Editorial
Radial head resection versus replacement for unreconstructable radial head fractures

Original Articles
Comparative study of glenoid version and inclination using two-dimensional images from computed tomography and three-dimensional reconstructed bone models
Prevalence of rotator cuff diseases in adults older than 40 years in or near Chuncheon city, Korea
Results of radial head resection after Mason type 3 or 4 fracture of the elbow
Comparison between minimally invasive plate osteosynthesis and the deltopectoral approach with allogenous fibular bone graft in proximal humeral fractures
Magnetic resonance imaging analysis of rotator cuff tear after shoulder dislocation in a patient older than 40 years

Technical Note
Intramedullary fibula strut bone allograft in a periprosthetic humeral shaft fracture with implant loosening after total elbow arthroplasty

Case Report
PHILOS plate fixation with polymethyl methacrylate cement augmentation of an osteoporotic proximal humerus fracture

Concise Review
Treatment of acute high-grade acromioclavicular joint dislocation
Aims and Scope

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Contents

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Editorial

117  Radial head resection versus replacement for unreconstructable radial head fractures
Beom-Soo Kim, Chul-Hyun Cho

Original Articles

119  Comparative study of glenoid version and inclination using two-dimensional images from computed tomography and three-dimensional reconstructed bone models
Chang-Hyuk Choi, Hee-Chan Kim, Daewon Kang, Jun-Young Kim

125  Prevalence of rotator cuff diseases in adults older than 40 years in or near Chuncheon city, Korea
Do-Young Kim, Jung-Taek Hwang, Sang-Soo Lee, Jun-Hyuck Lee, Min-Soo Cho

131  Results of radial head resection after Mason type 3 or 4 fracture of the elbow
Ferdinand Nyankoue Mebouinz, Amadou Kasse, Mouhamadou Habib Sy

136  Comparison between minimally invasive plate osteosynthesis and the deltopectoral approach with allogenous fibular bone graft in proximal humeral fractures
Joon Yub Kim, Jinho Lee, Seong-Hun Kim

144  Magnetic resonance imaging analysis of rotator cuff tear after shoulder dislocation in a patient older than 40 years
Jung-Han Kim, Jin-Woo Park, Si-Young Heo, Young-Min Noh

Technical Note

152  Intramedullary fibula strut bone allograft in a periprosthetic humeral shaft fracture with implant loosening after total elbow arthroplasty
Young-Hoon Jo, Seung Gun Lee, Incheol Kook, Bong Gun Lee

Case Report

156  PHILOS plate fixation with polymethyl methacrylate cement augmentation of an osteoporotic proximal humerus fracture
Do-Young Kim, Tae-Yeong Kim, Jung-Taek Hwang

Concise Review

159  Treatment of acute high-grade acromioclavicular joint dislocation
Jeung Yeol Jeong, Yong-Min Chun
Radial head resection and replacement are common treatment strategies for comminuted radial head fractures. In particular, the presence of more than three fragments in the setting of unstable radial head fracture has a poor prognosis and, if secure fixation cannot be achieved, radial head resection or replacement may be the best option [1]. Although the indications are controversial, radial head resection without replacement has been recommended in isolated unreconstructable radial head fractures when the degree of comminution hinders internal fixation, especially for those who have little demand [2].

In this issue, a study by Mebouinz et al. [3], “Results of radial head resection after mason type 3 or 4 fracture of the elbow,” discusses 11 patients treated with radial head resection for a comminuted radial head fracture for which internal fixation was not possible. They reported that nine patients had a stable and painless elbow with an average follow-up of 47.6 months. The extension-flexion arc ranged from 5° to 120° and the mean values of pronation and supination were 76.8° and 74.5°, respectively. The mean Mayo Elbow Performance Score was 83.2 points and recovery of overall function of the elbow was achieved in 81% of cases. They concluded that radial head resection remains a useful surgical procedure for radial head fractures.

However, this study should be interpreted with caution. The complication rate including instability or valgus deformity of the elbow joint was relatively high. They reported that seven of 11 cases had a valgus deformity and two of 11 cases had elbow instability in valgus stress. The radial head plays an important role in maintaining stability and force transfer from the hand to the shoulder. Previous studies have described the importance of mechanical block in functionality [4-6]. Hildebrand et al. [7] reported that radial head resection must not be performed with concurrent fractures or ligamentous injuries. Hilgersom et al. [4] reported that radial head resection can lead to proximal migration of the radius and concurrent derangement of the distal radioulnar joint.

Additionally, a study by Mebouinz et al. [3] included patients who had radial head fracture with combined injury (five patients with posterior dislocation and three patients with fracture of the coronoid process). Hilgersom et al. [4] emphasized that associated injuries influencing physiologic elbow kinematics, particularly those causing elbow instability or interosseous membrane injury, should be excluded for successful radial head resection outcomes. Therefore, radial head resection in fractures accompanied by such injuries can lead to additional instability on long-term follow-up. The increase in force load and tendency toward valgus deformity also affect the ulnar collateral ligament to progressive...
cubitus valgus, leading to the development of additional instability and ulnar nerve palsy [2].

In our opinion, radial head prosthesis is a reasonable option for unreconstructable radial head fractures. In a recent study, Lópiz et al. [6] described the higher rate of complications in patients who underwent radial head resection, together with a greater need for reoperation and a worse clinical score, as suggesting radial head replacement as the first-line treatment option. We agree with their opinion. Radial head replacement can achieve effective radiocapitellar contact that will improve the stability in valgus, posterolateral, and axial loading of the forearm. This treatment option has satisfactory short- and mid-term results even with other combined elbow injuries [2]. Thus, we recommend that surgeons prepare for and consider radial head replacement during all surgical procedures for comminuted radial head fracture.

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Comparative study of glenoid version and inclination using two-dimensional images from computed tomography and three-dimensional reconstructed bone models

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Department of Orthopedic Surgery, School of Medicine, Catholic University of Daegu, Daegu, Korea

Background: This study was performed to compare glenoid version and inclination measured using two-dimensional (2D) images from computed tomography (CT) scans or three-dimensional (3D) reconstructed bone models.

Methods: Thirty patients who had undergone conventional CT scans were included. Two orthopedic surgeons measured glenoid version and inclination three times on 2D images from CT scans (2D measurement), and two other orthopedic surgeons performed the same measurements using 3D reconstructed bone models (3D measurement). The 3D-reconstructed bone models were acquired and measured with Mimics and 3-Matics (Materialise).

Results: Mean glenoid version and inclination in 2D measurements were –1.705° and 9.08°, respectively, while those in 3D measurements were 2.635° and 7.23°. The intra-observer reliability in 2D measurements was 0.605 and 0.698, respectively, while that in 3D measurements was 0.883 and 0.892. The inter-observer reliability in 2D measurements was 0.456 and 0.374, respectively, while that in 3D measurements was 0.853 and 0.845.

Conclusions: The difference between 2D and 3D measurements is not due to differences in image data but to the use of different tools. However, more consistent results were obtained in 3D measurement. Therefore, 3D measurement can be a good alternative for measuring glenoid version and inclination.

Keywords: Glenoid version; Glenoid inclination; 2D measurement; 3D measurement

INTRODUCTION

Determining the appropriate orientation and location for glenoid components and assessing glenoid bone loss are very important for successful reverse total shoulder arthroplasty (RTSA) [1], because malpositioning of the glenoid component can result in early component loosening, failure, and instability [2,3]. Therefore, precise evaluation for glenoid version and inclination is essential for preoperative RTSA planning procedures.

Conventional two-dimensional (2D) computed tomography (CT) images have been used as the gold standard to evaluate glenoid version and inclination [4,5]. However, the accuracy of measurement based on 2D images from CT scans (2D measurement) depends on factors of the scapula plane, which can change based on patient positioning and scapula orientation (rotation or abduction) [6]. Furthermore, the results of 2D measurement can...
differ depending on choice of axial or coronal plane. Recently, several studies have indicated that measurement using three-dimensional (3D)-reconstructed bone models (3D measurement) for glenoid version and inclination is more accurate than 2D measurement [4,7,8]. More advanced analysis using software allows analysis of the scapula regardless of orientation [9]. Therefore, this study was performed to compare glenoid version and inclination in 2D and 3D measurements.

METHODS

Ethical Approval
This study was approved by the Institutional Review Board of School of Medicine, Catholic University of Daegu (IRB No. CR-19-090-L). Informed consent was obtained from all patients included in this study, who agreed to study publication including use of radiographic images.

Demographic Data
The population comprised 30 patients (7 males and 23 females) who had undergone conventional CT scans with the GE Revolution CT system (GE Healthcare, Little Chalfont, UK) in our hospital between May 2018 and September 2019. The slice thickness of each image was 2.0 mm. The underlying diseases were cuff tear arthropathy (23 cases), osteoarthritis (two cases), avascular necrosis of the humeral head (two cases), nonunion after proximal humerus fracture (two cases), and rheumatoid arthritis (one case). The mean age was 73 years (range, 58–86 years). Two orthopedic surgeons (CHC and DK) measured glenoid version and inclination three times with 2D measurements, and another two orthopedic surgeons (JYK and HCK) performed the same using 3D measurements. A specialist and a resident were assigned to each group to account for ability and career knowledge.

2D Measurement
The 2D axial and coronal images from CT scans were used to measure glenoid version and inclination, respectively. For measuring glenoid version, we first marked two landmarks: (1) the center of the glenoid fossa and (2) the most medial location of the scapula on the first axial image below the coracoid process of the glenoid. This location represents the diameter of the glenoid, as this is where it is largest considering the anatomy of the gleno-humeral joint and 2-mm slice thickness. Second, we drew a transverse line between the two points to define the anatomical axis of the scapula [10]. Third, we drew a straight line between the anterior and posterior margins of the glenoid fossa. Finally, we measured the angle between the two lines (Fig. 1A); a positive value indicated anteversion. Conversely, a negative value indicated retroversion.

For measuring glenoid inclination, a line was initially drawn along the most inferior margin of the supraspinatus fossa after selecting the coronal plane of the glenoid with the largest diameter [11]. Second, we drew a straight line between the superior and inferior margins of the glenoid fossa in that same coronal plane. Finally, we measured the angle between the two lines (Fig. 1B).

3D Measurement
The 3D measurement comprised the following four steps: (1) segmentation and 3D bone model reconstruction, (2) creation of a best-fit circle and sphere and identifying the center of the glenoid fossa, (3) creating three reference planes, and (4) measuring glenoid version and inclination. We used Mimics (Materialise, Leuven, Belgium) for 3D bone model reconstruction and 3-Matic (Materialise) for 3D measurement.

Segmentation and 3D bone model reconstruction
Axial and coronal images from CT scans were formatted as Digi-
tal Imaging and Communications in Medicine (DICOM) image files. We used Mimics to create the 3D reconstructed bone models as follows. First, the threshold level was selected based on Hounsfield units to mark the skeletal region in the CT images. Second, the boundary of the skeletal region was adjusted using the split mask function. Third, manual mask editing was conducted to fill the holes on the surface of the skeletal region. Fourth, a 3D-reconstructed model was created. Finally, wrapping and smoothing techniques were applied to decrease the surface roughness of the 3D reconstructed model [12].

**Best-fit circle and sphere creation and identification of the center of the glenoid fossa**

We created the anatomical best-fit circle and sphere to determine the center of the glenoid fossa. First, several points on the margin of the glenoid were marked (Fig. 2A). Second, we set the best-fit circle based on the identified points (Fig. 2B). The best-fit circle was determined by production of a circle based on the coordinates of the points above the glenoid margin with as little error as possible. Third, the inner surface of the glenoid fossa was marked (Fig. 2C). Fourth, we set the best-fit sphere based on the coordinate values of the glenoid inner surface (Fig. 2D). Finally, we drew a line between the center of the circle and sphere and marked the center of the glenoid fossa by extending the line (Fig. 2E).

**Reference planes**

The scapular anatomical plane (SAP) was defined as the coronal plane containing the following three landmarks: (1) the center of the glenoid fossa, (2) the most inferior spot of the scapula body, (3) the intersection of the scapula spine and medial border (3rd point) (Fig. 3A) [2]. The axial anatomical plane was determined as that passing through the 3rd point and glenoid center while perpendicular to the SAP (Fig. 3B). The sagittal anatomical plane was defined as that passing through the glenoid center while vertical to the SAP and axial anatomical planes (Fig. 3B).

**Measurement of glenoid version and inclination**

We defined the anatomical axis as the line connecting the centers of the best-fit circle and sphere. Glenoid version was described as the angle between the anatomical axis and SAP (Fig. 4A). Glenoid inclination was the angle between the anatomical axis and the axial anatomical plane (Fig. 4B) [2,9].

**Statistical Analysis**

Independent t-test and Pearson’s correlation analysis were applied to compare the results between 2D and 3D measurements, including glenoid version and inclination. IBM SPSS ver. 19.0 (IBM Corp., Armonk, NY, USA) was utilized for statistical analysis, with P < 0.05 indicating statistical significance.

**RESULTS**

Mean glenoid version and inclination in 2D measurements were −1.705° (standard deviation [SD], 4.73°) and 9.08° (SD, 9.76°), respectively, while those in 3D measurements were 2.635° (SD, 3.78°) and 7.23° (SD, 3.99°) (Table 1). These results indicate sta-
Table 1. Mean and standard deviation in two different measurement methods

<table>
<thead>
<tr>
<th>Variable</th>
<th>Glenoid version (°)</th>
<th>Glenoid inclination (°)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D measurement</td>
<td>−1.705 ± 4.73</td>
<td>9.08 ± 9.76</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>3D measurement</td>
<td>2.635 ± 3.78</td>
<td>7.23 ± 3.99</td>
<td>&lt; 0.05</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. 2D: two-dimensional, 3D: three-dimensional.

