Original Article
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Prevalence and Clinical Impact of Acromial Cupping after Arthroscopic Rotator Cuff Repair: Does Acromioplasty Matter?

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Background: Although the effectiveness of acromioplasty is controversial, it is commonly performed during rotator cuff repair to reduce external impingement. During follow-up, osteolysis under the acromion (acromial cupping) could be observed. However, this phenomenon has been rarely addressed in the literature. The purpose of this study was to compare the prevalence and severity of acromial cupping after rotator cuff repair depending on the concomitant performance of acromioplasty and evaluate the influence of acromial cupping on clinical and radiological outcome.

Methods: This is a retrospective study involving patients who underwent arthroscopic rotator cuff repair for small-to-large full-thickness rotator cuff tears from October 2015 to March 2019 and clinical follow-up and magnetic resonance imaging at least 1 year postoperatively. A total of 110 patients were enrolled and divided into two groups depending on whether acromioplasty had been performed (group A) or not (group N). The prevalence of acromial cupping was evaluated in each group. In addition, we stratified patients according to the severity of acromial cupping to investigate its influence on healing and functional scores (visual analog scale [VAS], American Shoulder and Elbow Surgeons [ASES] score, simple shoulder test [SST], and Constant-Murley score).

Results: There were 85 patients in group A and 25 patients in group N. The prevalence of acromial cupping and acromial cysts was as follows: 36.4% (40 patients) and 6.4% (7 patients), respectively, in the total subjects; 43.5% (37/85) and 5.9% (5/85), respectively, in group A; and 12.0% (3/25) and 8.0% (2/25), respectively, in group N. The prevalence of acromial cupping was significantly different between the two groups (p = 0.012). However, functional outcomes were not significantly different between groups stratified by the severity of acromial cupping (VAS, p = 0.464; ASES score, p = 0.902; SST, p = 0.816; and Constant-Murley score, p = 0.117). The difference in healing rate was statistically insignificant between groups (p = 0.726).

Conclusions: The incidence and severity of acromial cupping were significantly greater in patients who underwent rotator cuff repair with acromioplasty. It was a relatively common phenomenon, especially after acromioplasty. However, neither the existence nor the severity of acromial cupping affected functional outcomes or healing.

Keywords: *Acromioplasty, Acromion, Cupping, Osteolysis, Rotator cuff repair*

Since first described by Neer[1)] in 1972, acromioplasty has become the most common procedure accompanying arthroscopic rotator cuff repair to reduce mechanical impingement.[2-6)] However, recently, the effectiveness of acromioplasty has been questioned. While many studies have shown clinical effectiveness of acromioplasty,[7-9)] some studies argue that it is ineffective in improving clinical outcomes.[10-13)] Despite the controversy surrounding its effectiveness, acromioplasty is still frequently performed during arthroscopic rotator cuff repair.

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Osteolytic or cystic lesions can be observed in the undersurface of the acromion in imaging follow-up after rotator cuff repair. However, this phenomenon has been rarely described or evaluated. In this study, we refer to this phenomenon as acromial cupping based on the nature of the shape change. To the best of our knowledge, two recent studies recognized acromial cupping and hypothesized on its etiology.[14,15)] Hotta and Yamashita[15)] claimed knot impingement was the cause of acromial cupping whereas Park et al.[14)] showed there was no association between knot impingement and acromial cupping. Although the mechanism of the occurrence of acromial cupping remains unclear, it has been our impression that acromial cupping is more prevalent in patients with concomitant acromioplasty.

Therefore, the purpose of this study was to compare the prevalence of acromial cupping after rotator cuff repair according to concomitant acromioplasty and clinical outcomes according to the severity of acromial cupping. We hypothesized the prevalence and severity of acromial cupping would be higher in patients who underwent acromioplasty during rotator cuff repair and its presence would adversely affect functional outcomes.

METHODS

The Institutional Review Board of Seoul National University Hospital approved the study (IRB No. 2007-098-1141) and waived the need for informed consent from all patients.

Study Population

We retrospectively reviewed medical records of arthroscopic rotator cuff repairs performed from October 2015 to March 2019. The inclusion criteria were as follow: age over 18 years; a full-thickness rotator cuff tear based on preoperative magnetic resonance imaging (MRI); a small-to-large full-thickness (involving less than 2 tendons) rotator cuff tear (as described by Snyder[16)]); arthroscopic rotator cuff repair performed using a single-row technique; and availability for postoperative MRI and functional evaluation at 1 year after surgery. The exclusion criteria were a partial thickness tear, massive tear, isolated subscapularis or infraspinatus tendon tear, and previous surgical procedure on the affected shoulder (Fig. 1). One hundred and ten patients were finally included in the analysis.

