocollagen solution for injection was prepared by mixing lidocaine (1 mL) and gel-type atelocollagen (1 mL). During the procedure, upon detecting rotator cuff defect location by ultrasound examination, the solution was injected into the tendon defect by an in-plane technique. Total amount of injection was varied according to tear size present in each patient to prevent the volume effect, which can induce pain after injection. We stopped injection when the defect was full of atelocollagen materials based on ultrasound finding. Hence, the moment of injection cessation was determined by the practitioner. After the injection procedure, we recommended resting without rehabilitation treatment and prohibited anti-inflammatory medicine, such as nonsteroidal anti-inflammatory

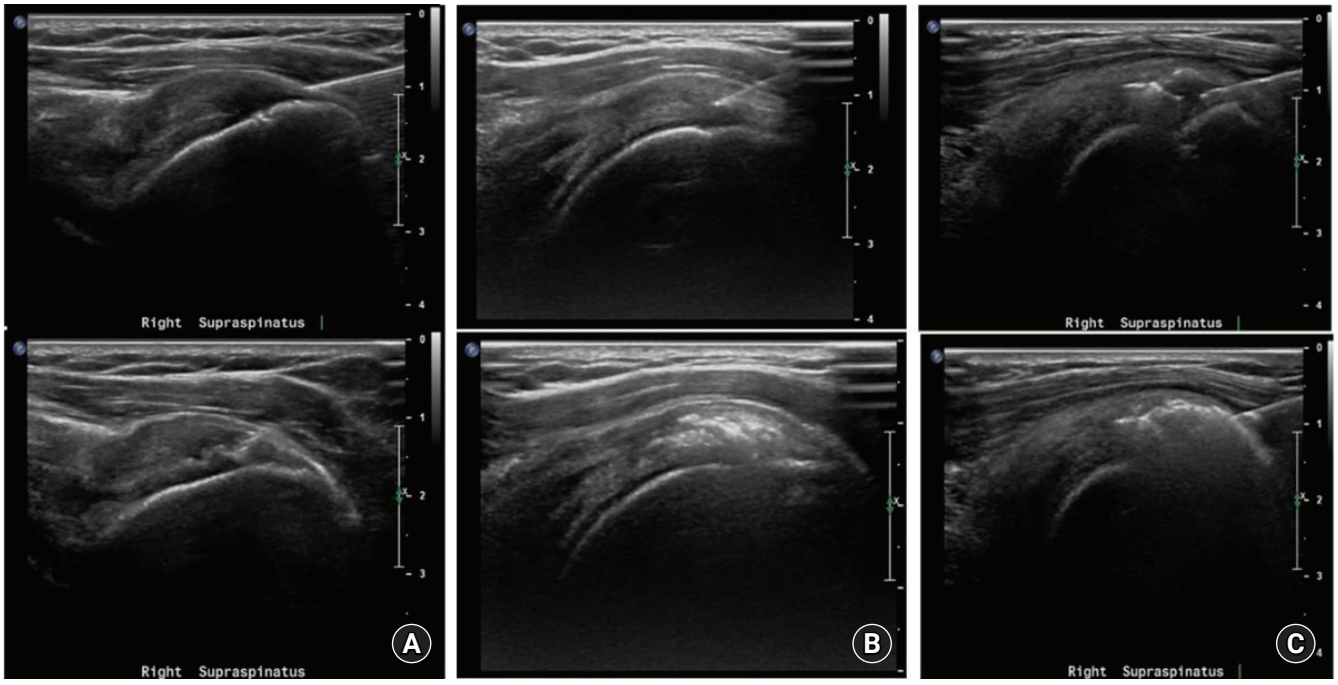

Fig. 1. Ultrasound-guided atelocollagen injection procedure on the (A) articular-side tear, (B) intra-tendinous tear, and (C) bursal-side tear.

drugs (NSAIDs) or glucocorticoid, since they can relieve inflammation, which is the first phase of tendon healing [9].

We examined range of motion (ROM), visual analog scale (VAS) results for pain and function, and patient-reported outcome scores (American Shoulder and Elbow Surgeons [ASES], Simple Shoulder Test [SST], Korean Shoulder Score [KSS]) before and 2 months after injection. We performed ultrasound examination and assessed the status of tendon healing at a 2-month follow-up for seven patients (46.6%, 7/15).

Statistical Analysis

The statistical analysis was conducted in IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA). For the nominal scale of demographics, the chi-square test was used. The Wilcoxon signed-rank test was used to compare the clinical outcomes of pre- and post-injection. The level of significance was set at $P < 0.05$.

RESULTS

From May 2019 to September 2019, a total of 42 patients with partial rotator cuff tear underwent ultrasound-guided atelocollagen injection, and 15 patients were included under the criteria of patient selection. The 15 study patients consisted of five males and 10 females, with a mean age of 54.9 years (range, 40–72 years). There were six patients with articular-side tear, three patients with intra-tendinous tear, and six patients with bursal-side tear. The mean follow-up interval after injection was 2.1 months (Table 1).

At the 2-month follow-up, ROM showed no significant difference compared to baseline. Clinical scores showed no significant change except in SST score ($P = 0.046$) and function-visual analog scale (F-VAS; $P = 0.009$) (Table 2) [10]. After atelocollagen injection, a complication of pain was common. Eight of 15 (53.5%) patients reported moderate (n = 2) to severe pain (n = 6). However, this injection-induced pain subsided approximately 2.5 days later according to the interview carried out at the 2-month follow-up. As there was no need to perform another procedure, such as steroid injection, NSAID medication was recommended to reduce residual pain.

Seven of 15 patients (46%) underwent follow-up ultrasound to observe the healing status of the rotator cuff tendon. We found hyperechoic remnants likely to be atelocollagen in three of seven (42%) patients (Fig. 2). In the four patients without remnants, there was no change in tear size.

DISCUSSION

This preliminary study showed no significant change in terms of ROM and clinical scores, except F-VAS and SST score ($P = 0.009$,

Table 1. Patient demographics

Variable	Value
Age (yr)	54.9 ± 11.5
Follow-up period (mo)	2.1 ± 0.5
Sex	
Male	5 (33.3)
Female	10 (66.6)
Affected side	
Right	13 (86.7)
Left	2 (13.3)
Tear site	
Articular side	6 (40)
Intra-tendinous	3 (20)
Bursal side	6 (40)

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

Table 2. Range of motion and clinical outcomes

Variable	Before injection	After injection (2 mo)	Improved	P-value
Forward elevation	145.7 ± 17.4	154.3 ± 19.1	8.57	0.213
Abduction	140.7 ± 24.6	145.0 ± 19.9	4.28	0.224
External rotation	55.0 ± 15.1	61.4 ± 16.6	6.4	0.720
Internal rotation (10-score)	7.4 ± 2.4	8.4 ± 2.5	1	0.084
P-VAS	4.2 ± 1.3	3.7 ± 1.1	–0.48	0.081
F-VAS	6.3 ± 1.3	7.1 ± 1.2	0.8	0.009
ASES score	57.0 ± 10.7	60.4 ± 10.8	3.33	0.125
Constant	56.4 ± 12.3	58.9 ± 13.3	2.5	0.224
KSS	64.6 ± 12.2	68.5 ± 12.2	3.9	0.169
SST	6.6 ± 1. 8	6.9 ± 2.4	0.29	0.046

Internal rotation range of motion was converted to a 10-point scale [10].
P-VAS: pain-visual analog scale, F-VAS: function-visual analog scale, ASES: American Shoulder and Elbow Surgeons, KSS: Korean Shoulder Score, SST: Simple Shoulder Test.

https://doi.org/10.5397/cise.2020.00066

P = 0.046), at 2 months of follow-up. More than half of the participants (53.5%) complained of pain after injection, which subsided after 2.5 days. According to ultrasound follow-up, less than half of patients (3/7, 42%) showed hyperechoic material, which was presumed as atelocollagen remnants.

A few difficulties were encountered during the atelocollagen injection procedure. First, the optimal amount of atelocollagen injection has not been established. Since the defect size of the partial rotator cuff tear was different from person to person, patients with a small defect complained of severe pain upon injecting the entire dose (2 mL) of atelocollagen solution. Therefore, except for the first few patients, solution amount was based on tear size (Fig. 3). Second, it was difficult to differentiate partial tear from tendinosis by ultrasound or MRI [11]. It is known that tendinosis shows focal hypoechoic swelling, whereas tendon tears are more linear, hypoechoic, and sharper in outline [12]. However, in some patients, excess pressure was required during injection at the tear site. We believe that this increased pressure might be due to failure of differentiation between tear and tendinosis by ultrasound.

Previously, Martinello et al. [13] showed successful recellularization of human tendon using atelocollagen scaffold , and Suh et al. [8] presented a biomechanical and histological study with better healing of the rotator cuff tendon in a rabbit model. Although those studies were positive and offered encouraging results on the effect of atelocollagen, the experimental setup differs from that in the present study. We performed ultrasound-guided atelocollagen injection in an outpatient clinic without additional stem

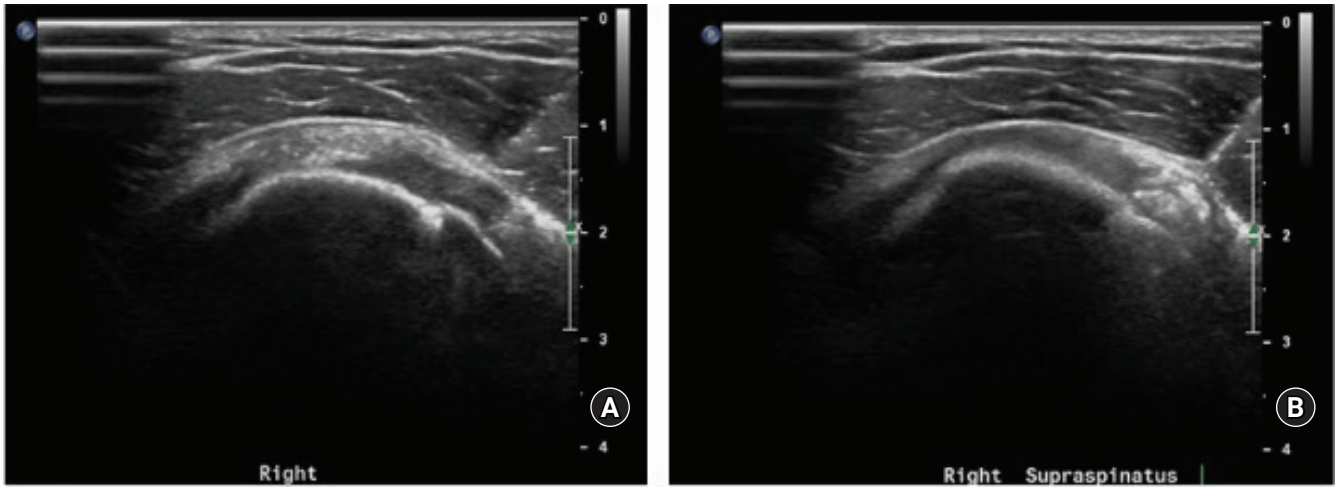

Fig. 2. (A) Ultrasound finding of bursal-side tear in the supraspinatus (transverse plane). (B) Ultrasound at 2 months after atelocollagen injection (transverse plane).

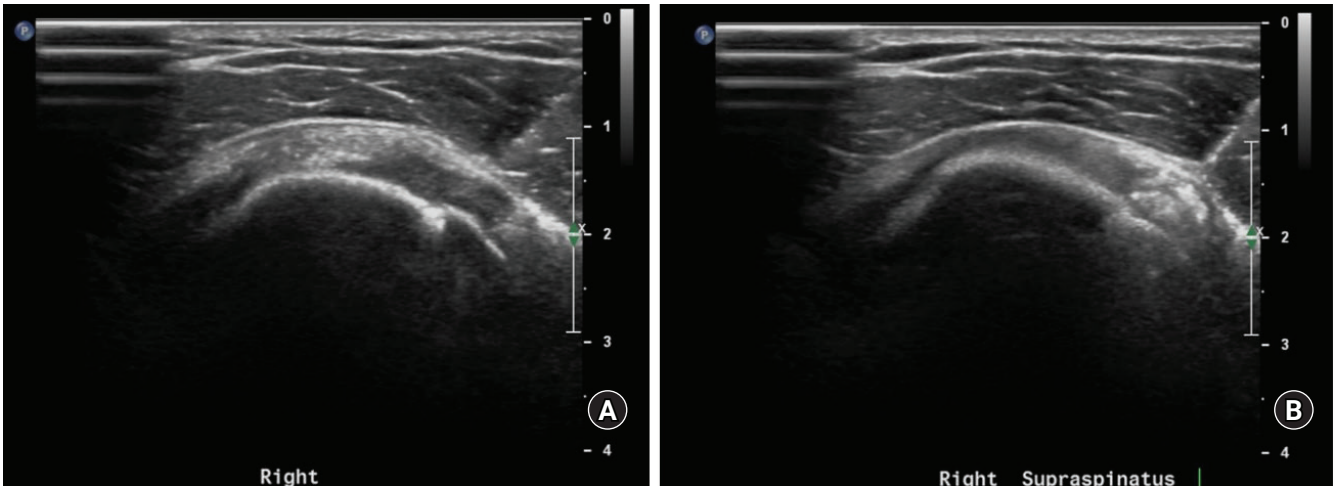

Fig. 3. Atelocollagen injection based on defect size. Before (A) and after (B) injection according to the size of the defect.

cell or bone marrow stimulation. Martinello et al.'s method [13] used adipose-derived mesenchymal stem cells with collagen gel, and Suh et al.'s method [8] used an atelocollagen patch for rotator cuff repair by transosseous equivalent technique.

It is not clear whether atelocollagen injection and bleeding from needle trauma are sufficient for tendon healing. One of the most important characteristics of ultrasound-guided injection is lack of bone marrow stimulation after the atelocollagen injection procedure. According to the natural healing process of tendon tears, the first inflammation stage begins with formation of hematoma, which could be caused by tendon injury [14]. Although a previous study [15] claimed that needle trauma can initiate the healing process with a small amount of bleeding, tendon to bone healing is more difficult than bone to bone healing [16]. Therefore, we believe the bleeding from needle trauma might be insufficient to heal the tendon.

One important complication after injection was post-injection pain. Eight of 15 patients (53%) complained of pain. Among the eight patients, three suffered from pseudo-paresis due to severe pain after injection, although it recovered spontaneously after 2 to 3 days. We thought the pain might result from inflammation due to healing, like in the mechanism of prolotherapy [15]. However, we could not identify healed tendon upon ultrasound examination at the 2-month follow-up. Although we found hyperechoic deposits in three of seven (1, bursal side injection; 2, intra-tendinous injection) patients, we interpreted hyperechoic deposits observed by ultrasound to be remnants of atelocollagen. We found no correlation between hyperechoic remnants and post-injection pain as none of the patients with hyper-echoic signals complained of pain. Regarding the tendon healing mechanism, we think a 2-month follow-up period may be insufficient for proper analysis. Considering the natural tendon healing process and features of atelocollagen as a scaffold for cell proliferation, we believe a healing period of at least 4 to 12 months is needed [14,17,18].

Our study has several limitations. First, there could be a technical bias since atelocollagen injection was performed by three orthopedic fellows. Only one of them (SHC) is included as an author. For that reason, we excluded the first 10 consecutive patients. Second, since this is a preliminary study, the follow-up period was short (2 months) and number of patients was small. Based on our research, further study is needed to elucidate the effect of atelocollagen injection. Third, there could be a technical bias because three practitioners of shoulder orthopedics performed baseline and 2-month follow-up sonography. However, simply exclusion of 10 consecutive patients cannot assure that we have eliminated technical bias. Fourth, the patients in this study may have had tendinosis misdiagnosed as partial tear. We cannot rule out the possibility that post-injection pain is related to tendinosis.