Table 2. Intra-observer reliability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Glenoid version</th>
<th>Glenoid inclination</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D measurement</td>
<td>0.605</td>
<td>0.698</td>
</tr>
<tr>
<td>3D measurement</td>
<td>0.883</td>
<td>0.892</td>
</tr>
</tbody>
</table>

p<0.001. 2D: two-dimensional, 3D: three-dimensional.

Table 3. Inter-observer reliability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Glenoid version</th>
<th>Glenoid inclination</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D measurement</td>
<td>0.456</td>
<td>0.374</td>
</tr>
<tr>
<td>3D measurement</td>
<td>0.853</td>
<td>0.845</td>
</tr>
</tbody>
</table>

p<0.001. 2D: two-dimensional, 3D: three-dimensional.

Fig. 3. Making three reference planes. (A) Three landmarks. (B) Three reference planes.

Fig. 4. Measurement of glenoid version and inclination. (A) Glenoid version is defined as the angle between the anatomical axis and scapular anatomical plane. (B) Glenoid inclination is decided as the angle between the anatomical axis and axial anatomical plane.

DISCUSSION

Preoperative assessment of glenoid version and inclination is important for implantation in RTSA. Conventional 2D images from CT scans have primarily been used to evaluate these values. However, measurement of glenoid version and inclination on radiographic images from CT scans have several drawbacks [6,13-16]. The first is that reference planes can be determined differently based on patient position and scapula orientation. Second, the reference plane setup can differ based on wear pattern and asymmetric shape of the glenoid. Third, it is more difficult to precisely set the reference planes with thicker CT slice thickness. Fourth, when measuring glenoid version and inclination, indistinct shapes of anatomical landmarks can result in measurement errors. Because of these shortcomings, 3D-reconstructed bone models (3D measurement) have been introduced for measuring glenoid version and inclination. Several studies have shown that 3D measurement of glenoid version and inclination was more accurate than 2D measurement [4,7,8]. Despite the advantages, 3D measurement is more costly and time consuming than 2D measurement. In this study, 2D measurement in each case could be completed within an average of 3 minutes, while that of 3D measurement required about 15 minutes.

In this study, difference was shown in mean values calculated by the two measurement methods. The results also showed that 3D measurement is more consistent than 2D measurement. Intra- and inter-observer reliabilities were determined for glenoid version and inclination with 2D and 3D measurements. The intra-observer reliability for glenoid version and inclination in 2D measurement was 0.605 and 0.698, respectively, while that in 3D measurement was 0.883 and 0.892 (Table 2). The inter-observer reliability for glenoid version and inclination in 2D measurement was 0.456 and 0.374, respectively, while that in 3D measurement was 0.853 and 0.845, respectively (Table 3). These outcomes show higher reliability of 3D measurement than that of 2D measurement.
orientation and patient position are not considered because of the use of 3D-reconstructed bone models.

In addition, the 2D and 3D measurements suggest different outcomes due to the difference in measurement space. In 2D measurement, the angle between two lines is utilized to measure glenoid version and inclination. However, as the lines are measured by shadows projected on the 2D plane, they do not reflect accurate anatomy. In comparison, in 3D measurement, glenoid version and inclination are measured as the angle between a line and plane and is more likely to represent reality because the line is not projected on the 2D plane.

In a previous study [2], the inner surface of the glenoid fossa was assumed to be a part of the sphere, and glenoid version and inclination were measured using the best-fit sphere method. However, because the inner surface of the glenoid fossa is not a perfect sphere, error can result when determining the precise location of the glenoid center. To reduce the probability of this error, we created a best-fit circle based on the coordinates of several points in the glenoid margin. Then, the line connecting the centers of the sphere and circle was set as the anatomical axis, and the point where the extension of this axis met the inner surface of the glenoid was defined as the glenoid center. If the margin of the glenoid is distorted due to other causes such as osteophytes or deformities, there is a possibility for an associated error in identification of the glenoid center. However, it is thought that a more accurate glenoid center can be determined when using the best-fit circle method “together” rather than the best-fit sphere method alone.

This study had several limitations. First, we did not consider patient positioning or scapula orientation. Second, there may be observation error in setting the anatomical axis and several coordinate values in 3D measurement. Third, the population of the study was collected from a single hospital and was small. Fourth, only static images that did not reflect range of motion were used. Finally, the difference in measurer abilities according to experience was not considered.

In summary, the difference between 2D and 3D measurements is not due to differences in image data but to use of different tools. However, more consistent results were obtained in 3D measurement. Additionally, detailed analysis of preoperative 3D images could be very helpful during operation. Therefore, 3D measurement can be a good alternative for measuring glenoid version and inclination.

REFERENCES


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Prevalence of rotator cuff diseases in adults older than 40 years in or near Chuncheon city, Korea

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Background: To determine the prevalence of rotator cuff diseases in a population older than 40 years in or nearby Chuncheon city, Republic of Korea.

Methods: Sixty shoulders of 30 people older than 40 years who participated in a health lecture were examined for free by an orthopedic surgeon. Visual analog scale of pain and American Shoulder and Elbow Surgeons scores were assigned, and routine physical examination was performed. Ultrasonography was performed on the shoulders.

Results: On ultrasonographic examination, there were one shoulder with full thickness rotator cuff tear, 20 of 60 (33%) with partial thickness rotator cuff tear, five of 60 (8%) with calcific tendinitis, one of 60 (2%) with tear of the long head of the biceps, and five of 60 (8%) with tendinitis of the long head of the biceps. Participants older than 60 years showed significantly high proportions of lesion of the long head of the biceps and rotator cuff diseases (P=0.019 and P=0.015, respectively). Participants who performed physical labor had high proportions of rotator cuff tear and rotator cuff disease (P=0.001 and P<0.001, respectively).

Conclusions: Rotator cuff diseases showed a high prevalence in aged persons and resulted in a decrease in shoulder function.

Keywords: Aged person; Prevalence; Rotator cuff; Occupation; Ultrasonography

INTRODUCTION

Shoulder pain is the third most common musculoskeletal pain and is estimated to compose 16% of all cases of musculoskeletal pain in primary medical care [1,2]. There are 15 musculoskeletal pain cases per 1,000 primary medical care cases each year, totaling about 1% of all adults receiving primary medical care annually [1,2]. Patients who experience shoulder pain for more than 1 year compose 60% of all shoulder pain patients; if not treated, these patients will experience severe disabilities, poor quality of life, and loss of occupation [1,2].

Shoulder pain is defined as chronic when it has been present for more than 6 months, regardless of any treatment the patient has previously received. The most common medical cause of chronic shoulder pain is rotator cuff disease, which includes tendinosis of the rotator cuff or long head of the biceps, partial- or deep-thickness tear of the long head of the biceps tendon, and calcific tendinitis. Other medical causes of chronic shoulder pain include adhesive capsulitis, osteoarthritis of the arm and shoulder joints, instability of the arm and shoulder joints, and acute...
micloaviculolar joint disease [1].

Despite active studies that have been conducted overseas on the treatment and prevalence of shoulder pain [1-5], studies on the prevalence of shoulder pain and that of rotator cuff diseases that cause shoulder pain in Korea remain limited [6]. Accordingly, we examined 60 shoulder cases of 30 adults older than 40 years of age living in Chuncheon city, Korea and nearby areas to determine the prevalence of rotator cuff diseases that cause shoulder pain in this population.

METHODS

Materials
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 Chuncheon Sacred Heart Hospital (No. 2020-04-011-003), and the need for informed consent was waived.

A total of 60 shoulder cases of 30 people over 40 years of age who participated in a health lecture held at the university hospital was included. The average age of study participants was 61.6 ± 1.7 years (range, 40–78 years). Twelve patients were male and 18 were female. Seven patients resided in rural areas, while 23 resided in urban areas. Twenty-three were manual workers and seven were office workers. Sixteen complained of night pain (Table 1).

Method
For functional assessment of shoulder joints, the American Shoulder and Elbow Surgeons (ASES) scoring system established by the American Shoulder and Elbow Society in 1994 was deployed, and a physical examination was performed. Among 57 participants in the health lecture, 30 underwent ultrasound tests for both shoulder joints performed by an orthopedic specialist with 5 years of experience who focused on treating shoulder and elbow joints. Additionally, the 30 study participants also underwent score assessment and physical examination performed by two orthopedic nurses with 7 years of experience.

Participants who reported pain during the examination for presence of shoulder joint pain were asked further about the presence and extent of night pains, medical history of analgesics, and location of pain. A visual analog scale (VAS) was used to score the severity of pain, ranging from 0 points for no pain to 10 points for the most severe pain. Ultrasound tests have been used to identify tendinitis or tear of the long head of the biceps tendon, partial- or full-thickness tears of the rotator cuff, and rotator cuff diseases including calcific tendinitis.

Diagnosis of full-thickness tear of the rotator cuff was performed in accordance with the criteria as follows (Fig. 1) [7]: (1) the supraspinatus is not visible due to retraction of torn supraspinatus below the acromioclavicular joint; (2) loss or discontinuity in the local rotator cuff muscle accompanied by continual loss of normal anterior arch in the subdeltoid bursa; (3) loss of normal supraspinatus muscle parenchyma accompanied by increased distance between the supraspinatus and long head of the biceps tendon and exposure of the bare area of the bone and cartilage; (4) hypoechoic or anechoic extension observed through the full parenchyma of the rotator cuff; (5) fluid in the subacromial and subdeltoid bursa with or without fluid in the sheath of the long head of the biceps tendon.

Partial-thickness tear of the rotator cuff was diagnosed by a local hypoechoic or anechoic defect of the bursa or a joint near the rotator cuff in two perpendicular planes (Fig. 2) [8]. Calcification of the rotator cuff appears as a hyperechoic lesion on ultrasound imaging (Fig. 3). Depending on the amount and stage of calcifi-

Table 1. Demographic data of the participants in this study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number</td>
<td>30</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>12:18</td>
</tr>
<tr>
<td>Age (yr), mean ± SD (range)</td>
<td>61.6 ± 1.7 (40–78)</td>
</tr>
<tr>
<td>Age distribution (&lt; 60: ≥ 60)</td>
<td>13:17</td>
</tr>
<tr>
<td>Region (rural:urban)</td>
<td>7:23</td>
</tr>
<tr>
<td>Labor (physical:mental)</td>
<td>23:7</td>
</tr>
<tr>
<td>Dominance (right:left:both)</td>
<td>24:1:4</td>
</tr>
<tr>
<td>Night pain</td>
<td>16</td>
</tr>
</tbody>
</table>

SD: standard deviation.
cation, the type of lesion can appear clear with acoustic shadowing or could be blurry or a type with no shadowing [9,10].

In the transverse sonographic view, tenosynovitis of the long head of the biceps tendon appears like a fried egg due to a halo effect of hypoechoic effusion near the dense shadow of the long head of the biceps tendon (Fig. 4) [11]. A partial-thickness tear could appear as a crevice (Fig. 5), while a full-thickness tear may not be visible because of an involution. Rupture is often accompanied by medial dislocation of the long head of the biceps tendon [12].

**Statistical Analysis**
The Mann-Whitney U-test was used to compare the measured mean values, and a statistical analysis was performed using the SPSS ver. 13.0 (SPSS Inc., Chicago, IL, USA), with statistical significance established at $P < 0.05$.

**RESULTS**
Of the 60 shoulder cases, 39 were painful, with 15 experiencing moderate degree of pain with a VAS score of 4 points or higher. The average VAS and ASES scores were $2.2 \pm 0.3$ (0–8) points and $80.2 \pm 2.1$ (35–100) points, respectively. During ultrasound examination, one shoulder showed a full-thickness rotator cuff tear, 20 of 60 (33%) showed a partial-thickness rotator cuff tear, five of 60 (8%) presented with calcific tendinitis, one of 60 (2%) demonstrаt-

**Fig. 2.** Sonographic finding of the partial-thickness rotator cuff tear. The arrow indicates the partial-thickness rotator cuff tear.

**Fig. 3.** Sonographic finding of calcific tendinitis of the rotator cuff. The arrow indicates a calcific deposit of the rotator cuff. The asterisk indicates acoustic shadowing.

**Fig. 4.** Sonographic finding of long head of the biceps tendinitis. The arrow indicates the long head of the biceps tendon. The asterisk indicates effusion surrounding the long head of the biceps tendon. The shape is similar to that of a fried egg.

**Fig. 5.** Sonographic finding of a long head of the biceps tendon partial-thickness tear. The arrow indicates a small clef on the long head of the biceps tendon.
ed a tear of the long head of the biceps tendon, and five of 60 (8%) presented tendinitis of the long head of the biceps tendon (Table 2). Of the participants aged 60 years or older, the rate of rotator cuff rupture, long head of the biceps tendon lesion, and rotator diseases was significantly higher (P = 0.006, P = 0.025, and P = 0.006, respectively) than those of younger participants (Table 3). Significantly high rates among manual workers were found regarding rotator cuff rupture and rotator cuff disease (P = 0.002 and P < 0.001, respectively). Meanwhile, significantly low ASES scores were observed among manual workers’ shoulders (P = 0.025) (Table 4).

In addition, VAS and ASES scores were significantly lower in shoulders presenting rotator cuff rupture (P < 0.001 and P = 0.004). Lower ASES scores were noted in shoulders with long head of the biceps tendon lesion (P = 0.032). The VAS and ASES scores were significantly lower among those with rotator cuff disease relative to those without rotator cuff disease (P < 0.001 and P < 0.001) (Table 5).