Surgical Technique

All operations were performed by a senior shoulder surgeon (SHK). The patient was placed in the lateral decubitus position with the operated arm in 20° to 30° of abduction and 20° of forward flexion, and traction was applied. In each case, after an initial diagnostic glenohumeral and subacromial examination, the torn rotator cuff was trimmed and repaired at its footprint using a single-row technique with triple-loaded bioabsorbable anchors. Self-locking sliding knots followed by two half hitches were used throughout the procedure. Prior to rotator cuff

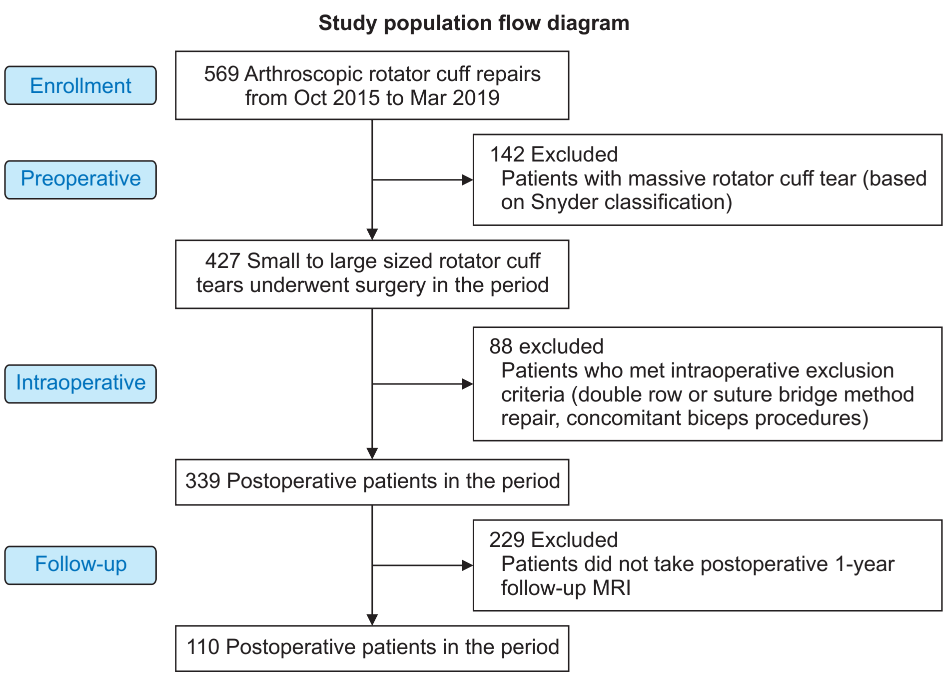

Fig. 1. Study flow diagram. MRI: magnetic resonance imaging.

repair, acromioplasty was performed in a selective manner on the patients with both impingement symptoms and subacromial spurs (lateral type or heel type). The anterior osteophytes and lateral spurs were removed to form a flat acromion; however, excessive bone removal or cortical disruption in the mid-portion of the acromion was avoided. Immediate postoperative radiographs were taken in every case to confirm if acromioplasty was adequately performed (Fig. 2) without undermining the acromion or making a dome-shaped acromion. If a spur was not present or minimal in radiography and MRI, acromioplasty was not performed. All patients underwent the same rehabilitation protocol. Immobilization was maintained with an abduction brace for 5 weeks. Controlled passive motion (forward flexion, abduction, and external rotation) was performed after brace weaning. Active assisted range of motion exercise and rotator cuff strengthening were started at 12 weeks postoperatively. All sports activities were permitted from 6 months after surgery.

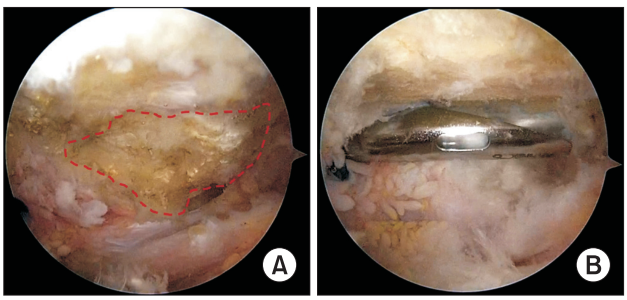

Fig. 2. Arthroscopic acromioplasty. Left shoulder images (subacromial space) of the same patient. (A) The dotted line delineates anterolateral acromial spur. The spur is thicker than the width of the burr. (B) The acromion after acromioplasty. Flattening of the acromion was checked by parallel positioning of the burr on the undersurface of the acromion.

Radiologic Evaluation

All patients underwent routine preoperative shoulder radiography, dual-energy X-ray absorptiometry (DEXA), and MRI and 1-year postoperative MRI. Preoperatively, the critical shoulder angle was measured on simple radiographs,[17] bone mineral density (BMD) was assessed in DEXA, and the grade of fatty infiltration was determined using Goutallier classification based on T1-weighted oblique sagittal MR images.[18] The tear size of the rotator cuff tendon was measured on T2-weighted oblique sagittal MR images and tendon retraction on T2-weighted oblique coronal images. Acromial morphological types in T1-weighted oblique coronal images were classified as (1) heel type spur, (2) lateral traction spur, and (3) bird beak spur as described by Oh et al. (Fig. 3).[19] Postoperative tendon status and acromial cupping were checked in postoperative MR images. Postoperative tendon healing was graded using the Sugaya classification,[20] and grades 4 and 5 were considered retears. Healing status was evaluated by radiologists (JYC and YEC) who were not involved in the study. Since there was no classification of acromial cupping available, we devised a grading system. On the postoperative MR image where the acromial cupping appears biggest in size, after drawing a reference line at the undersurface of the acromion (in coronal view and sagittal views), we measured the height (perpendicular to the reference line) of the acromion and the apex of acromial cupping (Figs. 4 and 5).