Ultrasound-guided atelocollagen injection for partial rotator cuff tear showed no significant change in clinical outcomes except F-VAS and SST score. Tendon regeneration was not clear due to remnants of atelocollagen at 2-month follow-up ultrasound. We recommend warning patients about post-injection pain for 2 to 3 days before atelocollagen injection in an outpatient clinic.

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Original Article

Clin Shoulder Elbow 2020;23(2):86-93
https://doi.org/10.5397/cise.2020.00031

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Clinical results of conservative management in patients with full-thickness rotator cuff tear: a meta-analysis

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Background: Several systematic reviews have reported on the conservative treatment of full-thickness rotator cuff tears; however, clinical results of this treatment still remain determined.
Methods: PubMed, Cochrane Library, PEDro, and CINAHL databases were systematically searched for randomized clinical trials and observational studies. Two independent researchers reviewed a total of 2,981 articles, 28 of which met the criteria for inclusion in the study. Clinical outcome measures included Constant score, visual analog scale score for pain, range of motion, and short-form 36 questionnaires. The meta-analysis used a linear mixed model weighted with the variance of the estimate.
Results: The meta-analysis showed a significant improvement after surgery. Pain score is 26.2 mm (1 month) to 26.4 mm (3 months), and 24.8 mm (12 months) ($P<0.05$); active abduction: 153.2° (2 months), 159.0° (6 months), 168.1° (12 months) ($P<0.05$); Constant score: 67.8 points (2 months) to 77.2 points (12 months) ($P<0.05$); short-form 36 questionnaires "vitality" section: 57.0 points (6 months) to 70.0 points (12 months) ($P<0.05$).
Conclusions: Our data confirmed the effectiveness of conservative treatment in patients with full-thickness rotator cuff tears 12 months post-intervention. The results suggest that conservative treatment for patients with full-thickness rotator cuff tears should be the first line of treatment before considering surgery.

Keywords: Shoulder; Rotator cuff injuries; Conservative management

INTRODUCTION

Rotator cuff tear is a common condition in middle-aged and elderly patients. Yamamoto et al. [1] investigated the prevalence of rotator cuff tear in 683 patients and reported that 20%–50% of individuals aged >60 years had such an injury. Moreover, Yamaguchi et al. [2] investigated 588 patients and found that 376 (63.9%) had rotator cuff tear. Symptoms of rotator cuff tear include pain, weak-

Received: January 25, 2020 Revised: March 21, 2020 Accepted: March 24, 2020
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Financial support: None.
Conflict of interest: None.

ness, and limitation of motion. In these patients, conservative treatment is primarily chosen and includes nonsteroidal anti-inflammatory drug administration, steroid injection, hyaluronic acid injection, physical therapy, and exercise therapy. Previous studies reported acceptable results in patients with rotator cuff tear treated with combinations of rehabilitation and local corticosteroid injections [3].

Systematic reviews on the conservative treatment of full-thickness rotator cuff tear (FT-RCT) have been reported [4]; however, previous reports have not provided sufficient knowledge on conservative treatment due to a paucity of high-quality studies. These results prompted us to conduct a systematic review of the conservative treatment of FT-RCT, including observational studies. Therefore, the purpose of the present study was to perform meta-analysis of clinical outcomes of patients with FT-RCT who received conservative treatment.

METHODS

We systematically searched the PubMed, Cochrane Library, PEDro, and CINAHL databases for studies conducted between January 1992 and July 2017, with the search terms rotator cuff, rotator cuff tear, subacromial impingement syndrome, rehabilitation, physiotherapy, physical therapy, exercise, conservative, and nonoperative. The references of the selected studies were also reviewed, when applicable, to identify additional studies. The inclusion criteria were as follows: randomized clinical trial; observational study; study investigating full thickness, massive, or inoperable rotator cuff tear; study explicitly mentioning that the treatment group received conservative treatment for this condition; and study reporting one or more of the outcome measures.

A meta-analysis was performed to estimate the clinical outcomes of conservative treatment in patients with FT-RCT. Case reports were excluded from the analysis. For each included article, synthesis began by pooling all reported outcomes gathered at all reported time points. The mean and standard deviation of the continuous results (i.e., Constant score and pain) were extracted from each study according to the follow-up period. When means or standard deviations were not reported in an article, they were calculated using the available information, if possible. Outcomes reported by two or more studies were pooled in a meta-analysis. Constant score, pain (visual analog scale [VAS]), range of motion (ROM) (active flexion/active abduction), and short-form 36 questionnaires (SF-36) results were the selected outcomes measured because they were reported as the mean and standard deviation of effect indicators in the included studies. The reasons for the outcomes that could not be analyzed were as follows: only one article was used as an effect indicator; articles used as effect indicators with unknown average or standard deviations, and a differing measurement method from other articles.

Analysis was performed using JMP ver. 13 (SAS Institute Inc., Cary, NC, USA). The meta-analysis used a linear mixed model [5] weighted with the variance of the estimate. A P-value less than 0.05 was considered statistically significant.

RESULTS

Study Selection

The initial database search yielded 2,981 abstracts. After removal of duplicates, 2,881 articles remained for review, of which 28 met the criteria for inclusion in the study. Of all included studies, six were randomized clinical trials, four were cohort studies, 15 were case series, and three were case reports (Fig. 1).

Characteristics of Studies

A total of 1,824 patients was included in the 28 investigations reviewed. The average age of patients who participated in these investigations was 62.9 years (44–83 years). The intervention period of the conservative treatment in these investigations ranged from 3 weeks to 2 years. The mean final outcome measurements were performed at a minimum of 2 months to a maximum of 7.6 years (Table 1) [3,6-32].

The outcome measures used in studies were ROM (15 trials) [6,8,11-14,16,18-20,24-26,31,32], Constant score (13 trials) [3,9-11,14,16,18-22,24,30], pain (10 trials) [3,6,8-10,12,16,18,19,22], strength (10 trials) [7,8,13,14,16,19-21,25,32], American Shoulder and Elbow Surgeons score (seven trials) [7,15,19,20,29-31], SF-36 score (four trials) [19,20,23,27], Western Ontario Rotator Cuff Index (three trials) [7,8,15], Simple Shoulder Test score (three trials) [9,14,27], University of California at Los Angeles Shoulder Score (two trials) [26,31], Japanese Orthopedic Association Score (two trials) [17,28], satisfaction (two trials) [19,26], shoulder rating questionnaire (one trial) [25], disability (one trial) [9], impairment (one trial) [22], Modified Wolfgang's Criteria (one trial) [32], Disabilities of the Arm, Shoulder, and Hand score (one trial) [7], Quick Disabilities of the Arm, Shoulder, and Hand score (one trial) [6], Oxford Shoulder Disability Questionnaire score (one trial) [23], SF-12 score (one trial) [15], Single Assessment Numeric Evaluation score (one trial) [15], shoulder activity scale score (one trial) [15], night pain (one trial) [18], EuroQol questionnaire score (one trial) [16], Rotator Cuff Quality of Life Index (one trial) [13], Global Rating of Change (one trial) [6], Dutch Simple Shoulder Test score (one trial) [9], and shoulder functional status (one trial) [3].

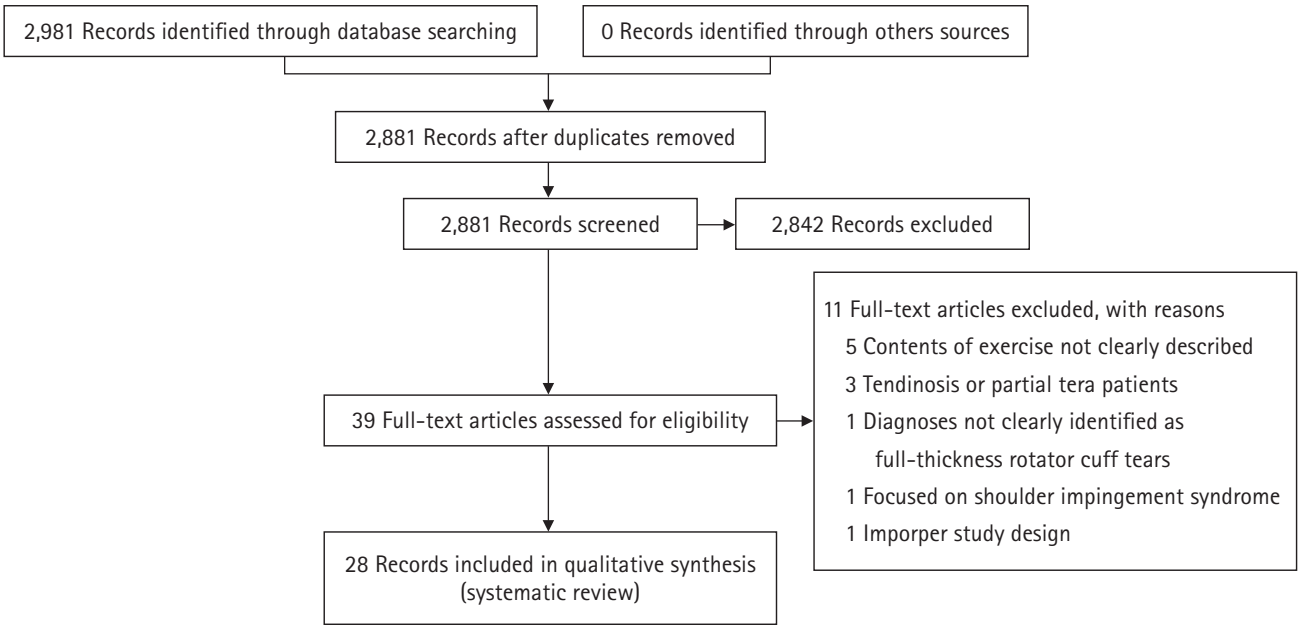

Fig. 1. Flowchart of the articles included in the systematic review.

Meta-Analysis

The analysis showed change in constant score, pain (VAS), ROM (active flexion/active abduction), and SF-36 1 year after the intervention from baseline. For the constant score, six studies [9,16,19,20,22,24] involving 174 shoulders were analyzed. The Constant score was 54.3 points (baseline), 67.8 points (2 months), 73.1 points (3 months), 78.0 points (6 months), and 77.2 points (12 months), and trajectories over time showed a significant difference ($P<0.05$). Constant score at 2–12 months after intervention was significantly higher than that at baseline ($P<0.05$) (Fig. 2A).

For the pain variable (VAS), six studies [3,8,9,16,19,22] involving 209 shoulders were included. The change in pain (VAS) was from 59.8 mm (baseline) to 26.2 mm (1 month), 35.1 mm (2 months), 26.4 mm (3 months), 30.4 mm (6 months), and 24.8 mm (12 months), and trajectories over time showed a significant difference ($P<0.05$). Pain (VAS) at 1–12 months after intervention was significantly lower than that at baseline ($P<0.05$) (Fig. 2B).

For the ROM, five studies [8,16,19,20,24] involving 144 shoulders were included. The ROM (active flexion/active abduction) changed from 135.7°/122.5° (baseline) to 159.5°/153.2° (2 months), 161.7°/156.4° (3 months), 160.0°/159.0° (6 months), and 171.9°/168.1° (12 months) (Fig. 2C). The transition of active flexion trajectories over time showed no significant difference, but active abduction showed a significant difference ($P<0.05$). Active abduction at 2, 6, and 12 months after intervention was significantly higher than that at baseline ($P<0.05$).

For the SF-36, two studies [19,20] involving 71 shoulders were included. In SF-36, the mean value of "vitality" showed a significant improvement at 6 and 12 months after intervention (all $P<0.05$). There was no significant difference in the other seven subscales because of missing data; however, the mean values of these scales tended to improve at 6 months after intervention (Fig. 3).

DISCUSSION

Several systematic reviews have reported conservative treatment approaches for FT-RCT. Seida et al. [33] reported a systematic review of conservative and surgical treatments. The review indicated limited data needed to reach clear conclusions for most of the interventions investigated. Recently, Piper et al. [34] used meta-analysis to compare conservative and surgical treatments of FT-RCTs. They reported a statistically significant improvement in clinical outcomes of surgical treatment compared to conservative treatment for patients with rotator cuff tear. However, clinical results from conservative treatment are limited. Therefore, the present meta-analysis focused on the effectiveness of conservative management in patients with FT-RCT by including randomized trials and observational studies. Our data showed that, in patients with FT-RCT who underwent conservative management, pain (VAS), ROM (active flexion/abduction), and Constant score improved at 3 months after treatment and SF-36 improved at 6 months after treatment.

In this meta-analysis, we found that treatment response in terms of Constant score followed a pattern of rapid improvement in the

https://doi.org/10.5397/cise.2020.00031

Table 1. Characteristics of the included studies

Study	Type of study	Subject (n)	Sample size	Mean age (yr)	Sex (M:F)	Outcome measure	Follow-up
Mischke et al. (2016) [6]	Case report	Nonoperative (1)	1	57	F, 1	Pain (VAS), quick DASH, GROC, ROM	Visit, 13
Miller et al. (2016) [7]	Case series	Nonoperative (5)	5	60.2	2:3	ASES, WORC, DASH, strength	3 mo
Baumer et al. (2016) [8]	Cohort study	Physical therapy (25)	25	60.2	7:18	Pain (VAS), WORC, strength, ROM	8 wk
		Healthy controls (25)	25	59	7:18		
Lambers Heerspink et al. (2015) [9]	RCT	Conservative (31)	31	60.5	20:11	Pain (VAS), disability (VAS), CS, DSST	1 yr
		Surgery (25)	25	60.8	15:10		
Kukkonen et al. (2015) [10]	RCT	Physiotherapy (55)	55	64	24:31	CS, pain (VAS)	2 yr
		Acromioplasty and physiotherapy (57)	57	65	29:28		
		Repair, acromioplasty, and physiotherapy (55)	55	65	29:26		
Collin et al. (2015) [11]	Case series	Nonoperative (45)	45	67	17:28	ROM, CS	2 yr
Nejati et al. (2014) [12]	Case report	Nonoperative (1)	1	53	M, 1	Pain (VAS), ROM	6 mo
Boorman et al. (2014) [13]	Case series	3-Month supervised program of nonoperative	93	60	54:39	RC-QOL, ROM, strength	3 mo
		"Successful (no surgery)" (70)					
		"Failed (underwent surgery)" (23)					
Benazzo et al. (2014) [14]	Case report	Nonoperative (1)	1	23	F, 1	SST, CS, ROM, strength	29 mo
Kuhn et al. (2013) [15]	Cohort study	Physiotherapy (422)	422	62.6	206:194	SF-12, ASES, WORC, SANE, Shoulder Activity Scale	2 yr
Krischak et al. (2013) [16]	RCT	Occupational therapy (22)	38	55.3	24:14	Pain (VAS), EQ-5D, strength, ROM, CS	2 mo
		Home-based exercises (16)					
Kijima et al. (2012) [17]	Case series	Nonoperative (43)	43	62	30:13	JOAS	12 yr
Gialanella et al. (2011) [3]	RCT	Physiotherapy+corticosteroids (×1) (20)	60	78.7	2:18	Pain (VAS), shoulder functional status, CS	6 mo
		Physiotherapy+corticosteroids (×2) (20)		77.3	1:19		
		Physiotherapy (20)		79.4	2:18		
Tanaka et al. (2010) [18]	Case series	Conservative (128)	128	69	67:61	CS, night pain, ROM	3.7 mo
Moosmayer et al. (2010) [19]	RCT	Nonoperative (51)	51	61	36:15	CS, ASES, SF-36, pain (VAS), ROM, strength, satisfaction	1 yr
		Operative (52)	52	59	37:15		
Baydar et al. (2009) [20]	Case series	Nonoperative (20)	20	60.9	7:13	ROM, ASES, CS, SF-36, strength	6 mo
Levy et al. (2008) [21]	Case series	Nonoperative (17)	17	80	6:11	Strength, CS	9 mo
Koubâa et al. (2006) [22]	Case series	Conservative (24)	24	59.2	9:15	CS, pain (VAS), impairment	6 mo
Ainsworth (2006) [23]	Case series	Nonoperative (10)	10	76	4:6	OSDQ, SF-36	3 mo
Heers et al. (2005) [24]	Case series	Nonoperative (34)	34	60.4	13:23	CS, ROM	3 mo
Vad et al. (2002) [25]	Cohort study	G1a: physiotherapy+medication (28)	108	G1: 63.2	50:58	SRQ, ROM, strength	3.2 yr
		G1b: physiotherapy+medication+steroid (12)		G2: 62.9			
		G2: arthroscopic (failed G1a/1b) (32)		G3: 59.4			
		G3: primary surgical repair (36)					
Shibata et al. (2001) [26]	RCT	G1: sodium hyaluronate (38)	78	G1: 59.5	55:23	UCLA, ROM, satisfaction	24 wk
		G2: steroid (40)		G2: 60.4			