**DISCUSSION**

The majority of patients in Korea who experience shoulder pain postpone visiting the hospital until no effect is achieved with a variety of conservative treatments such as physical therapy or acupuncture or significant dysfunction or severe pain is experienced. Because of this, it is difficult to identify and treat the cause of the pain early [6]. In this research, among 60 shoulder cases, 39 (65%) were painful and 15 (25%) experienced a moderate degree of pain with a VAS score of four points or higher. There is a difference in the distribution of causal diseases of shoulder pain by age. In patients younger than 40 years, shoulder instability or mild rotator cuff disease (i.e., impingement syndrome or tendinosis) is the most common cause, while, in patients older than 40 years of age, risk of developed chronic rotator cuff disease (partial or deep tear), adhesive arthritis, or glenohumeral osteoarthritis increases [1,2,13].

Manual occupations and leisure activities show correlations

<table>
<thead>
<tr>
<th>Pathology</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial thickness rotator cuff tear</td>
<td>20 (33)</td>
</tr>
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<td>Full thickness rotator cuff tear</td>
<td>1 (2)</td>
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<tr>
<td>Calcific tendinitis of rotator cuff tear</td>
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</tr>
<tr>
<td>LHB tendinitis</td>
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</tr>
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<td>LHB tear</td>
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</tr>
</tbody>
</table>

Table 3. The correlation between age and rotator cuff diseases

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age &lt; 60 yr</th>
<th>Age ≥ 60 yr</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC tear</td>
<td>4</td>
<td>17</td>
<td>0.006</td>
</tr>
<tr>
<td>Calcific tendinitis of RC</td>
<td>2</td>
<td>3</td>
<td>0.876</td>
</tr>
<tr>
<td>LHB disease*</td>
<td>0</td>
<td>6</td>
<td>0.025</td>
</tr>
<tr>
<td>RCD†</td>
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</table>

Table 4. The correlation between the type of labor and functional scores with pathology

<table>
<thead>
<tr>
<th>Variable</th>
<th>Physical labor</th>
<th>Mental labor</th>
<th>P-value</th>
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<tbody>
<tr>
<td>VAS, mean ± SD</td>
<td>2.5 ± 2.3</td>
<td>1.3 ± 1.6</td>
<td>0.089</td>
</tr>
<tr>
<td>ASES score, mean ± SD</td>
<td>77.6 ± 17.1</td>
<td>89.0 ± 11.5</td>
<td>0.025</td>
</tr>
<tr>
<td>RC tear</td>
<td>21</td>
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<td>0.002</td>
</tr>
<tr>
<td>Calcific tendinitis of RC</td>
<td>5</td>
<td>0</td>
<td>0.201</td>
</tr>
<tr>
<td>LHB disease*</td>
<td>6</td>
<td>0</td>
<td>0.158</td>
</tr>
<tr>
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<td>0</td>
<td>&lt; 0.001</td>
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**DISCUSSION**

The majority of patients in Korea who experience shoulder pain postpone visiting the hospital until no effect is achieved with a variety of conservative treatments such as physical therapy or acupuncture or significant dysfunction or severe pain is experienced. Because of this, it is difficult to identify and treat the cause of the pain early [6]. In this research, among 60 shoulder cases, 39 (65%) were painful and 15 (25%) experienced a moderate degree of pain with a VAS score of four points or higher. There is a difference in the distribution of causal diseases of shoulder pain by age. In patients younger than 40 years, shoulder instability or mild rotator cuff disease (i.e., impingement syndrome or tendinosis) is the most common cause, while, in patients older than 40 years of age, risk of developed chronic rotator cuff disease (partial or deep tear), adhesive arthritis, or glenohumeral osteoarthritis increases [1,2,13].

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RC: rotator cuff, LHB: long head of biceps, RCD: rotator cuff disease.
*LHB disease: LHB tendinitis and LHB tear; †Rotator cuff tear, LHB disease, calcific tendinitis of RC.

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*LHB disease: LHB tendinitis and LHB tear; †Rotator cuff tear, LHB disease, calcific tendinitis of RC.

Table 5. The correlation between the pathologies and functional scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>RC tear</th>
<th>No RC tear</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS</td>
<td>71.6 ± 14.8</td>
<td>84.9 ± 15.8</td>
<td>0.004</td>
</tr>
<tr>
<td>ASES score</td>
<td>70.4 ± 15.2</td>
<td>87.7 ± 13.7</td>
<td>&lt; 0.001</td>
</tr>
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</table>

Values are presented as mean ± standard deviation.
*LHB disease: LHB tendinitis and LHB tear; †Rotator cuff tear, LHB disease, calcific tendinitis of RC.

128 https://doi.org/10.5397/cise.2020.00178
with shoulder pain. Sports with frequent collisions or activities like lifting of heavy materials can trigger shoulder instability or osteoarthritis in acromioclavicular joints, and upward movement of arms in activities or sports may result in a morbid condition of the rotator cuff [1,13]. This research reported significantly higher rates of rotator cuff rupture and rotator cuff disease in manual workers compared to office workers (P = 0.002 and P < 0.001, respectively).

Previous treatments that aggravate or alleviate pain or causative factors could be clues in attempting to diagnose rotator cuff disease. Night pain that comes on after sleeping on the injured shoulder or a trauma history may be related to rupture of the rotator cuff. A painful arc induced by lifting activities involving the arm is not only related to rotator cuff rupture, but also to tendinosis. Past history of shoulder surgery is important because of early and late complications that may appear such as adhesive arthritis and glenohumeral osteoarthritis [1,13].

Hermans et al. [14] reported that the incidence of rotator cuff disease including tendinosis and rupture was 33% to 81% in their five studies performed using magnetic resonance imaging or ultrasound. In addition, Tashjian [15] observed deep-thickness rotator tear at a rate of 25% among those in their 60s and at a rate of 80% among those in their 80s using magnetic resonance imaging or ultrasound. In this study, there was one patient (1/60, 2%) with a full-thickness rotator cuff tear; 20 patients (20/60, 33%) with partial-thickness rotator cuff tear; and a significantly high ratio of rotator cuff rupture, long head of the biceps tendon lesions, and rotator cuff disease in those aged 60 years and older (P = 0.006, P = 0.025, P = 0.006, respectively).

Oliva et al. [16] reported the prevalence of calcific tendinitis of the rotator cuff as 2.7% to 22% and that it was especially prevalent in women aged 30 to 35 years. In this research, five of 60 (8%) cases of calcific tendinitis were observed. Murthi et al. [17] reported that, of more than 200 shoulders that underwent arthroscopic subacromial decompression surgery for impingement syndrome, 80 (40%) showed degenerative change of the long head of the biceps tendon. Beall et al. [18] reported that, among 111 patients who underwent arthroscopic or open surgery for shoulder pain, 23 (23%) showed partial- or deep-thickness rupture of the long head of the biceps tendon. In this research, five patients (5/60; 8%) showed tendinitis of the long head of the biceps tendon, and one patient (1/60, 2%) showed a tear of the long head of the biceps lesion.

Rotator cuff diseases of the shoulder appear with a high prevalence in elderly people and result in a decrease in shoulder function. Also, manual laborers more often experience rotator cuff disease than do office workers. Therefore, exploring more preventive and therapeutic considerations is thought to be appropriate in particular for old-aged manual laborers.

**ACKNOWLEDGMENTS**

We would like to express sincere gratitude to two clinical research nurses, Byeong-Yi Choi and Ok-Hwa Park, for helping with measurement of participant visual analog scale and American Shoulder and Elbow Surgeons scores and with the ultrasound tests. We also am grateful to specialist Byung-Chan Kwak, who helped with data organization.

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**REFERENCES**

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INTRODUCTION

The functional anatomy of the elbow joint complex is unique in orientation and configuration. The elbow is the mechanical junction between the first two segments of the upper limb, and its main function is to move the hand away from and bring it closer to the trunk [1]. To perform these actions, this joint must be mobile, stable, and mostly painless. The head of the radius is a secondary stabilizer of the elbow according to Morrey’s tripod [2]. It contributes to the overall stability of the elbow and the transmission of stresses, whatever the degree of extension flexion [3]. Its role in frontal and rotational stability has been highlighted by several authors [2,4,5]. Fractures of the head of the radius represent 1.5% to 4% of all fractures and 33% of all bone lesions in the elbow [6]. In these fractures, internal fixation of types 3 and 4 of the Masson classification, modified by Broberg and Morrey [7], is difficult and may not be possible in some cases [7,8]. The choice between resection of the radial head or arthroplasty is dependent on the associated ligament lesions, the equipment available, and the technical skills of the surgical teams. This study aimed to assess the function of the elbow after resection of the radial head in adults.

RESULTS

Nine patients had a stable and painless elbow. The mean extension-flexion arc was 97.73°±16.03°. The mean values of pronation and supination were 76.8° and 74.5°, respectively. The mean MEPI score was 83.2 points, and restoration of overall function was achieved in 81% of the cases. Poor function was noted in one in 10 that presented with a terrible triad.

Conclusions: Resection of the radial head restored elbow functionality at a rate of 81%, which was a good outcome for patients.
METHODS

Patients
A retrospective longitudinal study was carried out in the Department of Orthopedic Trauma Surgery, Idrissa Pouye General Hospital. The study enrolled patients who underwent radial head resection between 2008 and 2018. Using the electronic register of hospitalizations, files obtained from the archives were analyzed. Eleven of 28 patients who underwent radial head resection during this period were reviewed and included in this study. These were eight men and three women with an average age of 41 ± 10.3 years. The fractures were located on the dominant arm in half of the cases. The cause of injury was usually a work accident (54.5%). Type III of the Mason classification modified by Morrey was found in 54.5%. Posterior elbow dislocation and a fracture of the coronoid process were associated in five and three cases, respectively. There were three cases of terrible triads. The lateral surgical approach was used to access the radial head in 10 cases. The interval from initial injury to operation was 15.4 ± 13 days. The level of radial resection was distal to the proximal radial notch of the ulna in 63.6% of cases. The radial stump was regular and without bone indentation in 72.7% of the cases. Interposition of fascia was performed in all patients to address the empty space left after radial head resection. The fascia was taken from the extensor digitorum communis. Complementary procedures were reduction of dislocation and syntheses of associated fractures of the coronoid process. On average, the mean elbow immobilization time was 30.4 ± 6 days. Elbow function was assessed in all patients using the Mayo Elbow Performance Index (MEPI), and the values were scored by a single physician. The ethics committee of Idrissa Pouye General Hospital approved this study (No. 2018-06-014), which was exempted from informed consent.

Statistical Analysis
Data were captured and analyzed using Epi Info ver. 7.1.5.2 (Centers for Disease Control and Prevention, Atlanta, GA, USA). General patient characteristics and MEPI score items were described using standard descriptive statistics. Mean values and standard deviations were calculated for quantitative variables and numbers and percentages for qualitative variables.

RESULTS
At an average follow-up of 47.6 months, of the 11 patients reassessed, two had mild mechanical pain. Six patients had a functional arc greater than 100°, and this arc varied from 50° to 100° in the other 5. In regard to elbow mobility (Table 1), the average degree of flexion was 97.73° ± 16.03° and the average deficit of extension was 23.6°. The mean pronation and supination values were 76.8° and 74.5°, respectively. Overall, a cubitus valgus with an average value of 12.8° ± 4° was identified. Instability as assessed by forced valgus movements was present at a moderate degree in two of 11 cases and was absent in the other nine. A cumulative total of 21 complications was found in all patients. In eight cases, the issue was a limitation of the range of motion, seven cases had elbow valgization (Fig. 1), two cases had instability in the valgus (Figs. 2 and 3), and four cases had heterotopic ossifications (Figs. 4 and 5). No complications such as radial head ascension or Essex-Lopresti syndrome were noted. There were no daily activity limitations in 10 cases. Seven patients continued their professional activities, three had to adjust their original jobs, and one patient had not yet returned to work. The average score for all patients was 83.2 ± 11 points out of 100, and 81% were graded as good according to the MEPI. Elbow function was excellent in three cases, good in six cases, and average in two cases (Fig. 6).

DISCUSSION
Resection of the radial head is a therapeutic indication of interest, and several authors have reported similar findings in the literature. Characteristics of average age, male predominance, and impairment of the dominant side were reported by Karlsson et al. [9] and Obert et al. [10]. Work accidents have been implicated in most studies as the main cause of injuries [10]. Type 3 and 4 fractures according to the Mason classification were the most com-

Table 1. Range of motion of the elbow

<table>
<thead>
<tr>
<th>Setting</th>
<th>Mean (°)</th>
<th>Standard deviation (°)</th>
<th>Min (°)</th>
<th>Max (°)</th>
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<tbody>
<tr>
<td>Flexion</td>
<td>97.73</td>
<td>16.03</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Extension deficit</td>
<td>-23.64</td>
<td>15.67</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>Pronation</td>
<td>76.82</td>
<td>6.61</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>Supination</td>
<td>74.55</td>
<td>10.3</td>
<td>0</td>
<td>85</td>
</tr>
<tr>
<td>Cubitus valgus</td>
<td>12.8</td>
<td>4</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 1. Cumulative postoperative complications.
Fig. 2. The clinical result of case 1. (A) Cubitus valgus on the right. (B) Extension. (C) Full flexion.

Fig. 3. The elbow radiography of case 1. (A, B) Face and post traumatic profile. (C, D) Face and profile at 61 months; no ossifications.