Study	Type of study	Subject (n)	Sample size	Mean age (yr)	Sex (M:F)	Outcome measure	Follow-up
Goldberg et al. (2001) [27]	Case series	Nonoperative (46)	46	65	22:24	SST, SF-36	2.5 yr
Yamada et al. (2000) [28]	Case series	Nonoperative (14)	14	70	9:5	JOAS	4 yr
		Operative (26)	26	62	24:2		
Wirth et al. (1997) [29]	Case series	Nonoperative (60)	60	64	38:22	ASES	2 yr
Hawkins et al. (1995) [30]	Case series	Nonoperative (33)	33	59.6	27:6	CS, ASES	3.8 yr (2.6–4.6)
Bokor et al. (1993) [31]	Case series	Nonoperative (53)	53	62.2	40:13	ASES, UCLA, ROM	7.6 yr (3.7–12)
Itoi et al. (1992) [32]	Case series	Nonoperative (124)	124	63	59:55	MWC, ROM, strength	3.4 yr (1–9)

VAS: visual analog scale, DASH: Disabilities of the Arm, Shoulder, and Hand, GROC: global rating of change, ROM: range of motion, ASES: American Shoulder and Elbow Surgeons, WORC: Western Ontario Rotator Cuff index, RCT: randomized controlled trial, CS: Constant score, DSST: Dutch Simple Shoulder Test, RC-QOL: Rotator Cuff Quality-of-Life Index, SST: Simple Shoulder Test, SF-12: short-form 12 questionnaires, SANE: Single Assessment Numeric Evaluation, EQ-5D: EuroQol questionnaire, JOAS: Japanese orthopedic association score, SF-36: short-form 36 questionnaires, OSDQ: Oxford Shoulder Disability Questionnaire, SRQ: shoulder rating questionnaire, UCLA: University of California at Los Angeles Shoulder Score, MWC: modified Wolfgang's criteria.

Fig. 2. Plot showing the Constant score (A), pain (B), and active flexion/active abduction (C) for the conservative management group. Whiskers indicate 95% confidence interval. *P<0.05.

first 2 months after intervention and then recovery plateaus. Baydar et al. [20] showed that the Constant score significantly improved 6 months after conservative treatment in patients with FT-RCT. Moosmayer et al. [19] compared patient outcomes after sur-

https://doi.org/10.5397/cise.2020.00031

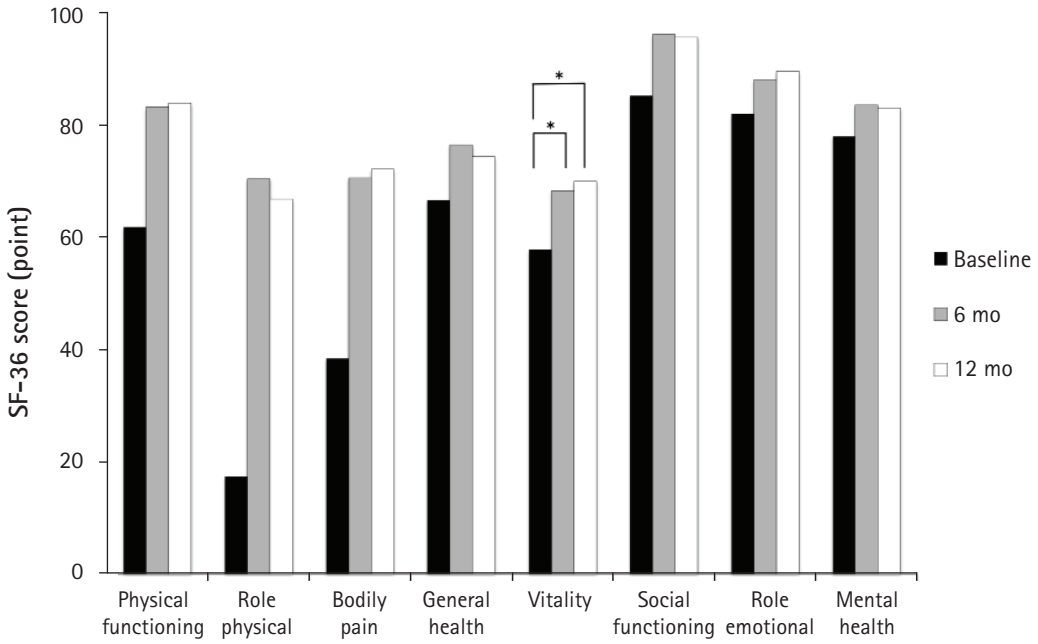

Fig. 3. Graph showing the short-form 36 questionnaires (SF-36) score for the conservative management group. *P<0.05.

gical or conservative treatment of FT-RCTs. Based on their results, 1 year after treatment, there was an improvement in the mean Constant score in both groups. The results of these studies suggest that conservative treatment produces satisfactory outcomes in the short and medium term. In this study, the Constant score significantly improved 2 months after treatment. Therefore, these results suggest that conservative treatment leads to significant improvement in functional outcomes in the first 2 months after therapy, after which the recovery plateaus.

Moosmayer et al. [19] showed that the pain score improved at 1-year follow-up in patients with FT-RCT who received conservative treatment. Similarly, Koubâa et al. [22] reported that patients with FT-RCT who received conservative treatment had improved pain scores. We showed that patients with FT-RCT demonstrated improved pain with conservative management. Altogether, the results of this review suggest the significance of improved pain within 2 months.

Several studies have reported that short-term and medium-term conservative treatment has a positive effect on ROM in patients with FT-RCT. Baumer et al. [8] reported that ROM in 25 patients with FT-RCT significantly improved 2 months after conservative treatment. Baydar et al. [20] and Moosmayer et al. [19] reported that ROM significantly improved 6 months after conservative treatment. In the present study, ROM significantly improved 2, 6, and 12 months after treatment. Thus, these results are consistent with previous studies on the importance of conservative treatment to improve ROM in patients with FT-RCT.

The SF-36 was developed in 1997, and consisted of eight independent items of general health, physical functioning, role physical, bodily pain, vitality, social functioning, role emotional, and mental health. The SF-36 scale has been widely used to evaluate patient quality of life, including both physical and mental health. The scales and summary components ranged from 0 to 100, of which higher values denote better functioning and fewer limitations. The present study evaluated this patient-based assessment score in patients with FT-RCT who underwent conservative treatment. As a result, "vitality," which was related to mental health, significantly improved at 6 and 12 months after treatment. Due to the lack of data, we were unable to analyze the other factors, but we indicated the effectiveness of conservative treatment in terms of the patient-based scale.

There were several limitations in this study. First, various types of FT-RCT were included (e.g., isolated supraspinatus tear and two or three tendon tears). Second, there was a lack of uniformity in the treatment modalities among the studies evaluated. Third, this study did not perform a subgroup analysis of patients with FT-RCT whose conservative treatment failed. Fourth, the parameters that indicated positive results of conservative treatment were limited. Therefore, future studies are warranted to address these issues.

This study showed that, for patients with FT-RCT who under-

went conservative management, pain, ROM, and Constant score improved at 3 months after treatment and SF-36 improved at 6 months after treatment. Our data confirmed the effectiveness of conservative treatment in patients with FT-RCT within 12 months postintervention.

Our data confirmed acceptable results for conservative treatment in patients with FT-RCTs. Pain, ROM (active abduction), and Constant score improved 3 months after treatment, and the "vitality" score of the SF-36 improved 6 months after treatment. We also confirmed that these effects continued for 1 year after treatment. Therefore, these results suggest that conservative treatment for patients with FT-RCTs should be the first step before considering surgery.

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Original Article

Clin Shoulder Elbow 2020;23(2):94-99
https://doi.org/10.5397/cise.2020.00052

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Comparison of open reduction and internal fixation with total elbow arthroplasty for intra-articular distal humeral fractures in older age: a retrospective study

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Background: Intra-articular distal humeral fractures can be surgically challenging. It remains under discussion whether open reduction and internal fixation (ORIF) or total elbow arthroplasty (TEA) is more beneficial for treatment of the elderly. This study aimed to compare the clinical and functional outcomes of ORIF and TEA for managing intra-articular distal humerus fractures in patients aged 65 years or older.
Methods: Patients who underwent ORIF (n=28) or TEA (n=43) for in intra-articular distal humerus fracture between May 2008 and December 2018 were reviewed. Range of motion, Mayo Elbow Performance Score (MEPS), Disabilities of the Arm, Shoulder, and Hand (DASH) score, radiologic outcomes, and surgical complications were evaluated at the final follow-up visit.
Results: The ORIF and TEA groups showed a mean arc of flexion–extension of 97°±21° and 101°±12°, respectively. The mean MEPS and DASH scores were 94±15 and 27±12 points, respectively, in the ORIF group and 81±27 and 47±28 points in the TEA group. This difference was statistically significant. The incidence of total complications was similar between the groups.
Conclusions: In patients older than 65 years with intra-articular distal humerus fracture, ORIF had better outcomes than TEA.

Keywords: Fracture fixation; Total elbow replacement; Humeral fracture; Aged, 65 and over; Treatment outcome

INTRODUCTION

Distal humeral fractures account for 2% of all fractures in adults [1]. In younger patients, these fractures are mainly caused by high-energy trauma, whereas, among older patients, they are more often the result of a direct injury that occurs from falling. Anatomical joint reconstruction and stable fixation of intra-articular and comminuted fractures remain difficult to achieve, and the operation for displaced intra-articular distal humeral fractures is particularly challenging.

Open reduction and internal fixation (ORIF) with double-locking plate osteosynthesis has become the gold standard for fixation of intra-articular distal humeral fractures, though the optimal positioning and configuration of the plates remain controversial [2-4]. In addition, elbow stiffness, malunion, nonunion, fixation failure, and ulnar neuropathy are common sequelae, with an overall complication rate greater than 35% [5-9]. In older individuals with low bone densities, there is an increased risk of osteosynthesis failure [10].

Received: January 31, 2020 Revised: March 22, 2020 Accepted: March 22, 2020
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IRB approval: Wonkwang University Hospital (No. WKUHIRB 2018-01-011)
Financial support: None.
Conflict of interest: None.

Total elbow arthroplasty (TEA) is considered effective for treating nonunion, malunion, posttraumatic arthritis, and posttraumatic instability, with the literature reporting good to excellent results in 85% to 90% of patients at 5 to 10 years after surgery [11-13]. However, TEA for these injuries is technically difficult, and the complication rates are higher than those for elbows that have not undergone prior operations [7,11]. The purpose of this study was to compare the clinical and functional outcomes of ORIF with those of TEA for displaced intra-articular distal humeral fractures in patients aged 65 years and older.

METHODS

This study was approved by Institutional Review Board of Wonkwang University Hospital (IRB No. WKUHIRB 2018-01-011), and it was exempted from informed consent. We retrospectively reviewed the medical records of patients who underwent ORIF or TEA for intra-articular distal humeral fractures between May 2008 and December 2018. Eligible patients were those that met the following inclusion criteria: (1) aged of 65 years or older; (2) displaced and comminuted intra-articular distal humeral fractures requiring surgical treatment (AO/Orthopaedic Trauma Association [OTA] classification type 13C) [14], (3) surgical treatment with either ORIF with double-locking plate osteosynthesis or TEA, and (4) a minimum follow-up of 2 years.

Patients with extra- or partial-articular distal humeral fractures (AO/OTA classification types 13A and 13B), intra-articular distal humeral fractures not requiring surgical treatment (AO/OTA classification type 13C), open fractures, vascular injuries, previous ipsilateral distal humeral fractures, pathologic fractures, or fractures with diaphyseal extension ≥8 cm were excluded. A total of 77 patients met the inclusion criteria of this study. Six patients died from unrelated causes. Of the remaining 71 patients, 28 underwent ORIF with double-locking plate osteosynthesis, while 43 underwent TEA. Patient demographics are summarized in Table 1.

Patient medical records were reviewed for demographic and perioperative data. All patients were invited for a clinical follow-up examination comprising evaluation of range of motion, elbow stability, and neurologic deficits. Additionally, pain status, patient satisfaction, and revision surgeries were documented. Finally, the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand (DASH) score were examined. The functional outcome, based on the arc of motion, MEPS, and DASH score, as well as minor and major complications were evaluated and compared between the TEA and ORIF groups. All follow-up assessments were conducted by the same surgeon who performed the surgery.

Surgical Techniques

All surgeries were performed by the same senior surgeon (JWK).

ORIF Group

ORIF was performed using a posterior approach. After exposing the triceps muscle, the elbow joint was revealed by chevron osteotomy of the olecranon for accurate anatomical reduction. After temporary K-wire fixation of the fracture fragments, double-locking plates were applied to the medial and lateral sides of the distal humerus. The ulnar nerve was transposed into an anterior subcutaneous position at the conclusion of all surgical procedures. After postoperative immobilization for two days, passive range-of-motion exercise was performed for 6 weeks.

TEA Group

A Coonrad-Morrey semiconstrained prosthesis (Zimmer Biomet, Warsaw, IN, USA) was used in all cases. A midline triceps split or

Table 1. Patient demographics

Variable	ORIF	TEA	P-value
Sex (male:female)	7 (25):21 (75)	9 (21):34 (79)	0.59
Age (yr)	76 (65–89)	79 (65–91)	0.16
BMI (kg/m^2)	24±3 (19–30)	23±4 (15–34)	0.49
DM	4 (14)	8 (18.6)	0.34
Smoking	2 (7)	2 (4.6)	0.28
Follow-up period (mo)	31 (9–58)	34 (6–116)	0.59
AO classification			0.31
C1	8	10	
C2	2	10	
C3	18	23	

Values are presented as number (%), mean (range), or mean±standard deviation (range).
ORIF: open reduction and internal fixation, TEA: total elbow arthroplasty; BMI: body mass index; DM: diabetes mellitus.

triceps-sparing approach was used. With the triceps-sparing approach, the surgeon used the working space created by condylar resection to perform TEA without detaching the triceps from the olecranon [11,15]. The ulnar nerve was transposed into an anterior subcutaneous position at the conclusion of all surgical procedures. After postoperative immobilization for 2 days, early functional mobilization was started without weight-bearing for 6 weeks.

Statistical Analysis

Statistical analyses were performed using IBM SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA). The functional outcomes were statistically compared using the Mann-Whitney U-test as a two-way analysis of variance for independent factors.

RESULTS

Clinical Outcomes

In the ORIF group, the mean pain score was 3.1 (range, 1–6), mean MEPS was 94 (range, 75–100), and mean DASH score was 27 (range, 10–45). Based on MEPS, there were 20 excellent and seven good results. With respect to motion, average extension was 17° (range, 5°–40°), average flexion was 120° (range, 80°–140°), and average arc of flexion–extension was 97° (range, 70°–130°). Mean supination angle was 84° (range, 80°–90°), and mean pronation angle was 88° (range, 75°–90°) (Table 2).

All radiographs of fractures that healed without revision (all patients) showed anatomical reduction with stable fixation (Fig. 1). We did not intentionally rule out fractured patients who needed revision, but there was no patient who required it.

Table 2. Functional results comparing ORIF and TEA

Variable	ORIF	TEA	P-value
Pain (NRS)	3.1 (1–6)	3.5 (0–8)	0.21
MEPS	94 ± 15 (75–100)	81 ± 27 (50–85)	0.028*
DASH score	27 ± 12 (10–45)	47 ± 28 (10–75)	0.038*
ROM (°)			
Extension	17 ± 21 (5–40)	15 ± 3 (0–30)	0.104
Flexion	120 ± 18 (100–140)	124 ± 15 (80–150)	0.265
Flexion–extension	97 ± 21 (70 –130)	101 ± 12 (80–140)	0.089
Supination	84 ± 6 (80–90)	84 ± 6 (80–90)	0.126
Pronation	88 ± 5 (75–90)	89 ± 6 (80–90)	0.072
Satisfaction			-
Excellent	20 (71.4)	5 (11.6)	
Good	7 (25)	18 (41.8)	
Fair	1 (3.5)	14 (32.6)	
Poor	0	6 (14.0)	

Values are presented as mean (range), mean±standard deviation (range), or number (%).
ORIF: open reduction and internal fixation, TEA: total elbow arthroplasty, NRS: numeric rating scale, MEPS: Mayo Elbow Performance Score, DASH: Disabilities of the Arm, Shoulder, and Hand, ROM: range of motion.
*Statistically significant.

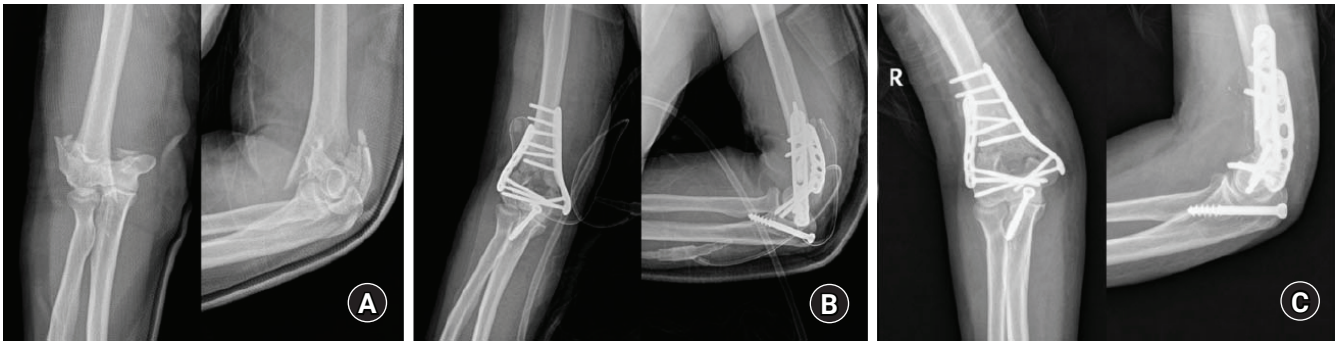

Fig. 1. Serial X-rays of open reduction and internal fixation (ORIF) case. (A) Anteroposterior and lateral X-rays of a 66-year-old female who suffered an AO classification 13C distal humerus fracture with a fall. (B) An X-ray performed after ORIF, showing dual-plate fixation. (C) Bone union after 6 months.

https://doi.org/10.5397/cise.2020.00052

Patients with infection were treated with antibiotics and did not need additional surgery. One patient had Brooker type III heterotopic ossification in the brachialis musculature.

In the TEA group, mean pain score was 3.5 (range, 0–8), mean MEPS was 81 (range, 50–85), and mean DASH score was 47 (range, 10–75). Based on MEPS, there were five excellent and 18 good results. With respect to motion, average extension was 15° (range, 0°–30°), average flexion was 124° (range, 80°–150°), and average arc of flexion–extension was 101° (range, 80°–140°). Mean supination angle was 84° (range, 80°–90°), and mean pronation angle was 89° (range, 80°–90°) (Table 2).

At the final follow-up, incomplete radiolucent lines were seen around the humeral implant in six cases and in the ulnar implant in five cases. Wear of the polyethylene bushings at the hinge was directly correlated with follow-up duration. When we calculated satisfaction, the ORIF group (96.4%) contained a higher percentage of patients who answered good or excellent compared with the TEA group (53.4%).

Complications

Complications occurred in 13 patients in the ORIF group and 14 patients in the TEA group (Table 3). Two patients underwent revision in the TEA group, including one due to deep infection and one due to periprosthetic fracture with aseptic loosening of the humeral stem. These two cases in the TEA group were separated from the other, nonrevised TEA cases when measuring the clinical scores. The single case of deep infection occurred seven years after the initial TEA in a female patient. She underwent implant removal, insertion of antibiotic beads, and an installation of new prosthesis with antibiotic-loaded acrylic cement in the first-stage surgery. Six weeks after the first-stage surgery, revision TEA was performed after confirming no infection. Separately, two cases of superficial infection occurred in the ORIF group and were treated with intravenous antibiotics without surgery.

Table 3. Complications

Variable	ORIF	TEA	P-value
Wound dehiscence	0	1 (2.3)	
Aseptic loosening	1 (3.5)	2 (4.7)	
Fracture	0	1 (2.3)	
Heterotrophic ossification	1 (3.5)	7 (16.3)	
Ulnar nerve symptom	7 (25)	2 (4.7)	
Infection	2 (7.1)	1 (2.3)	
Elbow stiffness*	2 (7.1)	0	
Total	13 (46)	14 (32)	0.18

Values are presented as number (%).
ORIF: open reduction and internal fixation, TEA: total elbow arthroplasty.
*Flexion <120° and loss of extension >30°.

In the TEA group, the case of periprosthetic fracture occurred around the tip of the humeral implant, which had completely loosened. Here, the humeral implant was replaced with a longer one and augmented using a humerus shaft strut allograft (Fig. 2). Another case of loosening occurred between the cement and both the humerus and the ulna, while screw-loosening occurred in one case in the ORIF group. Also, neurological complications occurred in nine cases, including two in the TEA group and seven in the ORIF group. These patients reported only dysesthesia of the fourth and fifth fingers without sensory or motor deficits, with all recovering. Heterotopic ossification occurred in eight patients, but there was no instability or other clinical symptoms, and no surgical treatment was required.

We classified aseptic loosening, fractures, and infection as major complications; thus, the ORIF group had mainly minor complications such as ulnar nerve symptoms. When we calculated the rate of major complications of total complications, three of 13 (23.1%) in the ORIF group and four of 14 (28.6%) in the TEA group had major complications. Thus, the rate was higher in the TEA group, although there was no statistical significance.

DISCUSSION

The purpose of this study was to compare the clinical and func-

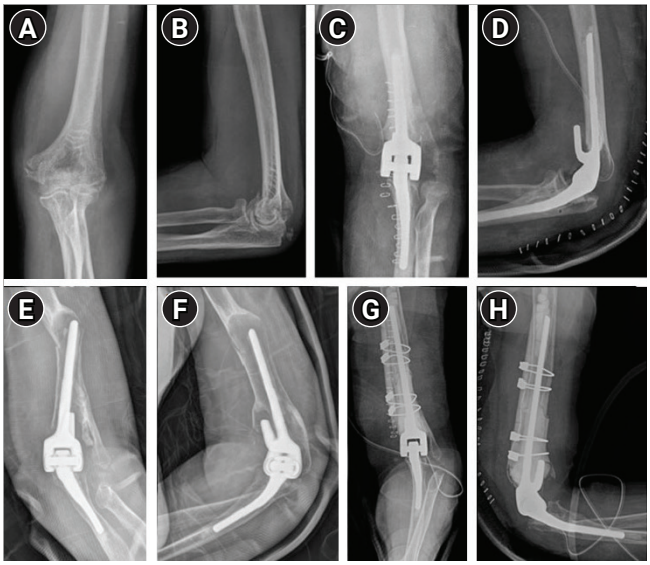

Fig. 2. A 75-year-old female suffered AO classification 13C distal humerus fracture with a slip down (A, B) and was treated with total elbow arthroplasty (TEA) (C, D). After 3 years, the patient complained of upper arm pain after carrying a heavy load. Periprosthetic fracture with aseptic loosening around the humeral stem was observed (E, F). Revision TEA with longer humeral stem and humerus shaft strut allograft was performed (G, H). The final functional outcome was relatively good.

tional outcomes of ORIF with those of TEA for displaced intra-articular distal humerus fractures in patients aged 65 years or older. At the time of final follow-up, the ORIF group had significantly higher MEPS and DASH scores compared with the TEA group.

Although the recommended treatment for comminuted and displaced intra-articular distal humerus fractures is osteosynthesis, this method can be technically difficult, especially in older patients [16,17]. Previous data on ORIF for distal humerus fractures indicate that complications such as fixation failure, persistent pain and/or stiffness, heterotopic ossification, ulnar nerve entrapment, nonunion, malunion, and posttraumatic arthritis are common in all age groups.

Several studies have suggested that primary TEA is a reliable treatment for severe intra-articular distal humerus fractures in elderly patients. Morrey et al. [18] reported a series of 21 patients with a mean age of 72 years who underwent primary TEA for comminuted distal humerus fractures. They reported good or excellent results in 95% of the patients at a mean follow-up of 3.3 years, with a reoperation rate of 5% (one elbow). Gambirasio et al. [19] reported 10 women (mean age, 85 years) who underwent primary TEA. Of them, eight had an excellent outcome and two had a good outcome based on MEPS. Garcia et al. [20] evaluated 16 patients with a mean age of 73 years (range, 61–95 years) who underwent primary TEA with a mean follow-up of 3 years (range, 1.5–5 years). These authors reported mean DASH score of 23 (range, 1–63) and mean MEPS of 93 (range, 80–100). Frankle et al. [21] reported 11 excellent, one good, zero fair, and zero poor results in patients who underwent TEA.

There are several studies comparing ORIF and TEA for comminuted intra-articular distal humerus fractures. Frankle et al. [21] reported better functional outcomes and higher MEPS in the TEA group as well as a higher incidence of complications in the ORIF group. In a prospective multicenter study, McKee et al. [22] reported improvement in MEPS and DASH scores in the TEA group relative to in the ORIF group. Egol et al. [23] reported no significant differences between the groups in a study comparing TEA and locking-plate osteosynthesis. Obremskey et al. [24] reported no strong evidence to choose one of two treatments for deployment in patients in their 60s who have a long predicted remaining lifespan and no comorbidities.

Ulnar neuropathy is a common complication after surgery. McKee et al. [22] reported that postoperative ulnar neuropathy was the single most common complication in their study comparing TEA and ORIF for distal humerus fractures. In our study, ulnar neuropathy was also the most common complication (nine cases) and was significantly more frequently observed in the ORIF group. We note that these complications occurred despite routinely transposing the ulnar nerve in all patients. Thus, the surgeon should be extremely cautious of the ulnar nerve during surgery. Rates of major complications, such as infection and loosening, were similar in the two groups.

Infection seems to occur due to swelling; soft tissue damage after trauma; or shear force during early range of motion or due to the large volume of the dual plate, which can irritate the skin because the elbow joint has thin soft tissue. In our study, the infection rate of the ORIF group (7.1%) was not as high as reported in other researches [25]. Proper soft tissue control during the operation should be ensured.

Limitations of our study, including its retrospective design and the small number of patients, are comparable to those of previous studies but might have underpowered our study. Furthermore, despite a mean follow-up length of 34 months, it is difficult to compare the preoperative status between groups because only the final follow-up results were evaluated.

In older patients with intra-articular distal humeral fractures, those undergoing ORIF had better clinical outcomes and similar complication rates than those receiving TEA. As life expectancy increases, many TEA patients become too old to undergo surgery when the lifespan of their prostheses ends, resulting in many cases where patients have no choice but to bear the worn-out prosthesis for longer, i.e., up to 20 to 30 years. Therefore, rather than performing primary TEA right away just because the patient is elderly, if it is possible to perform osteosynthesis, ORIF can be a better choice for older patients with intra-articular distal humeral fractures.

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Clin Shoulder Elbow 2020;23(2):100-104
https://doi.org/10.5397/cise.2019.00409

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Reverse shoulder arthroplasty with os acromiale

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Function and strength of the deltoid muscle are important in reverse shoulder arthroplasty (RSA). Moreover, location and shape of the acromion, clavicle, and scapular spine, which are origins of the deltoid muscle, are also important. The frequency of os acromiale is 5% to 15%; however, it is rare in the Asian population, affecting approximately 0.7% of Koreans. RSA has rarely been reported in patients with os acromiale. We present a case series of two patients with cuff tear and arthropathy combined with os acromiale who underwent RSA. From 2016 to 2018, two patients with os acromiale who presented with pain and limited range of motion (ROM) underwent RSA with cuff tear arthropathy using the subscapularis-sparing deltopectoral approach. Their ROM, visual analog scale (VAS), and satisfaction were evaluated before and after surgery. In both patients, VAS decreased, ROM increased, and postoperative satisfaction increased. There were no specific complications due to os acromiale. The VAS, ROM, and satisfaction of patients improved after surgery compared with values before surgery. However, careful attention must be given during surgery to ensure optimal repair and recovery.

Keywords: Os acromiale; Cuff tear arthropathy; Reverse shoulder arthroplasty

Os acromiale is a disease caused by failure of osseous union at the ossification center of the acromion. It is divided into preacromion, meso-acromion, meta-acromion, and basiacromion areas and is classified based on area (Fig. 1) [1,2]. The prevalence of os acromiale varies from 1.9% to 15% depending on population [3]. The condition is usually asymptomatic and is incidentally found on radiography, magnetic resonance imaging, or computed tomography, which is typically performed to diagnose shoulder cuff or other shoulder problems [4].

If treatment with reverse shoulder arthroplasty (RSA) is required, such as in cases of irreparable rotator cuff tears or cuff tear arthropathy, the tension in the deltoid muscle may increase, and the os acromiale, the origin of the deltoid muscle, may affect deltoid function and must be considered when planning treatment. We performed RSA in two patients two patients with os acromiale, using the previously published subscapularis-sparing deltopectoral approach [5], and compared the parameters before and after RSA.

CASE REPORT

All procedures were part of the standard medical care, and the need for ethics approval and consent to participate were waived. Written informed consent was obtained from the patients for publication of this case report and any accompanying images.

Case 1

A 71-year-old man presented with pain and limitation in range of motion (ROM) in his left shoulder, with no history of previous

Received: December 2, 2019 Revised: December 2, 2019 Accepted: February 10, 2020
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Financial support: None.
Conflict of interest: None.

trauma or operation. The patient stated that the pain had been persistent for about 7 years, for which he had been undergoing conservative treatment with analgesic medication. Initially, the pain was bearable but gradually increased. Limitation of movement had also increased.

Physical examination of the left shoulder revealed no gross deformity. Neer and Hawkins tests, external rotation lag sign, and pseudoparalysis assessment were positive. Passive ROM was almost normal, and active ROM was 10° flexion, 30° abduction, and internal rotation at the buttock level. The functional assessment score was 7 points on the visual analog scale (VAS).

Imaging exams of radiography and magnetic resonance imaging revealed upward migration of the humeral head, glenohumeral osteoarthritis, acetabulization (acromial thinning), and meso-acromion (Fig. 2). A nonsurgical treatment approach with analgesics and rest was used for several years with no clinical improvement. Thus, surgical treatment was recommended. The surgical technique for RSA is as follows. The patient was placed in the beach-chair position, and RSA was performed using the deltopectoral approach with preservation of the subscapularis tendon.