Fig. 4. The clinical result of case 2. (A) Cubitus valgus on the right. (B) Extension deficit of 25°. (C) Flexion limited to 100°.
The time from initial injury to operation varied from 8 days on average in the study by Eren et al. [11] to 29 days in the report from Obert et al. [10]. Our average follow-up of 4 years was still quite short compared to other studies. The longest follow-up period observed was 19 years in the Karlsson et al. [9] study and 30 years in the Janssen and Vegter [12] study. Radial head resection surgery has associated complications that can interfere with elbow function. Ascension of the head and instability in the valgus are complications specific to this indication and are frequently accompanied by valgization of the elbow [12-14]. Other complications common to any joint surgery such as joint limitations and heterotopic ossifications are quite common [15]. These specific and non-specific complications are often responsible for stiffness that further affects the function of the elbow [16]. In this study, valgization of the elbow was found in 63.6% of the cases compared to 20% in the Karlsson et al. [9] study. However, there was slight valgus instability that was identified in only 18% (2/11) of cases. This valgisation of the elbow had no impact on function. Antuña et al. [17] reported instability in the valgus at around 19%, similar to our study. Similar to the reports from Karlsson et al. [9] and Antuña et al. [17], rise of the radial head was not reported in our series. Heterotopic ossifications were found in 36% of our cases compared to 62% in the study by Obert et al. [10] with an average follow-up of 16 years. These ossifications were usually found around the resection edge in cases that did not have the space filled after radial head resection. However, these results did not impair the range of motion of the elbow. Joint limitation occurred in five (45.4%) of 11 patients. The range of joint limitation in these patients was between 50° and 100°. The proportion of this complication is three times higher than that reported by Eren et al. [11]. This can be explained by the relatively long term of immobilization in our series, which was an average of 30 ± 6 days. Long-term immobilization has been identified as a source of stiffness [18,19]. Active mobilization immediately after removal of the radial head is currently recommended because it induces formation of a functional cervico-condylar neoarticulation [20]. Regarding elbow mobility, almost all sectors had results similar to those found in the literature, with the exception of flexion. The average value for flexion was quite low, and the difference ranged from 30° to 40°, compared to results from Eren et al. [11], Karlsson et al. [9] and Antuña et al. [17]. This can be explained by the late start of mobilization or the osteoligamentary lesions in our series, dislocations in 45.4% of the cases (five cases of 11) and a terrible triad in three cases. In addition, the other studies had a longer rehabilitation period than ours, which may improve final results. Therefore, the functional score of the MEPI in our study was quite low, on aver-

![Fig. 5. The profile X-ray of case 2. (A) Posttraumatic. (B) Postoperative. (C) Heretopic ossifications at 19 months limiting flexion.](image)

![Fig. 6. Elbow function according to the Mayo Elbow Perfromance Index.](image)
age 10 points lower than those of similar studies. However, this score of 83.2 points out of 100 ranked the patients in our series at an overall function level of 81%. This level of function is judged to be good according to this assessment tool whose precision and reliability are internationally recognized [21]. The majority of patients was able to resume their professional activities without difficulty. This study had some limitations. First, due to the limited amount of follow-up and relatively small number of patients, the results cannot be generalized to a larger population. On the other hand, a relatively short-term follow-up in the reevaluation did not allow us an overview of the long-term functionality. Finally, that the patients were operated on by several surgeons, and that some had additional osteoligamentary lesions, may have produced selection bias.

Despite the fairly limited size of this series, resection of the radial head for a fracture that cannot be operated on by internal fixation was associated with rather satisfactory results, with moderate loss of mobility. Notwithstanding mild clinical signs of instability, residual elbow pain and disability were mild. These results suggest that radial head resection remains a useful surgical procedure for irreparable radial head fractures.

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REFERENCES

Comparison between minimally invasive plate osteosynthesis and the deltopectoral approach with allogenous fibular bone graft in proximal humeral fractures

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Background: The purpose of this study was to investigate the clinical differences between open reduction and plate fixation via a deltopectoral approach with allogenous fibular bone graft and a minimally invasive plate osteosynthesis (MIPO), in Neer's classification two-, three-part proximal humeral fractures.

Methods: In this retrospective study, 77 patients with two-, three-part proximal humeral fractures were treated at two different institutions. Clinical and radiological evaluations were performed in 39 patients, who underwent MIPO at one institution (group A), and 38 patients, who underwent a deltopectoral approach with allo-fibular bone graft (group B) at another institution. The results between the groups were compared.

Results: The MIPO technique was significantly less time consuming and caused less bleeding than the deltopectoral approach with allo-fibular bone graft (P<0.05). The duration of the fracture union was significantly reduced in group A (14.5±3.4; range, 10–22 weeks) compared to group B (16.4±4.3; range, 12–28) weeks (P<0.05). There were no statistically significant differences between the two groups when evaluating the visual analog scale and Constant scores between the two groups, 1 year postoperatively. In radiological evaluation, there was no difference in radiological outcomes between the two groups. There were no statistically significant differences in malunion between the two groups.

Conclusions: The MIPO technique and deltopectoral approach with allo-fibular bone graft for two-, three-part proximal humeral fractures, show similar clinical and radiological results. However, allogenous fibular grafts require longer surgery, cause more bleeding, and result in longer fracture healing time than MIPO technique.

Keywords: Proximal humeral fractures; MIPO; Delto-pectoral approach; Fibular allograft

INTRODUCTION

Proximal humeral fractures are relatively common fractures, accounting for about 5% of all fractures and are more frequent in older osteoporosis patients [1]. In most cases without severe displacement, good outcomes can be achieved through non-surgical...
treatment [2]. However, in cases in which bone fragments have large displacement or angulation, surgical treatment is required to restore normal shoulder function [3]. Surgical treatment methods include plate fixation, intramedullary nailing, and replacement arthroplasty; however, internal fixation with a locking plate is the most commonly used treatment method [4]. Patients with severe comminuted fractures or osteoporosis are more likely to develop complications such as fixation failure, interposition, and angulation during normal plate fixation. These complications often lead to poor clinical outcomes. Recently, allogenous fibular bone graft with relatively high bone strength and similar size to the inner diameter of the proximal humerus has been used to prevent these problems. Furthermore, recent studies have shown that in cases of severe comminuted fractures, superior clinical results were achieved using the graft method [5-7].

The deltopectoral approach was previously used for plate fixation in proximal humeral fractures. However, this approach requires a large incision range and considerable dissection of the soft tissue to secure the field of view of the lateral part of the humerus [8]. In order to address these drawbacks, plate fixation with minimally invasive plate osteosynthesis (MIPO) can shorten the surgery time and minimize bleeding and soft tissue injury, leading to superior fracture healing compared to the conventional deltopectoral approach [8,9]. In some studies, fixation with MIPO has demonstrated superior clinical outcomes compared to open reduction [8,10]. However, due to the limited visibility during surgery, especially in Neer classification three-, four-part with severe displacement, skillful operation is required for proper reduction. Due to the limited approach, performance of bone grafts including allogenous fibular bone grafts is difficult, especially when there is no greater tuberosity fracture or the extent of displacement is not severe [11].

Both allogenous fibular bone graft and MIPO have been introduced to minimize the problems of fixation failure, displacement, angulation, and nonunion after plate fixation of proximal humeral fractures. However, there have been no studies investigating the differences between the clinical results of these two treatment methods. The aim of this study was to investigate the clinical differences between plate fixation via the deltopectoral approach with allogenous fibular bone graft and MIPO without bone graft in proximal humeral fractures.

METHODS

Patient Selection
This study is a retrospective analysis of the medical records of patients diagnosed with proximal humeral fractures who underwent internal fixation with locking plates by the same shoulder surgeon with similar clinical experiences in two different medical institutions from January 2014 to December 2016. Patients over 19 years old with two-, three-part proximal humeral fracture who underwent surgical treatment were included. Patients under 19 years of age, with associated clavicle or scapula fractures, neurologic injuries such as brachial plexus injury, periprosthetic fracture, and those without at least 1 year of follow-up were excluded from the study. One surgeon performed locking plate fixation using MIPO in all patients with Neer classification two-, three-part fractures except for cases of greater tuberosity fractures alone. The other surgeon at another institution performed locking plate fixation and allogenous fibular bone graft via the deltopectoral approach in all two-, three-part fracture patients. Cases of four-part fractures were excluded from the analysis because MIPO was not performed in any. A total of 77 patients met the inclusion criteria. Clinical and radiological results were analyzed and compared for 39 patients who underwent MIPO (group A) and 38 patients who underwent allogenous fibular bone graft (group B).

Operative Technique
All patients underwent surgery in the beach chair position and the surgery was performed using image amplification equipment (C-arm) monitoring the status of reduction. Surgeries for both groups utilized the same locking plate type (PHILOS; Synthes, Paoli, PA, USA).

For MIPO, a 3-cm skin incision was made from the anterolateral side of the acromion to the distal part. The anterior raphe of the deltoid was detached and a finger was placed to feel the axillary nerve under the deltoid of the distal incision line. This was lifted to protect the nerve. Under the deltoid on the lateral side of the periosteum, blunt dissection was performed to create space to insert the plate. Greater tuberosity fracture with displacement cases were reduced while monitoring with image amplification equipment and fixed with two Kirschner wires. Upon securing enough space to place the plate under the deltoid and along the humeral surface, the axillary nerve was lifted and protected using a finger and the plate was inserted into the space. While monitoring using image amplification equipment, the plate was placed at an estimated height of 5 mm distal to the greater tuberosity. With an oblong-shaped hole in the distal plate as a reference, an approximate 3-cm incision was made in the distal part. Intra-muscular dissection was performed to expose the distal plate. For indirect reduction, a pin was inserted into the anterior humeral head, and the reduction was performed using the joystick method. Alternatively, a conventional screw was inserted in the ob-
long-shaped hole in the distal plate for indirect humeral head reduction. After investigating the state of reduction with the image amplification equipment, the humeral head was fixed by six locking screws from the proximal plate to the third row. The arm was used to secure adequate visualization of the distal plate, and the remaining locking screws were inserted to complete the procedure. Since the medial inferior screws of the fourth row of the plate were placed near the axillary nerve, these were not inserted in all patients (Fig. 1).

In the allogenous fibular bone graft group, the deltopectoral approach was performed in all patients. Commencing at the coracoid process end, an ~10 cm incision was made in the lateral inferior direction toward the deltoid attachment. The subcutaneous tissue was dissected with the cephalic vein placed to the lateral side, and a blunt dissection was performed between the deltoid and the pectoralis major muscle. The fractured proximal humerus was exposed by dissection of the attachment site under the deltoid and removal of the bursa tissue. After the allogenous fibula bone was trimmed to enter the humerus inner diameter, the fracture site was opened to secure a space. The allogenous fibula bone was inserted while monitoring with the image amplification equipment, resulting in indirect reduction of the humerus fracture site by allogenous fibula bone. In cases with greater tuberosity fractures, a few threads were passed through the sub-praspinatus tendon and infraspinatus tendon, applying traction to the fragments for reduction; temporary fixation was performed using K-wires. Complete reduction state of the fracture site was confirmed with the image amplification equipment, and the plate was secured by fixing the screw to complete the surgery (Fig. 2).

All patients were immobilized for 3 to 6 weeks using a sling after surgery. After pain was mitigated, the patients began passive exercise and assisted active exercise on a set schedule. Muscle strength exercise was performed after fracture union.

**Clinical and Radiological Assessments**

For clinical evaluation, the amount of bleeding during surgery was measured by referring to the medical record prepared by the anesthesiologist, and the surgery time was defined as the time from the first skin incision to completed suture. The visual analog scale (VAS) and Constant score were measured 1 year after surgery for functional evaluation. After the surgery, all patients were treated as outpatients, visiting the hospital on a regular basis. The anteroposterior (AP) X-ray and axillary X-ray images were examined to determine the reduction and maintenance status of the fracture site, the extent of fracture healing, and the occurrence of complications such as the avascular necrosis of the humeral head. Fracture union was defined as the presence of at

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**Fig. 1.** A 50-year old man with comminuted proximal humeral fracture who was treated with minimally invasive plate osteosynthesis technique. (A) Preoperative anteroposterior radiography. (B) Preoperative three-dimensional computed tomography scan. (C) Intraoperative gross photo. (D) Postoperative anteroposterior radiography. (E) Final scar from surgery.
least three bridging calluses observed in the AP and axillary X-ray images. For radiological evaluation, neck-shaft angle was measured on the final follow-up AP images (Fig. 3A) [12]. Malunion was defined as a neck-shaft angle less than 120° on postoperative radiographs during the follow-up period [11]. Plate height was measured as the distance from the lateral edge of the humeral greater tuberosity to the upper end of the plate in the final follow-up AP image (Fig. 3B).

RESULTS

The group that underwent plate fixation using MIPO (group A) consisted of 39 patients; and 38 patients were in group B, the group that underwent plate fixation using the deltopectoral approach with allogenous fibular bone graft. Group A had 20 cases of Neer classification two-part fractures (51.3%) and 19 cases of three-part fractures (48.7%); group B had 24 cases of two-part fractures (63.2%) and 14 cases of three-part fractures (36.8%). There were no statistical differences in the basic characteristics between the two groups prior to surgery (Table 1).

The surgery time was significantly shorter in group A (73.4 ± 17.9 minutes) than in group B (146.2 ± 53.7 minutes) patients (P < 0.001).

Intraoperative bleeding was also significantly lower in group A (86.2 ± 65.4 mL) than in group B (279.6 ± 189.2 mL; P < 0.001). There was no statistically significant difference between the two groups in the evaluation of clinical function by VAS score and Constant score at the 1-year postoperative follow-up (Table 2).

Postoperative radiological evaluation showed fracture union in both groups, and no nonunion was observed. The mean time for fracture union after surgery was 14.5 ± 3.4 weeks (range, 10–22 weeks) in group A patients and 16.4 ± 4.3 weeks (range, 12–28 weeks) in group B patients. Fracture union time was statistically significantly shorter for the group A patients (P = 0.032). The neck-shaft angle measured on the AP X-ray images after surgery was 130.4° ± 6.5° (range, 117.8°–141.1°) in group A and 132.9° ± 8.7° (range, 112.7°–155.1°) in group B, indicating no difference between the two groups. The plate height was 8.1 ± 2.1 mm (range, 3.6–13.4 mm) in group A and 8.8 ± 3.3 mm (range, 3.0–15.1 mm).