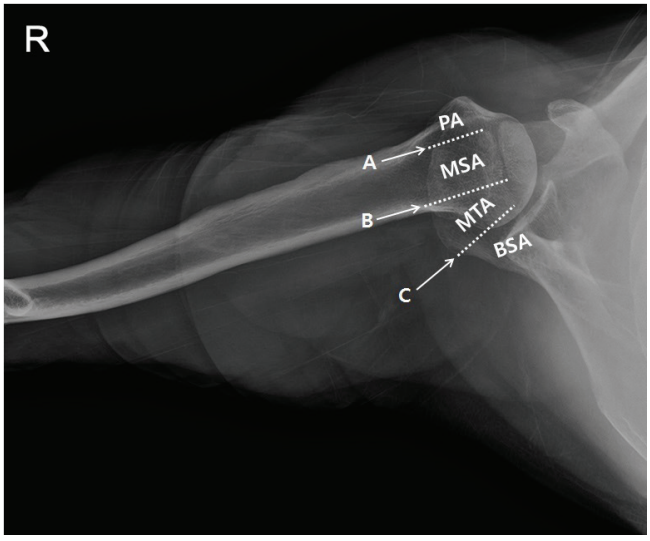

Fig. 1. Os acromion subtypes: pre-acromial (PA), meso-acromial (MSA), meta-acromial (MTA), basi-acromial (BSA). Depending on location of the osseous union at the ossification center of the acromion, the condition is classified as type A, type B, and type C.

A straight incision was placed approximately 10 cm from the lateral edge of the coracoid to the insertion site of the humerus along the anterior border of the deltoid, followed by deep dissection through the deltopectoral groove to the lateral side of the cephalic vein. The conjoint tendon was retracted to the medial side, the Hohmann retractor was placed in the subacromial space, the surrounding soft tissue was removed, and the head of the humerus was exposed.

After resection of the long head of the biceps tendon, the humeral head was pushed up to the rotator interval, the supraspinatus and infraspinatus were pushed apart, and the humeral head was completely exposed. Bone cutting was performed at the anatomical neck level using the resection guide. After cutting the humeral head and pressing the humerus downward, the glenoid was exposed, and glenoid reaming was performed after removing the glenoid articular surface and labrum. The baseplate and hemisphere were inserted, a humoral stem was installed, and stability, conjoint tension, and ROM were measured after joint reduction. The wound was closed after irrigation, and the surgery was completed after closed suction drainage.

Shoulder movement was not restricted after surgery. Immediately after the operation, the arm was placed in an arm sling with no abduction brace, and exercise was started immediately in the range with the least amount of pain. After stitches were removed,

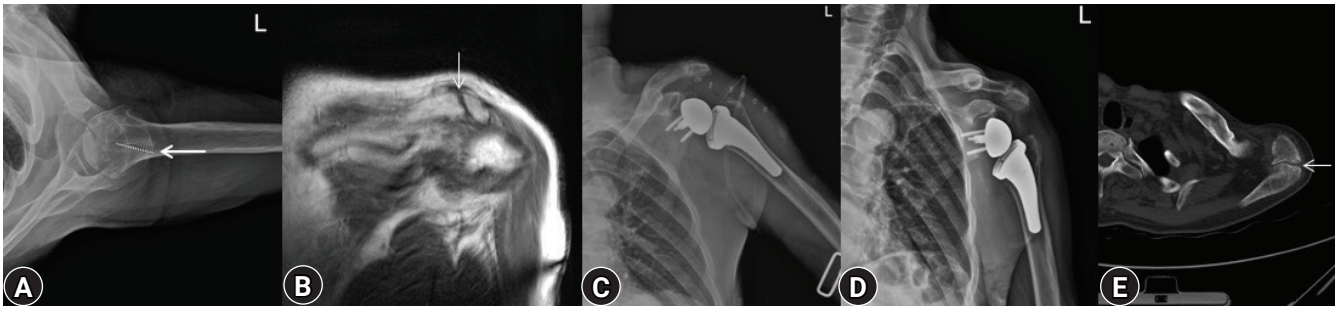

Fig. 2. A 71-year-old man with a left shoulder, full thickness rotator cuff tear underwent reverse shoulder arthroplasty, revealing os acromiale of meso-acromion type. (A) Preoperative axillary view X-ray showed meso-acromion findings. (B) T1-weighted coronal plane image showed a meso-acromion finding. (C) Anteroposterior postoperative X-ray showed no significant difference in the acromion before and after surgery. (D) One year later, the acromiale showed no morphological changes on the anteroposterior postoperative X-ray. (E) One year later, the acromiale showed no morphological changes on the postoperative computed tomography. Undefined (arrows, meso-acromion).

active ROM exercises were initiated, and no special physical treatments were performed. One year after the surgery, the postoperative parameters were satisfactory, with ROM flexion 160°, abduction 160°, internal rotation at the L5 level, and VAS score of 0. The University of California at Los Angeles (UCLA) shoulder score increased significantly from preoperative 7 of 35 (20.0%) to postoperative 31 of 35 (88.6%).

Case 2

A 73-year-old man presented with pain and limitation in ROM of his right shoulder. His shoulder problem had started about 20 years earlier, and there was no history of trauma. He had undergone right arthroscopic cuff repair due to complete cuff tear about 8 years prior and open reduction with plate fixation due to right olecranon fracture about 10 years prior to presentation.

Initially, the pain was partially relieved with use of analgesics and steroid injection therapy, but increasing shoulder pain followed. Physical examination revealed positive results of the Neer, Hawkins, empty can, and lift off tests of the right shoulder. Preoperative ROM was flexion 70°, abduction 90°, internal rotation at L5 level, and VAS score of 6. The os acromion type was B.

X-ray radiography images revealed upward migration of the humeral head, glenohumeral osteoarthritis, acetabulization, and os acromion type B (Fig. 3). Based on his condition, surgical treatment was decided as the best approach. Surgery and postoperative treatment were performed in the same way as discussed for case 1. The postoperative parameters were flexion 140°, abduction 140°, and internal rotation at L1 at 1 year postoperative. The patient was

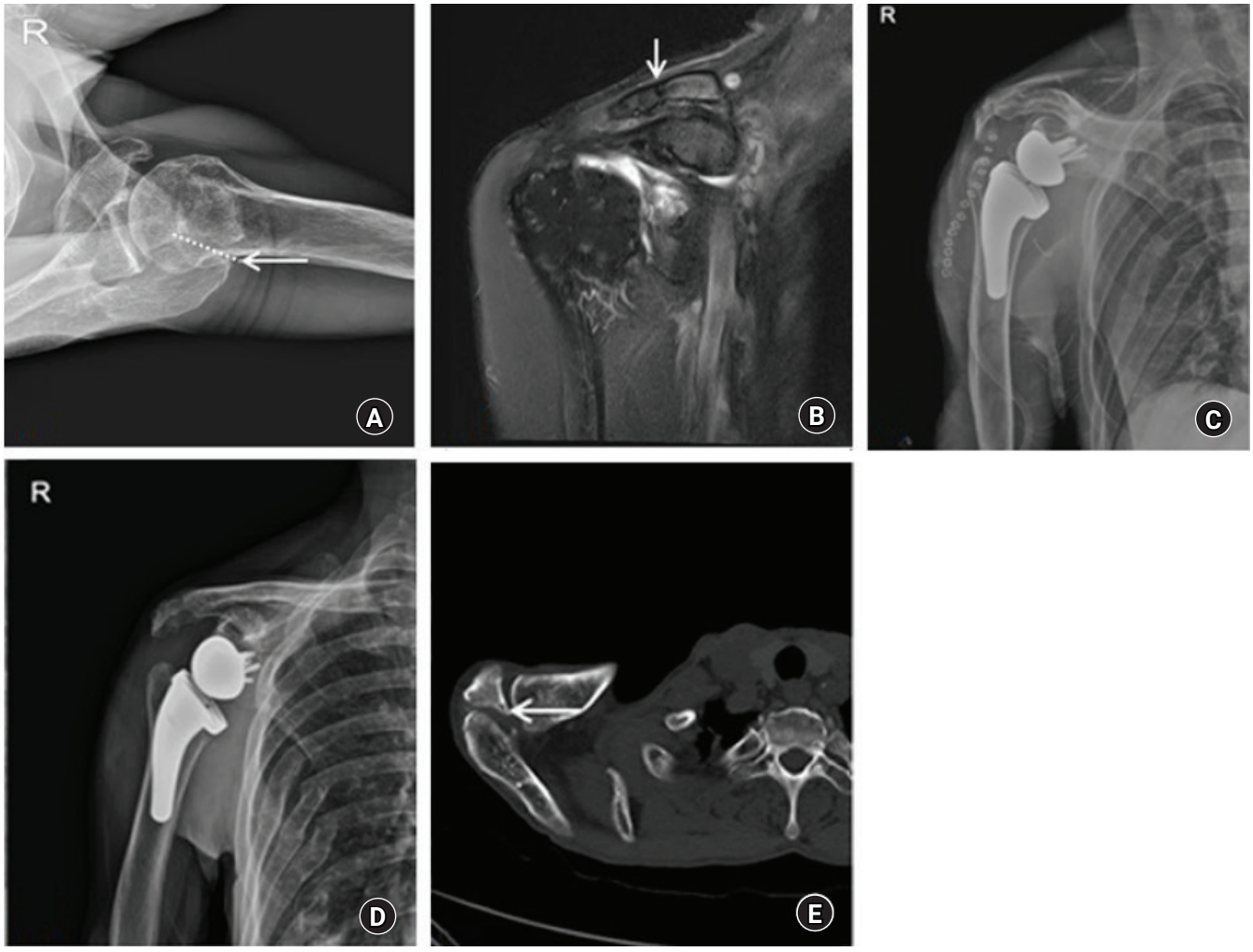

Fig. 3. A 73-year-old man with a right shoulder, full thickness rotator cuff tear underwent reverse shoulder arthroplasty that showed os acromiale type B. (A) Preoperative axillary view X-ray showed a type B os acromion finding. (B) T2-weighted coronal plane image showed a type B os acromion finding. (C) Anteroposterior postoperative X-ray showed no significant difference in the acromion before and after surgery. (D) One year later, the acromiale showed no morphological changes on anteroposterior postoperative X-ray. (E) One year later, the acromiale showed no morphological changes on postoperative computed tomography. Undefined (arrows, meso-acromion).

https://doi.org/10.5397/cise.2019.00409

satisfied with the surgery with a VAS score of 1. The ROM, pain, and patient satisfaction were comparable to those of patients who underwent RSA without os acromiale. The UCLA shoulder score also increased significantly from preoperative 12 of 35 (34.3%) to postoperative 30 of 35 (85.7%).

DISCUSSION

In this report, we compared pre- and postoperative parameters in two patients with os acromiale who underwent RSA with cuff tear arthropathy. The results indicated that the procedure improved the ROM, leading to decreased pain and increased patient satisfaction. The incidence of os acromiale varies and has been reported to be around 15%, with a higher incidence among African Americans (13.2%–18.2%) than in Caucasians (5.8%–9.5%). However, compared to other ethnic groups, the incidence among Koreans is low at 0.7% [6].

Os acromiale can be treated conservatively in asymptomatic cases or with surgery in cases with symptoms. Surgery is mainly comprised of excision, acromioplasty, and fixation [2,7]. Though no direct connection with rotator cuff tear has been demonstrated [1], some have argued that the lateral fragment of the os acromiale can be downsloped and cause impingement [8]. Acromial tilt is preferable to acromial downsloping. The conditions of the acromion, clavicle, and scapular spine are important assessments for RSA because they affect tension on the deltoid muscles [9]. Acetabulization can occur in patients with massive rotator cuff tears, thinning, fatigue fracture, or fragmentation of the acromion and is classified according to Hamada grade [3,10].

Os acromiale has been incidentally identified on radiographs. Many cases of os acromiale are asymptomatic, though patients with cuff tear arthropathy can experience acromion weakening due to acetabulization. This is accompanied by os acromiale and affects deltoid function. In these cases, careful attention should be paid to RSA surgery and treatment approaches. We performed RSA using a subscapularis tendon and pectoralis major muscle-sparing approach [5]. No symptoms were associated with os acromiale. The lateral fragment of the os acromiale was slightly disturbed during the operation, but no further treatment, such as removal of fixation, was performed. Other authors have argued that os acromiale itself does not affect surgical outcomes and is not a contraindication to surgery [4,9]. Although radiographs in the present case showed a slight increase in acromial downsloping, the patient did not complain of pain or discomfort at the acromial end.

A few reports have discussed outcomes of RSA in patients with os acromiale, including those by Aibinder et al. [4] in 2017, and Walch et al. [9] in 2009. However, cases of Asians, especially Koreans, have not been reported. Therefore, due to lack of cases reported for comparisons, the number of cases in the present study was not sufficient to compare or determine statistical significance. Thus, in patients with cuff tear arthropathy with os acromiale, RSA showed a change in postoperative acromial downsloping but did not affect the outcome. The VAS, ROM, and satisfaction of patients improved after compared to before surgery. However, careful attention must be given to surgery and appropriate approach, and follow-up is needed to ensure optimal patient recovery.

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https://doi.org/10.5397/cise.2019.00409

Case Report

Clin Shoulder Elbow 2020;23(2)105-108
https://doi.org/10.5397/cise.2020.00080

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Bilateral acromial stress fractures in a patient with a massive rotator cuff tear

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Stress fractures of the acromion and scapular spine are well-known complications following reverse total shoulder arthroplasty. However, these fractures in patients with massive rotator cuff tear or cuff tear arthropathy are extremely rare, and the pathogenesis, clinical features, diagnosis, and treatment of these fractures are poorly understood. We report a case of bilateral stress fracture of the posterior angle of the acromion in a patient with massive rotator cuff tear and discuss the pathogenesis, clinical manifestation, and treatment with a review of the literature.

Keywords: Scapula; Acromion; Fracture; Rotator cuff tear

Stress fractures of the acromion and scapular spine are well-known complications following reverse total shoulder arthroplasty (RTSA) [1]. However, stress fractures of the acromion and scapular spine in patients without any previous surgeries are extremely rare and have only been described in case reports in which the possible causes included repetitive subcritical trauma in healthy populations [2-4], massive rotator cuff tear (MRCT) or cuff tear arthropathy (CTA) [5-9], and RTSA [1]. Especially, stress fractures of the acromion and scapular spine in patients with MRCT or CTA are poorly understood for their pathogenesis, clinical features, diagnosis, and treatment because of their rarity. We report a case of bilateral stress fracture of the posterior acromion in a patient with MRCT and discuss the pathogenesis, clinical manifestation, and treatment with a review of the literature.

CASE REPORT

An 80-year-old woman visited Keimyung University Dongsan Medical Center with severe pain and limited motion of the right shoulder for 2 weeks. There was no history of acute trauma. She was an orchard farmer with long-standing pain in both shoulders for 10 years. One year ago, she was diagnosed with irreparable MRCT on her right shoulder, and RTSA was recommended by a physician at the local clinic if her pain and disability worsened.

Physical examination of the right shoulder revealed overall tenderness on the superior and posterior area without swelling or redness. The active range of motion (ROM) was not able to be assessed due to severe pain. The t-score of bone mineral density was –4.9. Plain radiographs and computed tomography (CT) on the right shoulder revealed a slightly displaced fracture of the posterior angle of the acromion and superior migration of the humeral head

Received: February 23, 2020 Revised: March 14, 2020 Accepted: March 17, 2020
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Financial support: None.
Conflict of interest: None.

(Fig. 1). Magnetic resonance imaging revealed chronic MRCT involving the supraspinatus, infraspinatus, and subscapularis (Fig. 2). The torn supraspinatus and infraspinatus tendons were retracted at the level of the glenoid with moderate muscle atrophy and fatty infiltration.

Because the patient also had long-standing symptoms in the left shoulder, plain radiographs of the left shoulder were obtained and revealed nonunion of the posterior part of the acromion and superior migration of humeral head (Fig. 3). On physical examination of the left shoulder, there was no specific tenderness on the acromion and active ROM was 140° of forward flexion, 130° of abduction, 60° of external rotation at the side, and internal rotation of the third lumbar vertebra level. She vaguely remembered a history of sudden onset pain and limited motion in the left shoulder several years ago. The symptoms improved by conservative treatment from the local clinic. However, she didn't remember the exact diagnosis of the left shoulder at that time.