Table 1. Patient demographics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A (n = 39)</th>
<th>Group B (n = 38)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>68.1 ± 12.7</td>
<td>69.8 ± 14.5</td>
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</tr>
<tr>
<td>Sex (male:female)</td>
<td>7:32</td>
<td>5:33</td>
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</tr>
<tr>
<td>Preoperative BMD, T score</td>
<td>−2.92 ± 0.83</td>
<td>−2.86 ± 0.91</td>
<td>0.754</td>
</tr>
<tr>
<td>Neer classification* (2:3)</td>
<td>20:19</td>
<td>24:14</td>
<td>0.292</td>
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<tr>
<td>Follow-up period (mo)</td>
<td>15.9 ± 5.6</td>
<td>17.2 ± 6.4</td>
<td>0.348</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation. Group A: minimally invasive plate osteosynthesis, Group B: deltopectoral approach with allogenous fibular bone graft.

BMD: bone mineral density.

*Neer classification: proximal humeral fractures classification based on the number of displaced parts, two-part and three-part fractures.

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139

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DISCUSSION

There have been a number of comparative studies on the clinical and radiological outcomes of different approaches in the surgical treatment of proximal humeral fractures [8,13-18]. Conventionally, the deltopectoral approach is the most commonly used approach for the proximal humerus. This approach is performed in the anterior direction but has the disadvantage of difficulty in maneuvering the fragments in the greater tuberosity area. Also, since the plate is positioned on the lateral side of the humerus, visibility is limited [11]. An extended anterolateral deltoit-splitting approach can be performed; however, there is a possibility of axillary nerve injury with this approach [19]. Hepp et al. [13] reported that this approach had better clinical outcomes compared to the deltopectoral approach due to the deltoid injury occurring in the operation process. In comparison to the deltopectoral approach, MIPO has been introduced and widely used because this method minimizes deltoid injury [20] and facilitates the placement of the plate. This method also ensures biological healing without compromising the blood flow at the periosteum [21]. There have been various reports on differences in clinical and radiological results between the MIPO and deltopectoral approaches. In particular, the recent meta-analysis by Li et al. [17] showed that MIPO had better outcomes than open reduction in terms of bleeding during surgery, operation time, postoperative pain, time taken for bone union, and functional score. However, this method required a longer radiation exposure time during the surgery and had a higher incidence of axillary nerve injury. Sohn et al. [15] reported no significant differences in the clinical and radiological evaluation of the two approaches in prospective studies, but MIPO was significantly less time-consuming. This can be advantageous in the treatment of polytrauma patients. In this study, allogenous fibular bone graft, which is not a simple open reduction, was performed in all patients; as a result, similar to previous findings, MIPO involved less bleeding during surgery and less surgical time. This was significantly different compared to the allogenous fibular bone graft group. Additionally, the time required for the fracture healing was less in the MIPO because, in order to perform allogenous fibular bone graft, spreading the fracture site for space is necessary. With MIPO, however, periosteum is kept intact. This is advantageous in terms of fracture healing. In this study, no axillary nerve injury was found among the patients who underwent MIPO. Axillary nerve injury can be prevented during the surgery by prior palpation of the area in which the axillary nerve passes under the deltoid and protecting the nerve using a finger. The nerve is also protected by performing blunt dissection using Cobb retractor, by use of the opposite finger when inserting a plate, and by inserting the plate with deltoid lifted.

Attempts have been made in order to prevent problems such as cutout or loosening of the screw or varus malalignment that may occur after the plate fixation procedure in patients with severe osteoporosis or comminuted fracture. One method used has been the intramedullary allogenic bone graft [22-24]. In addition, several studies compared clinical and radiological results with and without allogenous bone graft in patients who underwent open reduction using the same locking plate. Cha et al. [25] reported that, in radiological evaluation in the postoperative follow-up, allogenous bone graft maintained the reduction better. Furthermore, Cui et al. [26] also recently reported that in terms of clinical results, the allogenous bone graft group had better outcomes. In this study, however, there was no difference in clinical and radiological results between the patients who underwent...
plate fixation through MIPO and those who underwent allogeneous fibular bone graft in open reduction in the final postoperative follow-up. There was also no difference in the number of malunion occurrences.

Considering that the bone densities measured in the two groups were similar and that the fracture patterns of the two groups evaluated by Neer classification were also similar, the findings indicate that the neck-shaft angle is maintained after surgery to the same extent as providing sufficient medial support with a bone graft although there was no medial calcar screw insertion in the MIPO. In the case of MIPO with accompanying medial comminution, the immobilization period was longer than that of other patients and rehabilitation was performed slowly. The results indicate that with the open reduction, excess intervention on the fracture site is inevitable during the allogenous fibula bone graft process through open reduction, which certainly causes injury to the periosteum and in the soft tissue. Such intervention of the fracture site can be minimized in the simple MIPO, and, barring the presence of a severe comminuted fracture, sufficient support of the fracture site can be provided.

Neer classification four-part fractures were not included in this study. In the case of four-part fractures, difficulty arises in precise reduction of the fracture site through MIPO. In particular, there are cases when allogeneous fibular bone graft is needed, such as severe comminuted fracture of the medial cortical bone, but treatment by MIPO has limitations. Recently, Noh et al. [27] reported that allogeneous fibular bone grafts with MIPO for three-, four-part fractures showed good clinical results. Sohn and Shin [11] examined the difference in clinical and radiological results according to the type of fracture in the group of patients with proximal humeral fractures who underwent MIPO. This group reported that difficult arises in achieving good outcomes with MIPO in four-part fractures. Although not included in this study, the authors attempted MIPO in the case of a four-part fracture; but sufficient reduction was not possible, so the surgery proceeded with an extended anterolateral deltoid-splitting approach. The most important aspect in the internal fixation of fractures is the sufficient anatomical reduction of the fracture site rather than the surgical approach. Therefore, the flexibility is required in choosing MIPO or open reduction for sufficient reduction of the fracture site.

In this study, the two surgeons performed surgical treatment on the same group of patients only with their respective preferred surgical method. One surgeon performed the surgery with a belief that MIPO alone could provide sufficient fixation for two- and three-part fractures. Another surgeon preferred open reduction using allogenous fibular bone graft in all patients with two- or three-part fracture to facilitate reduction. This allowed for support of the medial cortex of inserted bone by use of an intramedullary nail. Furthermore, the two medical institutions are adjacent to each other, and the patient groups are similar. The two surgeons have similar clinical and surgical experiences, and the general characteristics of the two patient groups did not differ. Under these conditions, we believe that this study was suitable to compare between the two surgical methods.

Based on the results of this study, performing allogenous fibular bone graft in two- or three-part fractures does not seem to have a significant advantage over performing MIPO alone. Rather, allogenous fibular bone grafting caused longer surgery times, increased bleeding, and prolonged fracture healing. In particular, considering the additional cost from the use of allogeneic bone and risk of complications such as infection, we believe that the concurrent allogenous fibular bone graft does not have advantages for general use. Kim et al. [28] also reported that the performance of allogenous fibular bone graft did not significantly affect the clinical outcomes in three-part fractures.

This study had some limitations. First, the population size was relatively small. Also, this was a retrospective study, and different surgeries were performed by two different surgeons in two medical institutions. Although both practitioners are shoulder surgeons with similar clinical experience, ruling out the possibility of subjective intervention by the practitioner in terms of classifying fractures and determining the need for surgical method is difficult. However, considering that the surgery was performed using the same instrument and there were no complications such as malunion after surgery, we believe that the difference between the surgeons did not have a significant impact on the results. The importance of this study is that this is the first study to compare the differences between plate fixation through MIPO and allogenous fibular bone graft through open reduction.

The MIPO and allogenous fibular bone graft through open reduction showed similar clinical and radiological results in the fixation using locking plate in Neer classification two- or three-part proximal humeral fractures. However, allogenous fibular bone grafts required longer surgical time, caused more bleeding, and required a longer time for fracture healing compared to MIPO. Hence, careful consideration is required when selecting the fixation method according to fracture comminution.

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Seong-Hun Kim https://orcid.org/0000-0003-1831-7930
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Magnetic resonance imaging analysis of rotator cuff tear after shoulder dislocation in a patient older than 40 years

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Background: This study was designed to evaluate characters of the rotator cuff tear (RCT) recognized after primary shoulder dislocation in patients older than 40.

Methods: From 2008 to 2019, patients who visited two hospitals after dislocation were retrospectively reviewed. Inclusion criteria were patients over 40 who had dislocation, with magnetic resonance imaging (MRI) undergone. Exclusion criteria were patients who lost to follow-up, combined with any proximal humerus fracture, brachial plexus injury, and previous operation or dislocation history in the ipsilateral shoulder. Also patients who had only bankart or bony bankart lesion in MRI were excluded. We evaluated RCTs that were recognized by MRI after the primary shoulder dislocation with regard to tear size, degree, involved tendons, fatty degeneration, the age when the first dislocation occurred, and the duration until the MRI was evaluated after the dislocation.

Results: Fifty-five RCTs were included. According to age groups, the tear size was increased in coronal and sagittal direction, the number of involved tendons was increased, and the degree of fatty degeneration was advanced in infraspinatus muscle. Thirty-two cases (58.2%) conducted MRI after 3 weeks from the first shoulder dislocation event. This group showed that the retraction size of the coronal plane was increased significantly and the fatty accumulation of the supraspinatus muscle had progressed significantly.

Conclusions: Age is also a strong factor to affect the feature of RCT after the shoulder dislocation in patients over 40. And the delay of the MRI may deteriorate the degree of tear size and fatty degeneration.

Keywords: Dislocation; Magnetic resonance imaging; Rotator cuff; Fatty degeneration; Prognosis

INTRODUCTION

The prevalence of traumatic anterior shoulder dislocation in the elderly has increased due to recent changes in lifestyle and life expectancy [1]. Recurrent instability is the main problem after shoulder dislocation in young patients, while rotator cuff tear is more common in the elderly [2,3]. However, immediate diagnosis of pathology is very difficult because most patients visit and present via the emergency room and may not undergo further evaluation. Revisiting the clinic after reduction is relatively un-
common especially for elderly patients, and it is currently debated whether magnetic resonance imaging (MRI) should be performed within a short time period after the first dislocation [2,4-6].

It is unclear whether shoulder dislocation triggers rotator cuff tear or whether an asymptomatic, pre-existing rotator cuff tear induces imbalanced shoulder movement, resulting in shoulder dislocation with minor trauma [7,8]. In older patients, it is difficult to distinguish the acute and chronic features of rotator cuff tear that are recognized after primary shoulder dislocation. It is also uncertain whether delay of the diagnosis contributes to adverse outcomes and prognosis [4,5,9,10]. MRI is regarded as the most accurate diagnostic modality to detect rotator cuff tear and for estimating tear degree and tissue quality [6,11,12].

About 60% of nontraumatic rotator cuff tears remain asymptomatic for years [13-15], while most cases develop the first symptoms after significant trauma. One study reported significantly higher prevalence of rotator cuff tear after trauma compared to a control group without trauma [16]. Thus, it must be determined whether shoulder dislocation truly causes rotator cuff tear or if patients with an asymptomatic rotator cuff tear are exacerbated by a single dislocation event [9,17]. Although some studies suggest a number of symptoms to distinguish between solely traumatic and purely degenerative rotator cuff tear, such as patient medical history, physical examination, and imaging modalities [18,19], these factors are insufficient for complete differentiation and lack evidence-based data. This study was designed to evaluate characteristics of rotator cuff tear using MRI to recognize incidents after primary shoulder dislocation in patients older than 40 years.

**METHODS**

Seventy-four patients older than 40 years who presented for treatment of traumatic anterior dislocation of the shoulder from 2008 to 2019 were retrospectively reviewed. Of these patients, three were lost to follow-up. Eight patients with proximal humerus fracture, brachial plexus injury, previous shoulder operation, or dislocation history in the ipsilateral shoulder were excluded. Another eight patients were excluded because they had only Bankart or bony Bankart lesion on MRI. Therefore, a total of 55 patients was enrolled in this study.

Demographic data were obtained through chart review. All rotator cuff tears were confirmed by MRI after the dislocation event. MRI was performed at two imaging centers using a 1.5- or 3.0-T imaging unit (Sigma; GE Medical Systems, Milwaukee, WI, USA) equipped with a dedicated shoulder coil. A standardized imaging protocol was used according to hospital parameters, but two of the protocols did not align. The following MRI sequences were included for review: fat-suppressed T1-weighted fast spin echo sequences in the axial and oblique coronal planes parallel to the long axis of the supraspinatus tendon and the oblique sagittal plane perpendicular to the long axis of the supraspinatus tendon. Images were acquired with a slice thickness of 3 mm and an interslice gap with a 1 mm field of view of 16×16 cm. Images were interpreted using a standard picture archiving and communication system (PACS) workstation (Centricity, GE Medical Systems). All MRI findings were interpreted by two board-certified orthopedic surgeons (JHK, YMN) who confirmed the degree of fatty infiltration and tear size. Two weeks later, the procedure was repeated for validation (Table 1).

A tear was defined as a discontinuity of tendon fibers with the gap showing a high T2 signal [20-22]. A full-thickness tear was defined as a high signal extending through the depth of the tendon. The tear was measured in two planes (anterior to posterior [AP] and medial to lateral [ML]) on the full-thickness supraspinatus or infraspinatus muscle.