Despite conservative treatment including immobilization and medication for 2 weeks after initial presentation, the patient complained of unbearable right shoulder pain, and ROM had not improved. Therefore, the patient opted for open reduction and internal fixation (ORIF) and provided consent. After induction of general anesthesia, the patient was placed in the 60° beach chair position. An incision was made along the scapular spine towards the lateral edge of the acromion. After soft tissue dissection, the trapezius and deltoid fascia were opened towards the spine, and the fracture site was exposed. After the fracture was reduced using reduction forceps, two cannulated screws were fixed in a direction perpendicular to the fracture line. Then, a lateral clavicle anatomical plate (Acumed, Hillsboro, OR, USA) was bent along the acromial bony contour and fixed.

After surgery, the patient experienced immediate pain relief and started passive ROM exercise 2 weeks later. Two years after surgery, plain radiographs revealed complete healing of the fracture (Fig. 4). The active ROM was 130° of forward flexion, 120° of abduction, 50° of external rotation at the side, and internal rotation of the second lumbar vertebra level. Her visual analogue scale for pain, American Shoulder and Elbow Surgeons score, and Subjec-

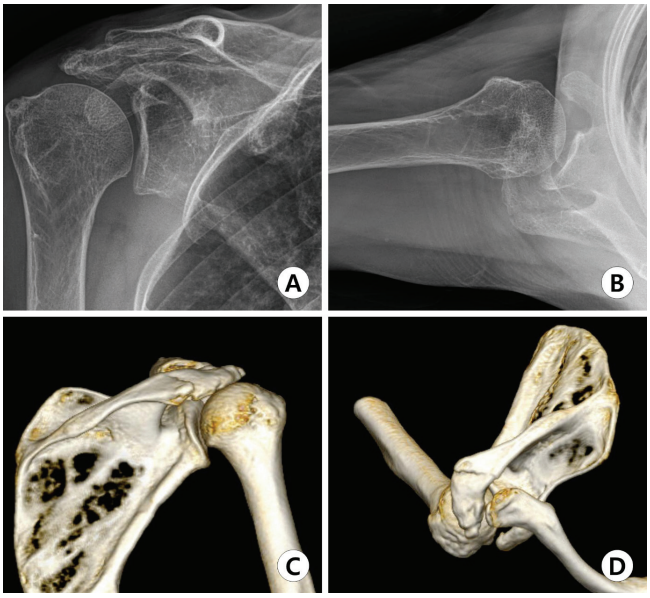

Fig. 1. Plain radiographs (A, B) and three-dimensional computed tomography (C, D) scan showed a slightly displaced acromial fracture through the posterior to the acromioclavicular joint and superior migration of the humeral head.

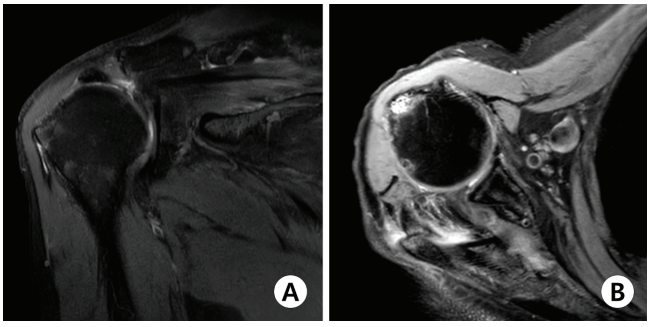

Fig. 2. (A, B) Magnetic resonance imaging demonstrated chronic massive rotator cuff tear involving the supraspinatus, infraspinatus, and subscapularis.

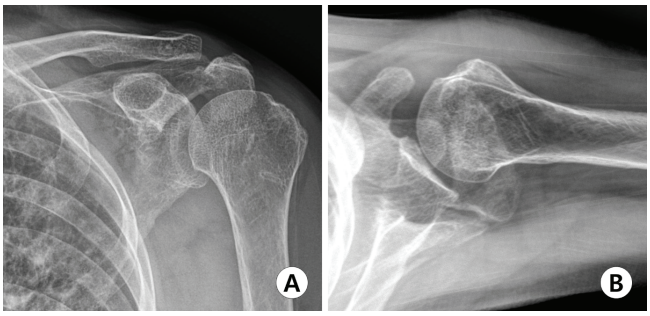

Fig. 3. (A, B) Plain radiographs revealed nonunion of the posterior part of the acromion and superior migration of the humeral head.

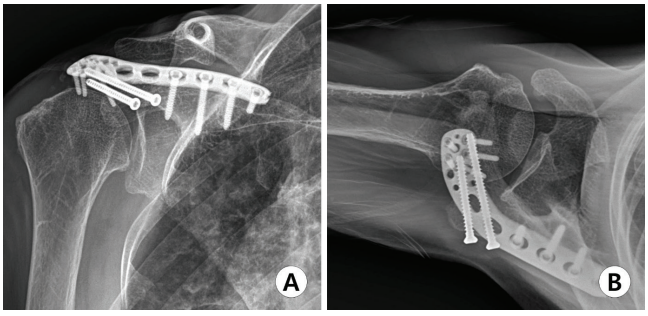

Fig. 4. Plain radiographs (A, B) 2 years after surgery showed complete union of the fracture.

https://doi.org/10.5397/cise.2020.00080

tive Shoulder Value were 1, 82, and 70%, respectively.

DISCUSSION

Stress fractures of the acromion and scapular spine in patients with MRCT or CTA are extremely rare and poorly understood. To date, there have been 11 cases reported in five studies of stress fractures of the acromion and scapular spine in patients with CTA (Table 1) [5-9].

Previous studies proposed the mechanism of stress fracture according to fracture location [5,8,9]. Dennis et al. [5] reported acromial stress fractures caused by superior migration of the humeral head in patients with MRCT or CTA. Abnormal pressure from the humeral head on the acromion in patients with CTA leads to acromial thinning and subsequent fracture of the anterior or lateral acromion [8]. Meanwhile, the mechanism for stress fractures of the acromial base or scapular spine in patients with CTA may be different. Shindle et al. [9] reported that scapular spine stress fractures are the result of altered mechanics about the shoulder compensating for the lack of a rotator cuff. They reported two cases of scapular spine stress fracture due to an indirect mechanism of a bending moment created by the trapezius and deltoid [9]. In the present study, our case had bilateral stress fractures of the posterior angle of the acromion in patient with MRCT, not CTA. Although superior migration of both humeral heads was evident, the acromiohumeral interval was preserved to more than 5 mm. Therefore, the pathomechanism in our case may be consistent with that proposed by Shindle et al. [9].

Patients with CTA who experienced stress fractures of the acromion or scapular fractures had sudden onset shoulder pain without a history of trauma, although the pain occurred insidiously as well [5]. If these fractures are suspected from history taking and physical examination, plain radiographs (especially, the axillary lateral view) and CT are useful to confirm the diagnosis. It is important that plain radiographs of the unaffected shoulder be taken, because these fractures can be confused with os acromiale [5]. Stress fracture of the acromion or scapular spine should be considered in the differential diagnosis when patients with MRCT or CTA complain of sudden onset severe shoulder pain and limited motion without a history of trauma.

Previous studies reported that most acromial stress fractures were minimally displaced fractures and healed with conservative treatment, such as immobilization for a few weeks followed by gradual motion [3-5]. Groot et al. [6] reported two cases in patients with CTA and oral steroid therapy who had a scapular spine stress fracture managed by conservative treatment. Although good clinical outcomes were not obtained in another report, conservative treatment seemed a reasonable alternative considering the risk

Table 1. A review of literature

Study	No. of fractures	Age (yr)	Sex	Location of factures	Treatment	Outcome
Dennis et al. [5]	4	65	F	Anterior acromion	CT	Reduced pain
		65	F	Anterior acromion	CT failed → fragment excision	Slight pain c sustained LOM
		64	F	Anterior acromion	CT failed → fragment excision+RCR	Satisfactory pain relief; FF, 60°
		77	F	Anterior acromion	Fragment excision & RCR & TSA	Mild pain; FF, 70°
Roy et al. [8]	1	82	F	Acromial base	CT	No pain at 6 months
Shindle et al. [9]	2	80	F	Scapular spine	CT failed → ORIF	Finally union, no pain
		78	F	Scapular spine	CT failed → RTSA	MRSA infection, death by COPD
Groot et al. [6]	2	72	F	Scapular spine	CT	Stiff shoulder; tolerable pain controlled by analgesics
		86	F	Scapular spine	CT	No pain but acceptable functional disability; ABD, 60°; ER, 0°
Karthik et al. [7]	2	61	M	Scapular spine	CT	Good clinical & radiographic outcomes
		61	M	Scapular spine	CT failed → ORIF	Good clinical & radiographic outcomes
This study	2	80	F	Posterior acromion	CT failed → ORIF	VAS, 1; ASES, 82; SSV, 70%
		80	F	Posterior acromion	CT	VAS, 1; ASES, 85; SSV, 80%

CT: conservative treatment, LOM: limitation of motion, RCR: rotator cuff repair, FF: forward flexion, TSA: total shoulder arthroplasty, ORIF: open reduction and internal fixation, RTSA: reverse total shoulder arthroplasty, MRSA: methicillin-resistance *Staphylococcus aureus*, COPD: chronic obstructive pulmonary disease, ABD: abduction, ER: external rotation, VAS: visual analog scale, ASES: American Shoulder and Elbow Surgeons, SSV: subjective shoulder value.

of operative treatment in elderly patients [6]. On the other hand, several studies reported that acromial stress fractures in patients with CTA may need surgical treatment [5,7-9]. Karthik et al. [7] reported that fracture healing either by conservative or operative treatment is associated with a good functional outcome. Dennis et al. [5] reported four cases describing stress fracture of the anterior acromion associated with CTA. One patient had conservative treatment. Three cases had operative treatment, including two with fragment excision and one with total shoulder arthroplasty and fragment excision. They described the fracture site bathed in synovial fluid, which may make union less likely due to the associated rotator cuff tear [5]. They recommended surgical excision of the fragment rather than internal fixation, as the healing potential is thought to be poor. In previously reported cases, two patients with failed conservative treatment for scapular spine stress fracture underwent ORIF and experienced good clinical outcomes with fracture healing after surgery [7,9]. Considering the previously reported cases and our cases, we recommend initial conservative treatment in patients with stress fracture of the acromion or scapular spine. If conservative treatment fails, we recommend ORIF rather than fragment excision and rotator cuff repair, or RTSA may be not necessary.

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https://doi.org/10.5397/cise.2020.00080

Concise Review

Clin Shoulder Elbow 2020;23(2)109-116
https://doi.org/10.5397/cise.2020.00143

CiSE
Clinics in Shoulder and Elbow

eISSN 2288-8721

Rotator cuff tear with joint stiffness: a review of current treatment and rehabilitation

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Repair of the rotator cuff tear is a joint-tightening procedure that can worsen joint stiffness. This paradoxical phenomenon complicates treatment of rotator cuff tear with joint stiffness. As a result, there is controversy about how and when to treat joint stiffness. As many treatments have been published, this review discusses the latest findings on treatment of rotator cuff tear with joint stiffness.

Keywords: Concomitant joint stiffness; Rotator cuff tear; Shoulder; Joint capsule release

INTRODUCTION

Rotator cuff tear is often accompanied by shoulder stiffness for various reasons [1,2]. Pain from the cuff lesion followed by joint disuse and secondary muscular weakness can lead to shoulder stiffness [3]. The treatment strategy for rotator cuff with concomitant stiffness can be paradoxical [1]. To promote proper healing of the repaired tendon, secure protection and immobilization after the surgery are crucial; however, constant range of motion (ROM) exercise is needed to prevent stiffness. In addition, repair of the torn cuff can exacerbate stiffness because it is a joint-tightening procedure, and postoperative immobilization is important for healing of the repaired tendon [4]. There is no concrete consensus on managing patients having both rotator cuff tear and shoulder stiffness. This review was performed to comprehensively summarize the latest knowledge on treatment of rotator cuff tear with joint stiffness.

DEFINITION AND ETIOLOGY

The term "frozen shoulder" was first mentioned by Codman [5] as being difficult to define, treat, and explain. The members of the Upper Extremity Committee of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine recently introduced a consensus on the definition of this pathology [6]. According to these authors, the term "stiff shoulder" is used in all patients with restricted ROM, and etiology can be divided into primary or secondary causes. "Frozen shoulder" should be used exclusively as a term to describe the primary idiopathic stiff shoulder that occurs regardless of trauma or specific shoulder disease. Secondary stiff shoulder is used to describe shoulder stiffness with a cause, such as trauma, surgery, or shoulder disease. In this review, we presume the term "stiff shoulder" as secondary stiff shoulder, as it is combined with rotator cuff tear.

Received: April 9, 2020 Accepted: April 21, 2020
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Financial support: None.
Conflict of interest: None.

TREATMENT FOR ROTATOR CUFF TEAR WITH JOINT STIFFNESS

Traditionally, ROM recovery was achieved before surgical repair of a torn cuff [4]. Some studies have insisted on achieving full ROM recovery before surgical treatment [1,7]. Kang [8] asserted that early operation was not needed because the symptoms of rotator cuff tear may not manifest in patients with rotator cuff tear and concomitant adhesive capsulitis. Therefore, sufficient follow-up should be considered for adhesive capsulitis after restoration of shoulder motion [8].

However, non-surgical treatments for shoulder stiffness including stretching, exercise, and manipulation are known to improve scapulothoracic motion rather than glenohumeral joint motion [9]. Moreover, there is a concern that ROM recovery before surgical treatment of rotator cuff tear may deteriorate the condition of the tear, progress muscle atrophy, or produce fat degeneration [10-12]. In fact, there is a possibility that a repairable cuff tear may progress to an irreparable tear during preoperative rehabilitation [13].

According to Oh et al. [14], moderate preoperative shoulder stiffness did not affect clinical outcome in arthroscopic capsular release with manipulation during rotator cuff repair. In other studies, there was no significant difference between a group that underwent capsular release simultaneous with rotator cuff repair and a group that performed rotator cuff repair after ROM recovery [15,16]. In addition, several authors have reported satisfactory results through single-stage treatment for rotator cuff tear and joint stiffness [2,14,17,18]. According to Cho and Rhee [2], manipulation was performed concurrent with rotator cuff repair, and all groups showed good results. Although the stiffness patients who performed manipulation took longer to recover ROM than those without stiffness, the final outcomes were similar to those in patients without stiffness [2].

Recently, Kim et al. [3] evaluated, in their prospective comparative study, the outcomes of rotator cuff tear with concomitant shoulder stiffness. Specifically, Kim et al. [3] compared immediate surgery in group I versus delayed surgery after 6 months of nonoperative treatment in group II. The author showed significant improvement in ROM and functional scores in both groups at the last follow-up. Moreover, no statistical differences were found in clinical scores (Fig. 1) and ROM, except for internal rotation at 3 and 6 months postoperatively (Fig. 2). Given the lack of benefit to preoperative physical therapy, the authors recommended early surgical treatment of rotator cuff tear with concomitant stiffness using a simultaneous capsular release method [3].

In the case of manipulation under anesthesia (MUA), complications such as fracture, dislocation, osteochondral fracture, rotator cuff tear, anterior labral detachment, superior labral anterior and posterior (SLAP) tears, and radial nerve injury may occur [4]. MUA is effective in improving forward elevation and abduction but is limited in rotation; further, a prior study suggests that fracture can be caused by torsional force [19]. Chuang et al. [20] mentioned that forward flexion and external rotation were improved in the capsular release group compared to the MUA group. According to some authors, simultaneous arthroscopic capsular release can be performed with repair of the torn cuff and improvement of arthroscopic technique. Arthroscopic capsular release has an advantage of meticulous excision or release of the capsule, but also can be an appropriate method for one-stage treatment of rotator cuff tear with joint stiffness [21,22].