Fatty infiltration was graded on a scale from 0 to 4 as a modification of the classification of Goutallier et al. [23]. It was adapted to MRI: grade 0 means no fatty deposits; grade 1, some fatty streaks; grade 2, more muscle than fat; grade 3, fat equal to muscle; and grade 4, more fat than muscle.

To evaluate the effect of delayed MRI after the first injury event, we divided patients into two groups based on time from injury to MRI evaluation. The first group (group I) waited less than 3 weeks after dislocation, while group II was evaluated more than 3 weeks after dislocation. Three weeks was used as the cutoff based on previous clinical reports [4,24].

Comparative statistics were performed using Student t-test, chi-square test, or Fisher’s exact test (IBM SPSS ver. 19; IBM

**Table 1. Overall patient data**

<table>
<thead>
<tr>
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<th>Value</th>
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<tbody>
<tr>
<td>Number</td>
<td>55</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>61.2 ± 11.5 (40–82)</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>34:21</td>
</tr>
<tr>
<td>Follow-up period (mo)</td>
<td>48.7 ± 36.6 (12–115)</td>
</tr>
<tr>
<td>Duration (wk)</td>
<td>17.1 ± 21.4 (1–96)</td>
</tr>
<tr>
<td>Fatty degeneration grade</td>
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</tr>
<tr>
<td>Supraspinatus muscle</td>
<td>1.71 ± 1.12</td>
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<tr>
<td>Infraspinatus muscle</td>
<td>1.33 ± 1.11</td>
</tr>
<tr>
<td>Subscapularis muscle</td>
<td>1.04 ± 0.83</td>
</tr>
<tr>
<td>Teres minor muscle</td>
<td>0.20 ± 0.48</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation (range) or mean ± standard deviation.
The level of significance was set at $P < 0.05$. Data are presented as mean ± standard deviation.

**RESULTS**

Fifty-five rotator cuff tears were recognized on MRI after the first anterior dislocation of the shoulder. The average follow-up period was $48.7 ± 38.6$ months (range, 12–115 months). The age of the patients at the time of primary shoulder dislocation was $61.2 ± 11.5$ years (range, 40–82 years). There were 21 women with a mean age of $64.5 ± 10.2$ years and 34 men with a mean age of $59.2 ± 10.9$ years. The mean duration between primary shoulder dislocation and MRI evaluation was $17.1 ± 21.4$ weeks (range, 1–96 weeks). The mean degree of fatty degeneration was 1.71 in the supraspinatus muscle, 1.33 in the infraspinatus muscle, 1.04 in the subscapularis muscle, and 0.20 in the teres minor muscle (Table 1).

Of the 55 shoulders, 26 (47.3%) had isolated rotator cuff tear (R group) and 29 (52.7%) had combined Bankart lesion with rotator cuff tear (B+R group). The mean age was $69.12 ± 8.84$ years in the R group and $61.14 ± 10.52$ years in the B+R group, a significant difference. The mean tear size in the sagittal and coronal planes in the R group was $31.12 ± 8.57$ mm and $30.81 ± 8.60$ mm, respectively. The R group had significantly longer tear size in both directions compared with the B+R group ($16.61 ± 12.80$ mm and $16.93 ± 12.32$ mm, respectively). The number of cases in the R group with more than two injured tendons was 26 (100%) and the number of cases that involved a long head of the biceps tendon lesion was 22 (84.6%). The degree of fatty degeneration of the rotator cuff was significantly different between the two groups, with exception of the teres minor muscle (Fig. 1). These findings are summarized in (Table 2).

Age and tear size in both directions were positively correlated (Pearson’s correlation coefficient 0.476 in the AP direction and 0.452 in the ML direction) (Fig. 2). The older age group showed significant increase in tear size, number of injured tendons, and long head biceps tendon lesions (Table 3). Interestingly, degree of fatty degeneration is advanced with age only in the infraspinatus muscle (Fig. 3).

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**Table 2.** Comparison of age, tear size, number of injured tendons, and accompanying injuries between two groups

<table>
<thead>
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<th>Variable</th>
<th>B+R group</th>
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<td>Number</td>
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<tr>
<td>Age (yr)</td>
<td>$61.12 ± 10.52$</td>
<td>$69.12 ± 8.84$</td>
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<tr>
<td>Tear size (mm)</td>
<td></td>
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<tr>
<td>AP</td>
<td>$16.61 ± 12.80$</td>
<td>$31.12 ± 8.57$</td>
<td>$0.000$</td>
</tr>
<tr>
<td>ML</td>
<td>$16.93 ± 12.32$</td>
<td>$30.81 ± 8.60$</td>
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</tr>
<tr>
<td>No. of injured tendons</td>
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<td></td>
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</tr>
<tr>
<td>1 (SS)</td>
<td>8</td>
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<tr>
<td>≥ 2 (SS+IS)</td>
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</table>

Values are presented as number (%) or mean ± standard deviation. B+R group: rotator cuff tear combined with labral tear group, R group: rotator cuff tear group. AP: anterior to posterior, ML: medial to lateral, SS: supraspinatus, IS: infraspinatus, LHB'T: long head of the biceps tendon.

---

**Fig. 1.** Distribution of degree of fatty degeneration of the supraspinatus muscle (A), infraspinatus muscle (B), and subscapularis muscle (C) between the B+R and R groups. The results indicate significant differences for these muscles. B+R group: rotator cuff tear combined with labral tear group, R group: rotator cuff tear group. Grade (Gr): 0: no fatty deposits, Gr1: some fatty streaks, Gr2: more muscle than fat, Gr3: fat equal to muscle.
Fig. 2. Distribution of tear size from anterior to posterior direction (A) and medial to posterior direction (B) as age increases. Both directions showed positive correlation.

Table 3. Comparison of tear size, number of injured tendons, and accompanying injuries according to age group

<table>
<thead>
<tr>
<th>Variable</th>
<th>40–49 yr</th>
<th>50–59 yr</th>
<th>60–69 yr</th>
<th>≥ 70 yr</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>9 (16.4)</td>
<td>15 (27.3)</td>
<td>17 (30.9)</td>
<td>14 (25.4)</td>
<td></td>
</tr>
<tr>
<td>Tear size (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>10.30 ± 9.16</td>
<td>20.40 ± 13.08</td>
<td>28.41 ± 9.91</td>
<td>29.21 ± 12.69</td>
<td>0.001</td>
</tr>
<tr>
<td>ML</td>
<td>10.78 ± 10.28</td>
<td>21.93 ± 13.15</td>
<td>28.06 ± 8.18</td>
<td>27.79 ± 13.29</td>
<td>0.003</td>
</tr>
<tr>
<td>No. of injured tendons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.016</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>≥ 2</td>
<td>5</td>
<td>12</td>
<td>17</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Accompanying injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LHBHT lesion</td>
<td>3</td>
<td>8</td>
<td>14</td>
<td>12</td>
<td>0.019</td>
</tr>
<tr>
<td>Labral tear</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>3</td>
<td>0.001</td>
</tr>
<tr>
<td>Hill Sachs lesion</td>
<td>8</td>
<td>12</td>
<td>10</td>
<td>12</td>
<td>0.215</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean±standard deviation.
AP: anterior to posterior, ML: medial to lateral, LHBHT: long head of the biceps tendon.

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When shoulders were divided into two groups by a 3-week duration between the first dislocation event and the MRI procedure, 23 (41.8%) were evaluated within 3 weeks after injury and 32 shoulders (58.2%) were evaluated after more than 3 weeks. There was no difference between the two groups in age, number of injured tendons, or associated lesions.

However, retraction size of the coronal plane was increased and fatty accumulation of the supraspinatus muscle was more advanced in group I (less than 3 weeks) than group II (more than 3 weeks) (Table 4, Fig. 4).

DISCUSSION

In this study, we focused on rotator cuff tear recognized on MRI after a dislocation event. As age progresses, the rotator cuff weakens and is more prone to tearing [25,26]. The results of this study indicate that age is a strong factor of tear size, number of involved tendons, and fatty degeneration of the infraspinatus muscle in primary shoulder dislocation in patients older than 40 years. It is apparent that fatty degeneration and tear progression progress in the AP direction (from supraspinatus to infraspinatus) because the degree of fatty degeneration was significantly different in the infraspinatus muscle in the older age group. Because the infraspinatus muscle is the main depressor of the humeral head, dysfunction results in upward migration of the humerus with subacromial impingement and loss of strength in external rotation and elevation [27,28]. We assumed that it is paramount to recognize rapid fatty infiltration of the Infraspinatus to avoid poor outcomes after cuff repair in patients older than 40 years, particularly for those with shoulder dislocation of fatty infiltration grade 2 or higher [29].

The rotator cuff significantly contributes to the stability of the glenohumeral joint, especially in elderly patients. It is possible that the higher prevalence of pre-existing rotator cuff disease in older patients may lead to abnormal glenohumeral motion and predispose an older individual to shoulder instability with low-energy trauma [7,30]. Hsu et al. [30] showed in a cadaver model that rotator cuff tear resulted in abnormal glenohumeral translation, and that larger tears had a greater tendency for direct

### Table 4. Comparison of age, tear size, number of injured tendons, and accompanying injuries according to duration from injury to MRI

<table>
<thead>
<tr>
<th>Variable</th>
<th>Duration (wk)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>0–3</td>
<td>≥ 3</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>62.87 ± 11.61</td>
<td>60.03 ± 10.65</td>
</tr>
<tr>
<td>Tear size (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>20.52 ± 13.79</td>
<td>25.58 ± 12.42</td>
</tr>
<tr>
<td>ML</td>
<td>19.09 ± 11.62</td>
<td>26.66 ± 12.70</td>
</tr>
<tr>
<td>No. of injured tendons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>≥ 2</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>Accompanying injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LHBT lesion</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Labral tear</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Hill Sachs lesion</td>
<td>15</td>
<td>27</td>
</tr>
</tbody>
</table>

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

MRI: magnetic resonance imaging, AP: anterior to posterior, ML: medial to lateral, LHBT: long head of the biceps tendon.

Fig. 4. Distribution of fatty degeneration grade in the supraspinatus muscle (A), infraspinatus muscle (B), and subscapularis muscle (C) according to duration from injury to magnetic resonance imaging. Degree of fatty degeneration showed a significant difference in the supraspinatus muscle. Grade (Gr)0: no fatty deposits, Gr1: some fatty streaks, Gr2: more muscle than fat, Gr3: fat equal to muscle.

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anterior translation. Pouliart and Gagey [31] showed that the humeral head dislocates in the presence of less extensive capsuloligamentous lesions when rotator cuff lesions are present. Increased age, advanced fatty infiltration, and longer tear size might have weakened the posterior structures and resulted in anterior dislocation without anteroinferior labral lesion, such as Bankart lesion in the elderly. These characteristics are also shown in our results, which indicated that the rotator cuff tear group (R group) was statistically much older than the rotator cuff combined with labral tear group (B+R group). The R group cases all involved an infraspinatus tear, while infraspinatus tear involvement was present in about 72.4% of the BR group. These results suggest that shoulder dislocation without labral tear is strongly related with infraspinatus tear in elderly patients and is referred to as the posterior shoulder dislocation mechanism [7,30,31]. In our results, fatty degeneration of the subscapularis was not statistically different according to age or between the R and B+R groups.

Delayed diagnosis of rotator cuff tear after dislocation may decrease the recovery potential. Previous studies [4,24] reported that patients who experienced acute injury with severe compromise of shoulder function that could be due to the rotator cuff tear should be diagnosed using further evaluations, and that surgical repair of rotator cuff tear should be performed within 3 weeks of injury to achieve the best surgical results. Failure to meet the conservative 3-week treatment window after primary dislocation in older patients and persistence of significant pain or weakness are indications for further investigation [32,33]. Another study showed that infraspinatus fatty infiltration increased significantly when multiple tendons were torn, and that surgical repair should be performed before stage 2 fatty infiltration in older patients [34].

We hypothesized that rotator cuff tear identified by MRI after 3 weeks from dislocation may have features different from those of tear identified earlier. Based on our results, coronal tear size and degree of fatty infiltration in the supraspinatus muscle were increased significantly in the group with more than 3 weeks before intervention (Table 4, Fig. 4). These results suggest that shoulder dislocation may worsen the course of degeneration even in the early period of post-dislocation in elderly patients. These results also provide a theoretical background for understanding why rapid rotator cuff repair might be considered in acute shoulder dislocation due to the tendency of rapid fatty progression in elderly patients. Previous studies have reported inferior clinical results after delayed treatment of traumatic rotator cuff tear, which is likely due to loss of elasticity in tendons and the significantly increased tension of the repair. Increased tension is related to decreased viscoelastic properties of the tendons and poor rotator cuff healing [24,35]. In a rat model, supraspinatus tendon detachment resulted in rapid loss of muscle mass by 1 week after injury [36,37]. In biomechanical studies, tension at the repaired tendon progressively increased with time from injury because of increase in retraction of the musculotendinous unit and in stiffness of the muscle and tendon [38,39]. Unfortunately, we could not evaluate clinical outcomes according to duration and so assumed that delayed diagnosis and treatment may have adverse effects on clinical outcomes based on our results and previous studies.

This study had several limitations; in particular, the relatively small number of cases and their retrospective enrollment. This study could not distinguish between acute lesion and chronic lesion of the rotator cuff, and there were no clinical outcomes to evaluate function, satisfaction, or additional dislocation in patients because of difficulty with long-term follow-up. We also did not have a uniform MRI protocol because the MRI studies were conducted at different institutions and during different timeframes from 2008 to 2019. However, we do not believe that such differences compromised our ability to analyze fatty infiltration.

We concluded that tear size of the rotator cuff and fatty infiltration of the infraspinatus muscle are positively correlated with age in primary shoulder dislocation in patients older than 40 years. Combined Bankart lesion is more frequently observed in younger patients. Tear size (ML) of the rotator cuff and fatty infiltration of the supraspinatus may advance faster after dislocation in this age group, and careful attention, diagnosis, and follow-up are important for optimizing patient outcomes.

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Intramedullary fibula strut bone allograft in a periprosthetic humeral shaft fracture with implant loosening after total elbow arthroplasty

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¹Department of Orthopedic Surgery, Hanyang University Guri Hospital, Guri, Korea
²Department of Orthopedic Surgery, Hanyang University College of Medicine, Seoul, Korea

Periprosthetic fracture after total elbow replacement surgery is a difficult complication to manage, especially when it comes together with implant loosening. If stem revision and internal fixation of the periprosthetic fracture are performed simultaneously, this would be a very challenging procedure. Most of total elbow replacement implants are cemented type. Cement usage at periprosthetic fracture site may interfere healing of fractured site. Authors underwent internal fixation with use of locking plate and cerclage wire for periprosthetic fracture, allogenous fibular strut bone inserted into the humerus intramedullary canal allowing the fractured site to be more stable without cement usage. At 10-month follow-up, the complete union and good clinical outcome was achieved. We present a novel technique for treating periprosthetic fracture with implant loosening after total elbow replacement surgery, using intramedullary allogenous fibula strut bone graft.

Keywords: Elbow; Periprosthetic fracture; Arthroplasty

Total elbow replacement was used first in treatment of rheumatoid arthritis patients in 1970 [1]. Development of implants and better surgical techniques have led to widespread use of this method in various elbow diseases, such as osteoarthritis, post-traumatic arthritis, severe comminuted fracture with bone loss, chronic instability, and tumors [2,3]. However, total elbow replacement can cause various complications, such as aseptic loosening, infection, and periprosthetic fractures, during long-term follow-up. To address these issues, revision surgery has been reported [4].

Periprosthetic fracture is widely recognized as a complication of total hip or knee replacement but may also occur following total elbow replacement [5]; the incidence has been reported to range from 5% to 29% [6,7]. Periprosthetic fractures after total elbow replacement are classified according to location, degree of bone loss around the implant, and presence of implant loosening [6]. If the periprosthetic fracture is accompanied by implant loosening, complex techniques such as revision surgery and bone grafting for bone defects are often required in addition to internal fixation. Due to the high rate of complications after surgery with this procedure, it is vital to have an appropriate preoperative surgical plan.

Sanchez-Sotelo et al. [5] reported 11 cases of total elbow replacement with allograft strut bone augmentation and cement
fixation that required revision for periprosthetic fracture following total elbow replacement caused by implant loosening. However, six of these 11 cases had poor prognosis with one or more complications, and technical difficulties were reported. If internal fixation and bone graft are performed after fixing the implant with cement, circulation at the fracture site may be compromised by the cement, which will likely delay bone union. In addition, it is also difficult to perform simultaneous internal fixation and bone grafting.

This report introduces a novel surgical technique using an allogenous fibula strut bone graft inserted into the intramedullary canal to improve stability without cement to treat periprosthetic fracture around the humeral stem after total elbow arthroplasty.

TECHNIQUE

The patient was a 65-year-old woman who had been diagnosed with rheumatoid arthritis 10 years prior. She had recently undergone total elbow replacement surgery using a Coonrad-Morrey (Zimmer, Warsaw, IN, USA) implant at another hospital after sustaining an injury while lifting a heavy object. She had undergone regular bone mineral density testing once a year and did not need medication for osteopenia. Upon radiographic examination, a periprosthetic fracture around the humeral stem corresponding to Mayo classification type H-II was identified, and implant loosening and osteolysis were also observed (Fig. 1).

The authors performed revision of total elbow replacement using the Coonrad-Morrey implant (Zimmer). The previous operative skin incision was used along with a triceps-preserving approach. The incision was deepened to the subcutaneous tissue, and then the triceps fascia was undermined to identify the medial and lateral edges of the triceps muscle. On the medial side, the ulnar nerve was identified and confirmed to be located anteriorly. A longitudinal incision was made on the exposed triceps tendon on the radial side of the midline; care was taken to avoid the tip of the olecranon, and then the joint was exposed. To obtain an adequate view during the approach, the authors elevated the flexor carpi ulnaris and part of the pronator muscle group subperiosteally and released the triceps partially. Debridement was carried out with complete removal of all soft tissue around the humeral stem. The ulnar stem was stable with no sign of loosening, so ulnar replacement was not required. After removal of a link between a polyethylene insert and the humeral stem, thorough cement removal and irrigation of the intramedullary canal was performed to avoid influencing the revision surgery. Because the cortical bone around the fracture site was thin and the medullary canal was wide, we opted to perform revision total elbow replacement with a novel technique using an intramedullary fibula bone graft.

For the revision procedure, we used allogenous fibula strut bone (Community Tissue Services, Kettering, OH, USA). After determining the joint line and optimum size of the humeral stem, the diameter and length of the allogenous fibula strut bone were estimated according to the diameter and size of the bone defect and humeral stem. To resolve the difference in diameter between the humeral bone defect lesion and the allogenous fibula strut bone, the latter was trimmed using a high-speed burr to fit the outer diameter to better enter the humeral bone defect area. In addition, the inner diameter of the allogenous fibula

Fig. 1. Elbow anteroposterior (A) and lateral (B) radiographs, coronal (C) and sagittal (D) view of computed tomography images of total elbow arthroplasty with periprosthetic fracture. Previous fracture line are marked with arrow (A), and implant loosening areas are marked with arrowheads (A).
strut bone was enlarged using a burr to allow the humeral stem to pass (Fig. 2A). Next, it was necessary to confirm whether the allogenous fibula strut bone was located in the fracture site so that the trial stem could pass into the allogenous fibula strut bone before cementation. After closing the proximal portion of the distal fragment from the fracture site using a gauge, we inserted the cement compactly from the distal portion and placed the humeral stem from the distal end. At this time, the cement at the fracture site was removed, and the allogenous fibula strut bone, which contained the humeral stem, was passed through the fracture site. The proximal part of the humeral stem was not performed infusion of bone cement which would inhibit bone union at the fracture site. The fracture site was additionally fixed using a locking plate, eight locking screws, and three cerclage wires (Fig. 2B). After confirming the appropriateness of fixation and bone graft using simple radiographs (Fig. 2C, D), the surgery was complete.

Postoperatively, the elbow was positioned in a long arm splint at a 90° flexion position for 6 weeks. Two weeks after surgery, the previous long arm splint was replaced with a removable splint, and passive elbow joint motion was performed. Active elbow joint motion was allowed beginning at six weeks after surgery. No other physical therapy or additional fixation was performed. At three months postoperatively, the range of motion (ROM) of the affected elbow was confirmed at 0°−110°, and no other complications were observed. At 10 months after surgery, bone union was confirmed on radiographs (Fig. 3A, B), and a satisfactory clinical outcome was obtained with an ROM from 0° to 150° of the affected elbow without complications (Fig. 3C, D).

---

**Fig. 2.** Allograft fibula strut bone that was manipulated with a high-speed burr (A), and clinical photograph of the operative field after fixation with a locking plate and cerclage wire (B). Anteroposterior (C) and lateral (D) radiographs after operation.

**Fig. 3.** Anteroposterior (A) and lateral (B) radiographs at postoperative 10 months. Postoperatively, fibula strut-graft incorporation and union were observed with satisfactory clinical outcome and range of motion 0° to 15° (C, D).
DISCUSSION

Periprosthetic fracture following total elbow replacement surgery is graded using the Mayo classification system according to fracture site, fixation status of the implant, and bone stock around the implant [5,6]. Different operative techniques may be required for different stages [5]. Treatment strategy can be chosen based on type of humeral shaft fracture [7]. Non-displaced periprosthetic fracture without loosening of the implant is treated with conservative treatment, including long arm splint fixation [6], whereas fracture with implant loosening should undergo revision surgery with internal fixation. Various internal fixation techniques have been reported, including allogenous strut bone graft [5], locking plate and cerclage wire, and external fixation using the Ilizarov system [7]. To manage humeral bone loss, various methods including humeral shortening, use of a longer humeral stem or bone graft around the anterior flange, use of a tumor prosthesis system, or attachment of a humeral intramedullary nail to the humeral stem followed by autogenous bone graft have been reported [8].

In this case, which was Mayo classification type H-II, implant loosening and osteolysis with periprosthetic fracture prompted revision of the humeral stem, bone graft, and internal fixation. A previously reported technique used an allogenous strut bone graft obtained from outside of the fracture site or an on-lay technique fixed with cerclage wire, which resulted in instability around the fracture site [5]. Even when additional plate fixation is used for stability, allogenous bone graft with cerclage wire may interfere with satisfactory positioning of the plate above the humeral shaft. This technique could cause the fracture site to be bulky and might produce surgical site discomfort. This approach can also give rise to complications such as nerve injury and extensor mechanism rupture [5]. Cement leakage via a fracture gap may also occur, causing cement-related complications and increasing risk of non-union.

In this case, we manipulated the allogenous fibular strut bone into a cylinder shape and inserted it into the humerus shaft in an intramedullary manner to maintain the advantage of allogenous bone graft and to reduce possible complications. This approach improved stability without bone loss or shortening and prevented or reduced cement leakage or cement-related complications because the cement was only injected into the distal area of the humeral stem. This technique also provided good positioning of the plate compared to the on-lay technique as no allogenous bone was present outside the humerus.

The most important and challenging component of this technique was shaping the allogenous fibular strut bone into the appropriate diameter to fit into the humeral intramedullary area and allowing the humeral stem to pass through the inner diameter of the fibular bone graft. Thinning the fibular bone while preserving its shape requires delicate handling and precautions, which may take up a substantial amount of time.

The authors’ case showed fracture site union, good elbow joint ROM, and pain relief at 10 months postoperatively, indicating that this novel technique can be considered as a treatment option for periprosthetic fracture with implant loosening after total elbow replacement surgery.

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REFERENCES

PHILOS plate fixation with polymethyl methacrylate cement augmentation of an osteoporotic proximal humerus fracture

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PHILOS plate fixation in osteoporotic proximal humerus fracture of old age is well-known for high complication rate, especially metal failure, providing various augmentation techniques, such as calcium phosphate cement, allogeneous or autologous bone graft. We report a case of polymethyl methacrylate augmentation to provide appropriate reduction with a significant mechanical support. This can be a treatment option for displaced unstable osteoporotic proximal humerus fracture with marked bony defect.

Keywords: PMMA cement augmentation; Osteoporotic proximal humerus fractures; PHILOS plate fixation

Proximal humerus fractures are common in the elderly, the second most common fracture in the upper extremity, and lead to high morbidity and loss of function [1,2]. The incidence of proximal humerus fractures in Finland was 82 per 100,000 person-years, and 73% of patients with proximal humerus fractures were women. The incidence increased with older age groups [3]. Another study revealed that osteoporotic bone increased the risk of proximal humerus fractures and suggested that the high incidence of proximal humerus fractures in older female patients is likely to be related to osteopenia and osteoporosis [4]. Because of the various complications after fixation of a proximal humerus fracture using a plate (e.g., osteonecrosis of the humeral head, humeral head settling with loss of neck-shaft angle, nonunion or malunion, screw penetration into the glenohumeral joint, and implant failure), there has yet to be an accepted consensus on the clear surgical indication for treatment of these fractures [5]. During surgery for a proximal humerus fracture, a surgeon sometimes encounters a metaphyseal void after reduction of impaction of the metaphysis. Several strategies exist for void filling to help structural stability, enhance healing, and minimize failure of fixation [6]. Bone cement is commonly used in orthopedic surgery due to its osteoconductive properties and resistance to compression force [7]. For example, augmentation with calcium phosphate cement in the treatment of proximal humeral fractures with locked plates increased fracture settling and significantly decreased intra-articular screw penetration in one report [6]. Herein, we present a case of polymethyl methacrylate (PMMA) cement augmentation in a failed osteoporotic proximal humerus fracture.

CASE REPORT

A 56-year-old female was sent to our emergency department af-
after a fall in which she landed on her left arm. The patient complained about left shoulder pain, swelling and ecchymosis. On palpation, tenderness was noted all around the shoulder, especially at the level of the axilla. Both neurological and vascular examinations were normal. Anteroposterior X-ray and computed tomography of the left shoulder showed a two-part surgical neck fracture of the proximal humerus (Fig. 1). A preoperative bone mineral density showed osteoporosis (T = -3.8).

Three days after the injury, an open reduction and internal fixation (ORIF) was performed with the Proximal Humerus Internal Locking System (PHILOS; DePuy Synthes, Raynham, MA, USA) plate and screws. On postoperative day (POD) 4, the patient fell down from her bed, and there was screw back-out and reduction loss at the humeral head (Fig. 2).

Thus, revisional ORIF was done on POD 7. Using the previous incision (deltopectoral approach), we removed the previous locking plate. After the revisional ORIF with a PHILOS plate and screws, including a long calcar screw, a metaphyseal defect developed. Thus, we put PMMA cement in the void area to fill the defect and provide structural stability (Fig. 3A, B). We applied an abductor brace. The postoperative X-ray showed firm fixation with the PHILOS plate and cement augmentation (Fig. 3C, D).