ARTHROSCOPIC CAPSULAR RELEASE

Arthroscopic capsular release is an effective treatment for refractory shoulder stiffness. However, there have been many debates regarding extent of disease, especially regarding the necessity of posterior capsular release [19]. Many studies have revealed that release of the rotator interval improves range of flexion and external rotation [18,23]. Several studies have shown that subscapularis tendon, inferior capsule, or global capsule release improves elevation and internal rotation, as well as external rotation [24,25]. Regarding the results of the posterior capsular release, there are some conflicting outcomes. According to the studies by Ide and Takagi [26] and Nicholson [27], posterior capsular release showed improvement in internal rotation. On the other hand, some clinical studies have reported no actual benefit from additional posterior capsular release. Snow et al. [19] suggested that additional posterior capsular release produced no significant difference compared to anterior capsular release. Chen et al. [28] reported similar results that extended posterior capsular release showed no advantage in function or ROM. According to the level I study by Kim et al. [23] that compared the result of arthroscopic release of the anterior/inferior capsule and additional posterior capsular release, there was no significant differences in ROM and clinical outcomes after at least 12 months of follow-up. In addition, Kim et al. (unpublished data) recently tested this suggestion through histologic study. They evaluated anterior and posterior glenohumeral joint capsule tissues from patients with rotator cuff tear who underwent arthroscopic capsular release for shoulder stiffness along with rotator cuff repair. Patients who underwent arthroscopic rotator cuff repair without stiffness were enrolled as

https://doi.org/10.5397/cise.2020.00143

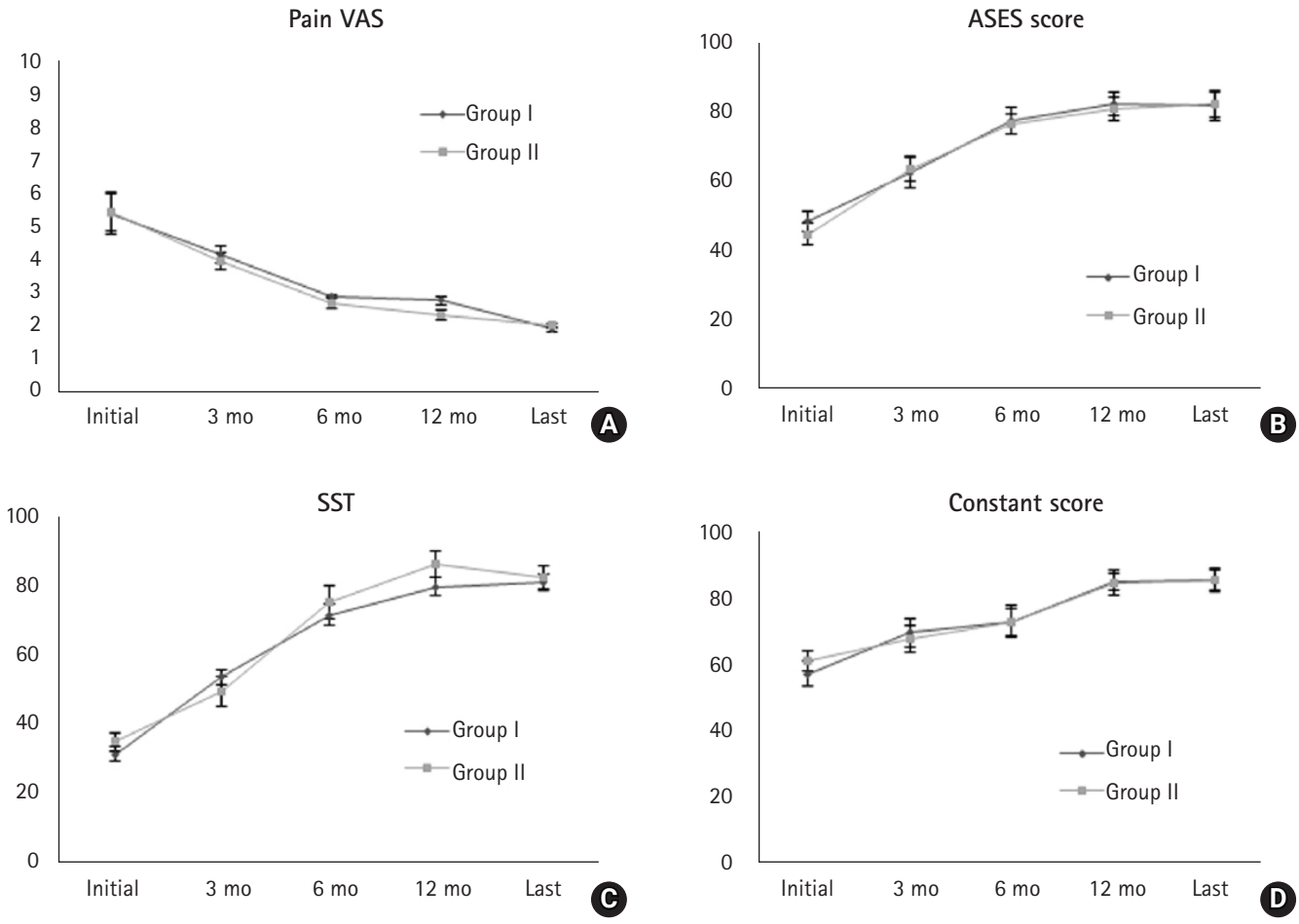

Fig. 1. Functional scores: (A) pain visual analog scale (VAS), (B) American Shoulder and Elbow Surgeons (ASES), (C) Simple Shoulder Test (SST), and (D) Constant. All scores improved after surgery in both groups. No significant differences between groups were seen at any time point.

controls. The gene expression of collagen I and III; fibronectin; extracellular matrix (ECM); basic fibroblast growth factor; transforming growth factor beta; connective tissue growth factor; matrix metalloproteinases (MMPs)-1, MMPs-2, and MMPs-9; tissue inhibitors of metalloproteinase (TIMP)-1 and TIMP-2; intercellular adhesion molecule 1, interleukin-1 and tumor necrotizing factor-alpha were analyzed using real-time reverse transcription polymerase chain reaction. The expression levels of collagen I and III were significantly higher in the anterior capsule compared to those of the posterior capsule and control (Fig. 3). The levels of fibronectin, ECM, MMP-2, and MMP-9 in the anterior capsule were significantly higher than those in the posterior capsule (Fig. 4). Kim et al. (unpublished data) concluded that a more intense fibrogenic process occurs in the anterior capsule compared to posterior and normal capsule tissues, and treatment should be focused on release of the anterior capsule while that of the posterior capsule can be selectively performed.

SURGICAL TECHNIQUE

The patient is placed either in the lateral decubitus position or in the beach-chair position, depending on surgeon's preference. In cases of lateral decubitus position, the position of the arm varies from 60° to 70° of abduction and 15° to 20° of forward flexion [15]. Capsular release begins with treatment of the rotator interval and middle glenohumeral ligament via 3.0-mm 90° electrocautery through the anterior portal [15,19,23]. Anterior capsular release begins below the biceps origin, preserving the glenoid labrum. Without violating the subscapularis tendon, capsular release is performed to the 7-o'clock (right) or 5-o'clock (left) position involving both the anterior and posterior bands of the inferior glenohumeral ligament [15,23,28]. For an easier approach to the inferior and posterior capsules, the working portal is switched to the posterior portal [15]. To avoid axillary nerve damage, capsular release should be performed just off the glenoid rim without violating the glenoid labrum. The closest distance between

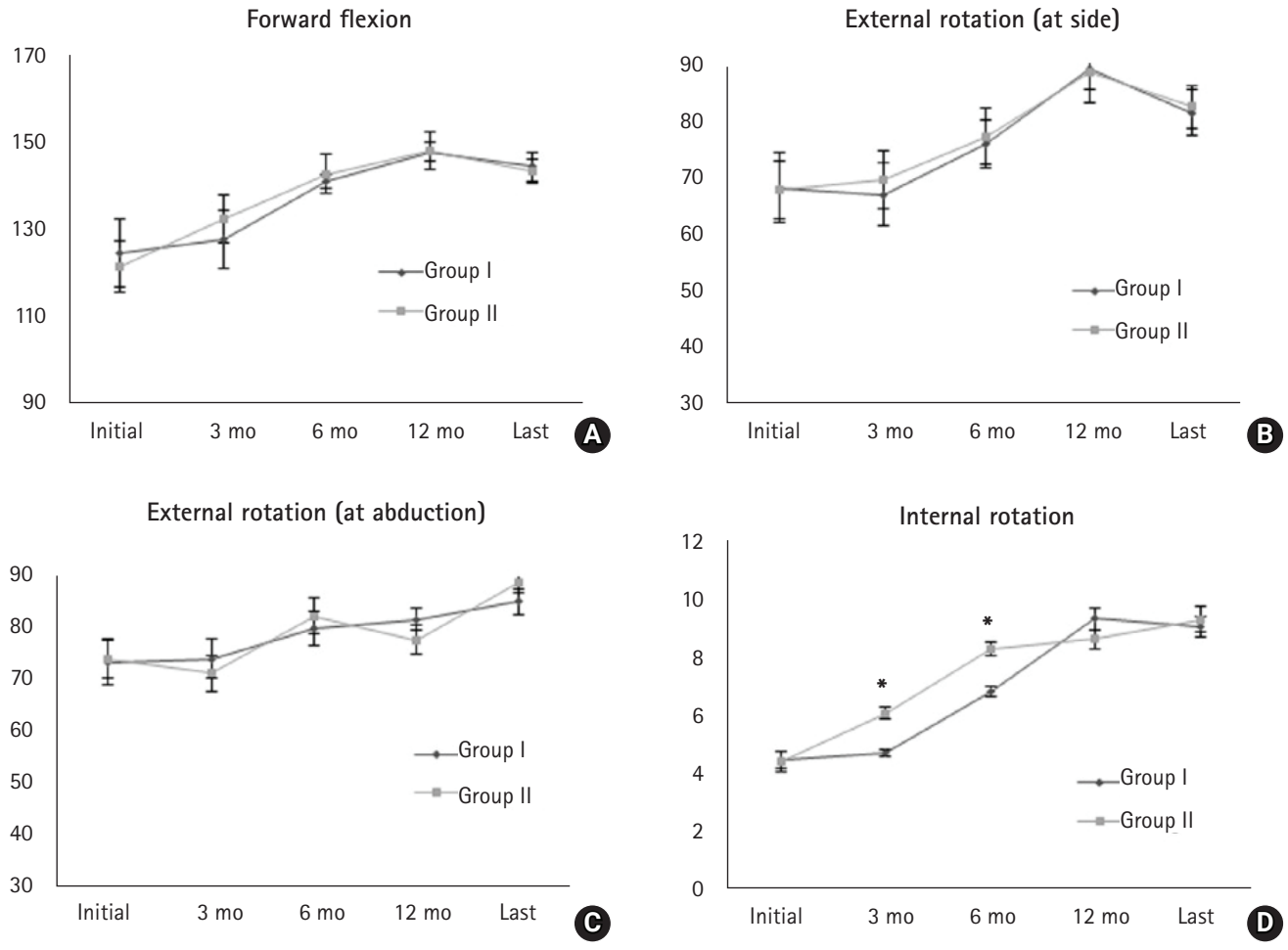

Fig. 2. Passive range of motion (forward flexion [A], external rotation with at side [B] and with abduction [C], and internal rotation [D]) was improved after surgery in both groups. There were no significant differences between the two groups, except for internal rotation (D) at 3 and 6 months. *P < 0.05.

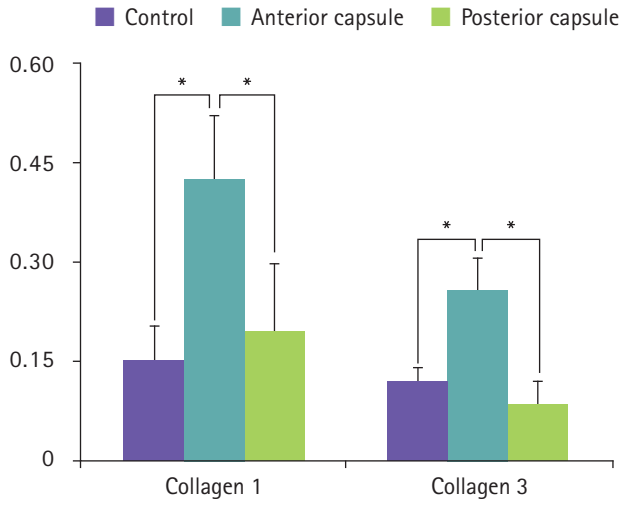

Fig. 3. Gene expression of collagens I and III in the glenohumeral joint capsule. *P<0.05.

the axillary nerve and the glenoid, ranging from 10 to 25 mm, was observed with the arm in the neutral position, and the greatest distance was noted with the arm in an abduction-neutral position [29]. Release of the coracohumeral ligament and the subscapularis is performed with the camera in the lateral portal viewing the anterior portion of the subdeltoid space. The anterior portal is used as a working portal. Using the electrocautery device, the base of the coracoid process is located. The part of the coracohumeral ligament that originates from the coracoid process and extends to the rotator interval is mostly removed during the process of rotator interval tissue removal. However, the coracohumeral ligament extends to the superior part of the subscapularis muscle and covers a broad area of the anterior surface of the subscapularis. For complete release of the coracohumeral ligament, thorough examination and debridement of the anterior and superior portions of the subscapularis are required [15].

https://doi.org/10.5397/cise.2020.00143

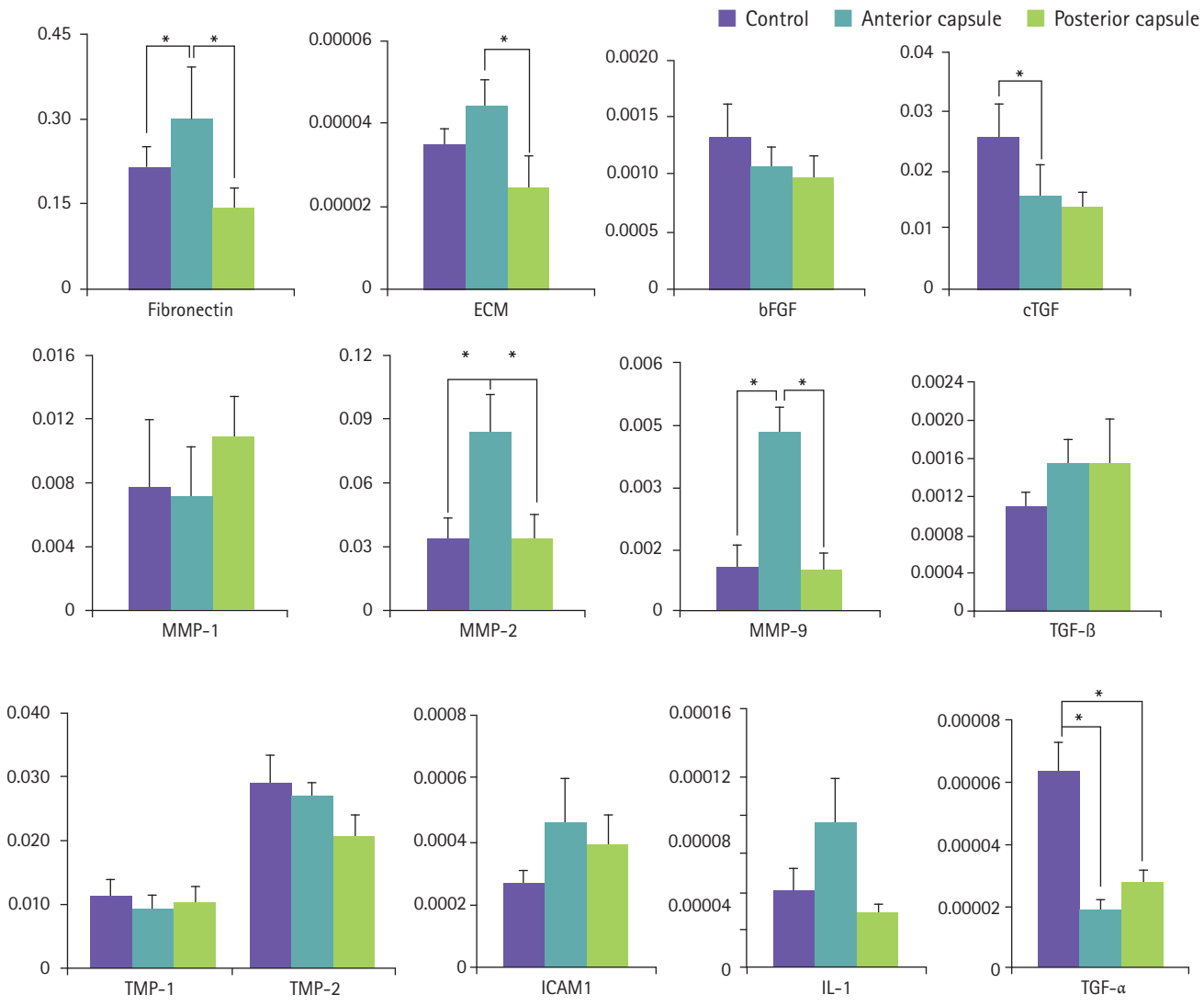

Fig. 4. The gene expression of inflammatory, fibrogenic, and growth factors in the anterior and posterior capsules as well as control tissue. ECM: extracellular matrix, bFGF: basic fibroblast growth factor, cTGF: connective tissue growth factor, MMP: matrix metal, TGF: tumor necrotizing factor, TIMP: tissue inhibitors of metalloproteinase, ICAM: intercellular adhesion molecule, IL: interleukin. *P<0.05.

POSTOPERATIVE REHABILITATION

The incidence of shoulder stiffness after rotator cuff repair is reported to be 4.9%–32.7% [30,31]. Such joint stiffness may be associated with tear morphology, postoperative immobilization, glenohumeral adhesion, capsular contracture, or underlying predisposing patient comorbidities such as diabetes [6]. To minimize the incidence and duration of postoperative stiffness, various methods were proposed for postoperative rehabilitation. There are many studies about postoperative rehabilitation after rotator cuff tear, though few are comparative studies relating to preoperative rotator cuff tear and concomitant stiffness. In most studies about postoperative rehabilitation, preoperative shoulder stiffness patients were excluded because of restriction of variables. As few studies have investigated postoperative rehabilitation of preoperative shoulder stiffness, the inclusion and exclusion criteria of each study were mentioned herein.

Early passive motion has historically been considered the established protocol to reduce adhesion and stiffness after rotator cuff surgery [32]. Li et al. [33] suggested that continuous passive motion after rotator cuff injury in rabbits promotes basic fibroblast growth factor expression, contributing to tendon recovery by inducing type III collagen synthesis at the tendon-bone interface in the early stages of supraspinatus tendon recovery. According to Cuff and Pupello [34] in their randomized controlled study, early passive motion may help to quickly recover ROM,

and forward elevation is improved six months after surgery, although patients with accompanying adhesive capsulitis at the time of rotator cuff repair were excluded. However, their study showed no statistical difference between early and delayed rehabilitation 1 year after surgery. Arndt et al. [35] compared immediate passive motion and immobilization after arthroscopic rotator cuff repair in a prospective randomized study. In their study, although preoperative stiffness was not mentioned as an exclusion criterion, the preoperative group had a mean ROM of 174° and 170°, respectively, and early passive motion showed better functional results with no significant difference in healing of the repaired rotator cuff tendon [35].

Conversely, some recent studies have reported that delayed motion has benefits in clinical and biological outcomes. Sonnabend et al. [36] reported that, at four weeks after surgery, the rotator cuff repair site was still in the early healing phase and remained histologically immature. Gimbel et al. [37] also suggested that delayed motion in the rat model increases the organization of collagen fibers, which subsequently improves tendon to bone healing. Parsons et al. [38] documented favorable outcomes of slower rehabilitation after arthroscopic rotator cuff repair. In their study, all patients underwent full-time sling immobilization without formal therapy for 6 weeks after arthroscopic rotator cuff repair. At 6 to 8 weeks after operation, the patients were allocated into two groups. They categorized patients as "stiff" if they demonstrated forward elevation less than 100° and external rotation less than 30° passively; all others were designated as "non-stiff." There was no significant difference in mean ROM, functional scores, or retear rate. They concluded that sling immobilization for 6 weeks after arthroscopic rotator cuff repair did not result in increased long-term stiffness and may improve the rate of tendon healing [38]. Recently, Kim et al. [39] suggested that early passive motion exercise is not mandatory after arthroscopic repair of small to medium-sized full-thickness rotator cuff tears, and postoperative rehabilitation can be modified to ensure patient compliance. In their study, patients were instructed to wear an abduction brace for 4 to 5 weeks after surgery and to start active-assisted shoulder exercise after brace weaning. Group I conducted movement three to four times per day during the abduction brace-wearing period, and group II was allowed no passive motion during the same period. There was no statistical difference in ROM, function score, or tear rate between the early passive motion group and delayed motion group at 1 year follow-up in a prospective randomized study, although patients with preoperative shoulder stiffness were excluded [39]. Therefore, the author recommended that the postoperative rehabilitation protocol be individualized according to patient condition.

CONCLUSION

Several treatment strategies can be considered when treating rotator cuff tear with joint stiffness. One-stage treatment, namely simultaneous procedures for joint stiffness and repair of the torn cuff, seems to be an effective treatment considering the time required and clinical results. It is also conceivable that arthroscopic capsular release is a useful technique for treating stiffness. When performing arthroscopic capsular release, good results can be obtained even if only anterior and anteroinferior capsules are released. The rehabilitation program can be individualized according to patient compliance.

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https://doi.org/10.5397/cise.2020.00143

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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

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- Contributors: Any researcher who does not meet all four ICMJE criteria for authorship discussed above but contribute substantively to the study in terms of idea development, manuscript writing, conducting research, data analysis, and financial support should have their contributions listed in the Acknowledgments section of the article.

Process for Managing Research and Publication Misconduct

When the journal faces suspected cases of research and publication misconduct, such as redundant (duplicate) publication, plagiarism, fraudulent or fabricated data, changes in authorship, undisclosed conflict of interest, ethical problems with a submitted manuscript, appropriation by a reviewer of an author's idea or data, and complaints against editors, the resolution process will follow the flowchart provided by COPE (http://publicationethics.org/resources/flowcharts). The discussion and decision on the suspected cases are carried out by the Editorial Board.

Editorial Responsibilities

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.

3. EDITORIAL POLICY

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It is recommended that any research that deals with a clinical trial be registered with a clinical trial registration site, such as http://cris.nih.go.kr, http://www.who.int/ictrp/en, and http://clinicaltrials.gov.

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ICiSE encourages data sharing wherever possible, unless this is prevented by ethical, privacy, or confidentiality matters. Authors wishing to do so may deposit their data in a publicly accessible repository and include a link to the DOI within the text of the manuscript.

- Clinical Trials: CiSE accepts the ICMJE Recommendations for data sharing statement policy. Authors may refer to the editorial, "Data Sharing statements for Clinical Trials: A Requirement of the International Committee of Medical Journal Editors," in the Journal of Korean Medical Science (https://dx.doi.org/10.3346/jkms.2017.32.7.1051).

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CiSE provides electronic archiving and preservation of access to the journal content in the event the journal is no longer published, by archiving in the National Library of Korea. According to the deposit policy (self-archiving policy) of Sherpa/Romeo (http://www.sherpa.ac.uk/), authors cannot archive pre-print (i.e., pre-refereeing) but they can archive post-print (i.e., final draft post-refereeing). Authors can archive the publisher's version/PDF.

4. SUBMISSION AND PEER-REVIEW PROCESS

Submission

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.
- After review, the editorial board determines whether the manuscript is accepted for publication or not. Once rejected, the manuscript does not undergo another round of review.

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.
- Only standard abbreviations should be used. Abbreviations should be avoided in the title of the manuscript. Abbreviations should be spelled out when first used in the text and the use of abbreviations should be kept to a minimum.
- 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).

Composition of Manuscripts

- The manuscript types are divided into Original Article, Review Article, Case Report, and other types. There is no limit to the length of each manuscript; however, if unnecessarily long, the author may be penalized during the review process.
- Original Articles should be written in the following order: title page, abstract, keywords, main body (introduction, methods, results, discussion), acknowledgments (if necessary), references, tables, figure legends, and figures. The number of references is limited to 30.
- 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.
- Case Reports should be written in the following order: title page, abstract, keywords, main body (introduction, case report, discussion), acknowledgments (if necessary), references, tables, figure legends, and figures. The number of references is limited to 10.

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.
- Current Concepts deal with most current trends and controversies of a single topic in shoulder and elbow. Authors are recommended to update all the knowledge to most recent studies and researches.
- Systemic Review examines published material on a clearly described subject in a systematic way. There must be a description of how the evidence on this topic was tracked down, from what sources and with what inclusion and exclusion criteria.
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- Letters to the Editor: The journal welcomes readers' comments on articles published recently in the journal or orthopedic topics of interest.
- Editorial is invited by the editors and should be commentaries on articles published recently in the journal. Editorial topics could include active areas of research, fresh insights, and debates in the field of orthopedic surgery. Editorials should not exceed 1,000 words, excluding references, tables, and figures.
- Concise Review is short version of systemic review requested to submit in the journal by the Editorial board. Usually, previous papers regarding such topic were published by the main author(s).
- Special Reports/Expert Opinions (Level V studies) of various topics in shoulder and elbow can be submitted. They are limited to 2,700 words excluding references, tables, and figures.

Title Page

- The title page must include a title, the authors' names and academic degrees (include ORCID*), affiliations, and corresponding authors' names and contact information. In addition, a running title must be written in English within up to 50 characters including spaces. The corresponding authors' contact information must include a name, addresses, e-mails, telephone numbers, and fax numbers.
- **ORCID:** We recommend that the open researcher and contributor ID (ORCID) of all authors be provided. To have an ORCID,

authors should register in the ORCID website: http://orcid.org/. Registration is free to every researcher in the world.

- If there are more than two authors, a comma must be placed between their names (with academic titles). Authors' academic titles must be indicated after their names.
- The contributions of all authors must be described using the CRediT (https://www.casrai.org/credit.html) Taxonomy of author roles. All persons who have made substantial contributions, but who have not met the criteria for authorship, are acknowledged here.
- All sources of funding applicable to the study should be stated here explicitly.

Abstract and Keywords

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.

- Background: The rationale, importance, or objective of the study should be described briefly and concisely in one to two sentences. The objective should be consistent with that stated in the Introduction.
- Methods: The procedures conducted to achieve the study objective should be described in detail, together with relevant details concerning how data were obtained and analyzed and how research bias was adjusted.
- 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."
- Description of participants: Ensure the correct use of the terms "sex" (when reporting biological factors) and "gender" (identity, psychosocial, or cultural factors), and, unless inappropriate, report the sex and/or gender of study participants, the sex of animals or cells, and describe the methods used to determine sex and gender. If the study was done involving an exclusive population, for example, in only one sex, authors should justify why, except in obvious cases (e.g., ovarian cancer). Authors should define how they determined race or ethnicity and justify their relevance.
- Introduction: State the background or problem that led to the initiation of the study. Introduction is not a book review, rather it is best when the authors bring out controversies which create interest. Lead systematically to the hypothesis of the study, and finally, to a restatement of the study objective, which should match that in the Abstract. Do not include conclusions in the Introduction.
- Methods: Describe the study design (prospective or retrospective, inclusion and exclusion criteria, duration of the study) and the study population (demographics, length of follow-up). Explanations of the experimental methods should be concise, but yet enable replication by a qualified investigator.
- 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.
- Discussion: The first paragraph of the discussion should deal with the key point in this study. Do not start by article review or general comment on the study topic. In the Discussion, data should be interpreted to demonstrate whether they affirm or refute the original hypothesis. Discuss elements related to the purpose of the study and present the rationales that support the conclusion drawn by referring to relevant literature. Discussion needs some comparison of similar papers published previously, and discuss why your study is different or similar from those papers. Care should be taken to avoid information obtained from books, historical facts, and irrelevant information. A discussion of study weaknesses and limitations should be included in the last paragraph of the discussion. Lastly you must briefly state your new (or verified) view of the problem you outlined in the Introduction.
- References must be numbered with superscripts according to their quotation order. When more than two quotations of the same authors are indicated in the main body, a comma must be placed between a discontinuous set of numbers, whereas a dash must be placed between the first and last numerals of a contin-

uous set of numbers: "Kim et al. [2,8,9] insisted…" and "However, Park et al. [11–14] showed opposing research results."
- Figures and tables used in the main body must be indicated as "Fig." and "Table." For example, "Magnetic resonance imaging of the brain revealed… (Figs. 1–3).

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.

- Staining techniques used should be described. Photomicrographs with no inset scale should have the magnification of the print in the legend.
- Papers containing unclear photographic prints may be rejected.
- Remove any writing that could identify a patient.
- Any illustrations previously published should be accompanied by the written consent of the copyright holder.

Tables

- Tables should be numbered sequentially with Arabic numerals in the order in which they are mentioned in the text.
- If an abbreviation is used in a table, it should be defined in a footnote below the table.
- Additional information for any clarification is designated for citation using alphabetical superscripts ($^{a)}$, $^{b)}$…) or asterisks (*). Explanation for superscript citation should be done as following examples: $^{a)}$Not tested. *P < 0.05, **P < 0.01, ***P < 0.001.
- Tables should be understandable and self-explanatory, without references to the text.

References

- The number of references is recommended to 30 for original article and 10 for case report and technical note.
- All references must be cited in the text. The number assigned to the reference citation is according to the first appearance in the manuscript. References in tables or figures are also numbered according to the appearance order. Reference number in the text, tables, and figures should in a bracket ([ ]).
- List names of all authors when six or fewer. When seven or more, list only the first three names and add et al.
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- The journals should be abbreviated according to the style used in the list of journals indexed in the NLM Journal Catalog (http://www.ncbi.nlm.nih.gov/nlmcatalog/journals).
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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.

6. FINAL PREPARATION FOR PUBLICATION

Final Version

After the paper has been accepted for publication, the author(s) should submit the final version of the manuscript. The names and affiliations of the authors should be double-checked, and if the originally submitted image files were of poor resolution, higher resolution image files should be submitted at this time. Symbols (e.g., circles, triangles, squares), letters (e.g., words, abbreviations), and numbers should be large enough to be legible on reduction to the journal's column widths. All symbols must be defined in the figure caption. If references, tables, or figures are moved, added, or deleted during the revision process, renumber them to reflect such changes so that all tables, references, and figures are cited in numeric order.

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7. ARTICLE PROCESSING CHARGES

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Author's checklist

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- ☐ Manuscript in MS-WORD (.doc) format.
- ☐ Double-spaced typing with 10-point font.
- ☐ Sequence of title page, abstract and keywords, introduction, methods, results, discussion, conclusions, acknowledgments, references, tables, and figure legends. All pages and manuscript text with line should be numbered sequentially, starting from the abstract.
- ☐ Title page with article title, authors' full name(s) and affiliation(s), address for correspondence (including telephone number, e-mail address, and fax number), running title (less than 10 words), and acknowledgments, if any.
- ☐ Abstract in structured format up to 250 words for original articles and in unstructured format up to 200 words for case reports. Keywords (up to 5) from the MeSH list of Index Medicus.
- ☐ All table and figure numbers are found in the text.
- ☐ Figures as separate files, in JPG, GIF, or PPT format.
- ☐ References listed in proper format. All references listed in the reference section are cited in the text and vice versa.
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