After 4 weeks of immobilization, the brace was removed, and the patient started exercise to increase the range of motion of the shoulder joint (forward elevation, 120°; external rotation, 60°; internal rotation, L3 level). At that time, a follow-up X-ray showed healing of the fracture without screw backout or loss of reduction. Three months after the revision operation, the patient's range of motion was within the normal range (forward elevation, 150°; external rotation, 80°; internal rotation, T8), her pain was tempered (visual analog scale score, 1), and the function of her shoulder was

![Fig. 1](https://example.com/fig1.png)

**Fig. 1.** Preoperative anteroposterior (AP) X-ray and computed tomography showing two-part surgical neck fracture with metaphyseal impaction. (A) Shoulder AP X-ray showed two-part fracture of proximal humerus. (B) Anterior view of three-dimensional computed tomography (3D CT) showed two-part fracture with varus angulation. (C) Lateral view of 3D CT showed two-part fracture.

![Fig. 2](https://example.com/fig2.png)

**Fig. 2.** Open reduction internal fixation with locking plate and screws. (A) Postoperative anteroposterior (AP) X-ray showed reduced state. (B) Metal failure was shown after fall-down on AP X-ray at postoperative day 4.

![Fig. 3](https://example.com/fig3.png)

**Fig. 3.** PolyMethyl methacrylate (PMMA) cement was inserted into the metaphyseal area to fill the void. (A) The metaphyseal void was shown. (B) The metaphyseal void was filled with PMMA cement. (C) Shoulder true anteroposterior (AP) X-ray showed PMMA cement was inserted to the metaphyseal void. (D) Open reduction and internal fixation with PMMA cement augmentation showed firm fixation on shoulder AP X-ray.

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improved (American Shoulder and Elbow Surgeons [ASES] score, 73.3; Korean Shoulder Scoring [KSS] system score, 82).

Finally, 6 months after the revision operation, the patient was pain-free with full range movement of the left shoulder and improved clinical outcomes (ASES score, 80.2; KSS score, 92). X-rays revealed union of the proximal humerus fracture with no sign of avascular necrosis of the humeral head (Fig. 4).

**DISCUSSION**

The present case demonstrated a satisfactory result from ORIF using a precontoured PHILOS plate combined with PMMA cement augmentation for an osteoporotic proximal humerus fracture. Compared to other materials, such as calcium phosphate cement, allogeneic bone or autologous bone, PMMA cement provides a reduced fracture with significant mechanical support [6-9].

Osteoporotic proximal humerus fracture has high rates of complication and reoperation. There are many augmentation techniques for fixation with a plate as follows: structural allogeneic or autologous bone grafting to enhance the medial support, filling the metaphyseal void with synthetic bone substitutes or bone grafts, and screw-tip augmentation with bone cement [6]. Some studies revealed that bone grafting to fill the void had a positive effect on healing the fracture and reducing the failure rate [8]. One review showed that PMMA augmentation of proximal femoral nail fixation might have the potential to prevent reoperations by strengthening the osteosynthesis construct [9]. In the present case, there is a possibility that some thermal injury occurred from the PMMA cement, but it was used for its ability to provide mechanical support.

Although bone graft or calcium phosphate cement might be better than PMMA cement in the aspect of biocompatibility, PMMA cement augmentation could be better for unstable fractures with severe osteoporotic bone in the aspect of mechanical support. Therefore, the present case report provides another surgical option for displaced osteoporotic proximal humerus fractures with significant bony defects: ORIF with PMMA cement augmentation. Moreover, this option may also be applied for a revisional ORIF of an osteoporotic proximal humerus fracture.

**REFERENCES**


**Fig. 4.** Healing of fracture without screw back-out or loss of reduction 6 months later. Union is shown with no sign of avascular necrosis. (A) Union was shown on shoulder true anteroposterior X-ray at 6 months after revision surgery. (B) Shoulder axillary X-ray showed union at 6 months after revision surgery.
Acromioclavicular (AC) joint dislocations account for about 9% of shoulder injuries. Among them, acute high-grade injury following high-energy trauma accounts for a large proportion of patients requiring surgical treatment. However, there is no gold standard procedure for operative treatment of acute high-grade AC joint injury, and several different procedures have been used for this purpose in clinical practice. This review article summarizes the most recent and relevant surgical options for acute high-grade AC joint dislocation patients and the outcomes of each treatment type.

Keywords: Acute high-grade acromioclavicular joint injuries; Treatments; Shoulder

INTRODUCTION

Numerous surgical techniques to treat acute high-grade acromioclavicular (AC) joint dislocation have been reported in previous studies [1-5]. Opening fixation techniques, such as using a hook plate or Bosworth screw, are still widely used. Arthroscopic fixation techniques have recently been developed and used in a variety of ways to treat AC joint dislocation [6]. However, the optimal surgical treatment of these options is still unclear.

The stability of the AC joint is maintained mainly by the coracoclavicular (CC) and AC ligaments. The CC ligament is composed of conical and trapezoid ligaments, which play an important role as vertical stabilizers of the AC joint. Surgical treatment is recommended for Rockwood Type III and V injuries due to AC joint instability caused by a complete rupture of the CC and AC ligaments by higher energy trauma [7].

Hook plate fixation is a reliable and widely used treatment for AC joint dislocations. However, the role of the clavicle hook plate is to produce nonanatomical reduction of the AC joint, which may have negative effects on the shoulder rehabilitation process and can lead to loss of reduction following plate removal. In addition, this technique has the disadvantage of requiring a second operation to remove the plate. Arthroscopically, cortical button fixation has recently been introduced and has shown successful results, including several advantages over open procedures [8]. However, this arthroscopic fixation technique is concerning regarding its ability to provide horizontal stability; several complications related to metals have been reported, such as
loss of CC reduction and risk of fracture of the clavicle or coracoid process [1,9].

Recently, Lee et al. [5] introduced an arthroscopic CC fixation technique that uses multiple soft anchor knots to overcome these complications and reported satisfactory clinical outcomes. Their technique ensured both horizontal and vertical stability to the AC joint while maintaining anatomic fixation [5]. Today, more than 150 surgical and conservative treatment options have been described to treat AC joint dislocations, although many are controversial. The present review summarizes the currently available data regarding surgical options for acute high-grade AC joint dislocation.

**CLASSIFICATION**

The most commonly used classification for AC joint dislocation is the Rockwood classification system [10]. This approach is based on radiological findings and classifies AC joint dislocations into six types. Low-energy trauma injuries, which are classified as type I or type II injuries, are treated conservatively using a Kenny-Howard brace [11]. In contrast, high-energy trauma injuries, such as type IV, type V, and type VI injuries, are treated surgically [12], while the treatment for type III injuries is still being debated [13].

**SURGICAL PROCEDURES**

**Hook Plate Fixation**

AC joint fixation allows time for the native AC and CC ligaments to heal in place by reducing the AC joint and maintaining the reduced AC joint. Hook plate fixation is one method of primary fixation across the AC joint (Fig. 1). In this fixation method, the hook portion of the plate is positioned beneath the acromion, and the plate is then fixed to the clavicle with screws to maintain adequate reduction of the AC joint. The technique can be used to treat acute injuries and may be combined with ligament reconstruction for chronic injuries with good short-term outcomes. Kienast et al. [14] used AC hook plate fixation to treat 225 patients with Rockwood type III–V AC joint dislocations and reported excellent or good outcomes in 89% of patients; however, the overall rate of complications was relatively high (10.6%). It is not rare for hook plate fixation to result in serious complications, including upward cutting of the hook through the acromion [15], subacromial osteolysis [16], fracture [17], AC joint osteoarthritis, subacromial impingement, and rotator cuff tears [18]. In vivo analyses of AC joint motion after hook plate fixation have indicated that clavicular motion and AC joint biomechanics change significantly after hook plate fixation [19]. The main disadvantage of this surgical procedure is the need for a second surgery to remove the implanted hardware.

**Bosworth Screw Fixation**

In 1941, Bosworth [20] introduced a fixation technique involving placement of a screw between the clavicle and the coracoid. Typically, a 6.5-mm partially threaded cancellous screw is used. Most surgeons favor open screw insertion, as percutaneous techniques are associated with a high rate of technical failure (32%) [21]. According to Rockwood et al. [22], five types of motion between the coracoid and the clavicle can lead to fatigue or failure of the implant over time. Because of the high rate of hardware migration and screw breakage over time, reoperation is usually required between 8 and 12 weeks after the initial sur-

![Fig. 1. Serial radiographs from a 45-year-old man treated with reconstruction of an acute acromioclavicular joint separation of Rockwood type V using a hook plate showing good joint reduction and maintenance of joint reduction. (A) Preoperative. (B) Postoperative.](https://doi.org/10.5397/cise.2020.00150)
gical procedure [23].

**Arthroscopic Fixation of the CC Joint**

Arthroscopic-assisted procedures with CC suspension devices aim to increase the healing ability of torn AC and CC ligaments and reduce the CC distance. In the management of AC joint injuries, arthroscopy-assisted procedures provide several advantages over open procedures. These techniques offer superior visualization of the base of the coracoid and require less soft tissue dissection and smaller incisions than open procedures [24]. Additionally, arthroscopic techniques have the theoretical benefit of allowing the surgeon to identify and treat associated injuries within the glenohumeral joint and subacromial space [25].

**The TightRope/EndoButton/Dog Bone technique**

A prosthetic CC suspension device, such as the TightRope device (Arthrex, Naples, FL, USA), can also be implanted (Fig. 2). This device contains titanium buttons placed on top of the clavicle and under the coracoid that are connected with a continuous loop of no. 5 FiberWire suture (Arthrex). A similar device, the EndoButton device (Smith & Nephew, Memphis, TN, USA), was also used with a no. 5 Ethibond suture (Ethicon Inc., Somerville, NJ, USA) (Fig. 3). The TightRope device was based on the principles of the EndoButton system [26]. Subsequently, the Dog Bone device (Arthrex) (Fig. 4), which is similar to the TightRope/EndoButton devices, has also been introduced [27].

Using these single metallic suspension devices anchored at the...
isometric point of the CC ligament, good clinical results have been reported in many other studies; however, the risk of secondary subluxation is a concern [28]. The most commonly reported complication was hardware migration into the clavicle, coracoid, or both. The rate of migration was as high as 89% as reported by Scheibel et al. [29]. In addition, many patients complain of persistent symptoms after surgery related to hardware irritation over the superior clavicle fixation site [9].

Since vertical placement of these single metallic suspension devices does not replicate the normal orientation of the CC ligaments, this non-anatomic technique has recently been criticized in biomechanical studies [30]. Therefore, while vertical stability may be restored, horizontal instability may persist [31]. Theoretically, the use of two or more vertical stabilizers along the course of the CC ligament can better restore the anatomical and biomechanical properties of the natural ligaments [30]. Scheibel et al. [29] published good to excellent early clinical results using arthroscopic-assisted techniques with two TightRope devices in 28 patients with acute AC joint dislocation. In addition, Venjakob et al. [32] reported reliable stability of AC joints in 96% of patients in a study of arthroscopic-assisted, double EndoButton device procedures to treat AC joint dislocation with a mean follow-up duration of 58 months [32].

Despite these favorable results, the use of two metallic CC suspension devices risks fracture of the clavicle or coracoid process due to the non-negligible diameter of the drill holes, 4.0 mm [33-35]. Martetschläger et al. [36] showed that 20% of the fractures of the clavicle or coracoid process were related to complications resulting from technical errors in the drilling technique. Despite these technical surgical problems, the TightRope/EndoButton/Dog Bone techniques had the lowest rate of radiographic failure at only 5% of patients with recurrent dislocation.

**Multiple all-suture anchor technique**

CC suspension devices, such as the 1.8-mm Y-Knot Flex All-suture Anchor (ConMed Linvatec, Utica, NY, USA), were used. In contrast with procedures that use metal knots, soft knots are anchored at the bottom of the coracoid process at the entrance to the tunnel. The use of three vertical stabilizers rather than a single vertical stabilizer was intended to restore horizontal stability as well as vertical stability, as in the suspension bridge principle (Fig. 5). It is important to create small-width bone tunnels to re-

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**Fig. 3.** A coracoclavicular suspension device: the EndoButton device.

**Fig. 4.** A coracoclavicular (CC) suspension device: (A) the Dog-Bone device, (B) illustration of CC fixation using a Dog Bone device.
duce the risk of clavicle or coracoid process fractures [37]. Recently, Lee et al. [5] reported satisfactory clinical outcomes at a mean follow-up of two years in 27 patients with acute high-grade AC joint injury treated with an arthroscopic CC fixation technique using multiple soft anchor knots. These outcomes are likely due to the small tunnel width and multiple strands used, which allow for safe fixation while minimizing complications of metallic fixation and providing strong vertical and horizontal stability. It is important to note that the learning curve for this procedure is steep because it is technically demanding. Nevertheless, according to currently available biomechanical and clinical evidence, multiple all-suture anchor fixation can be considered a feasible and reliable treatment strategy for AC dislocation.

Fig. 5. (A) A computed tomography image after three-dimensional reconstruction shows correction of horizontal instability of the left clavicle. The red lines show the horizontal stability of the acromioclavicular joint. (B) The arthroscopic finding of multiple knots anchoring under the base of the coracoid process. (C) The suspension bridge. (D) An illustration of coracoclavicular (CC) fixation using three vertical stabilizers. This method can restore horizontal stability and vertical stability, as in the suspension bridge principle. (E) Bilateral anteroposterior plain radiograph at final follow-up after surgery, showing maintenance of the CC distance. Asterisks indicate the clavicle tunnels.
CONCLUSION

AC joint dislocation is a relatively common injury in the general population. A large proportion of these patients demonstrate acute high-grade AC joint injury that requires surgical treatment. Surgical treatment methods have made great progress in the past 30 years, and various surgical procedures are suitable for treatment of AC joint injuries. However, no gold standard procedure has been established. It is therefore vital to consider various surgical treatments depending on patient age and physical needs and the surgeon’s proficiency.

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REFERENCES


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