We defined mild acromial cupping as an osteolytic lesion < 1/3 of the acromial height (Fig. 4) and severe acromial cupping as ≥ 1/3 of the acromial height (Fig. 5). Intracancellous lesions in the acromion with high signal intensity in T2-weighted postoperative MR images were considered as acromial cysts (Fig. 6).

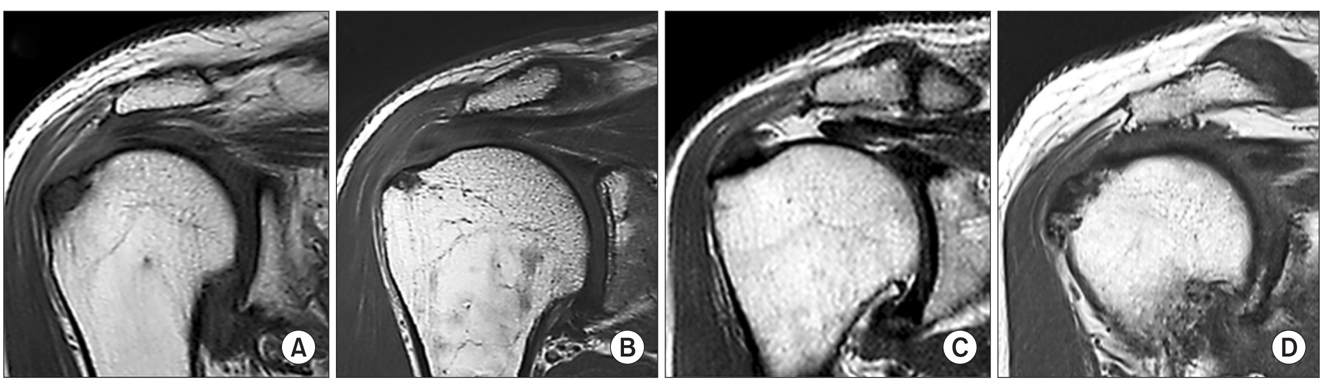

Fig. 3. Types of acromial spurs as categorized in oblique coronal plane magnetic resonance images. (A) Normal acromion. (B) Lateral traction spur. The lateral acromial spur is congruent with the acromial undersurface. (C) Lateral bird beak type spur. The lateral acromial spur is incongruent with the acromial undersurface. (D) Heel type spur. The shape of the spur (inferior protrusion) looks like the heel of a shoe.

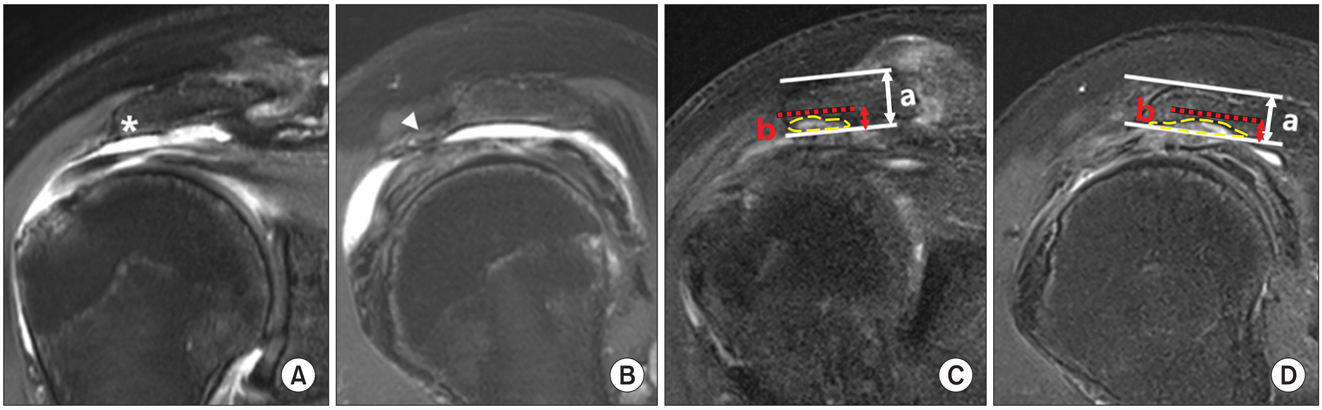

Fig. 4. Mild acromial cupping of the acromial undersurface. (A) Preoperative T2-weighted oblique coronal magnetic resonance (MR) image showing a mild heel type spur (asterisk). (B) Preoperative T2-weighted oblique sagittal MR image showing an anterior bird beak spur (arrowhead). (C) Postoperative T2-weighted oblique coronal MR image showing mild acromial cupping (yellow dotted line). The depth of acromial cupping (b) versus acromial height (a) was < 1/3. (D) Postoperative T2-weighted oblique sagittal MR image showing mild acromial cupping (yellow dotted line).

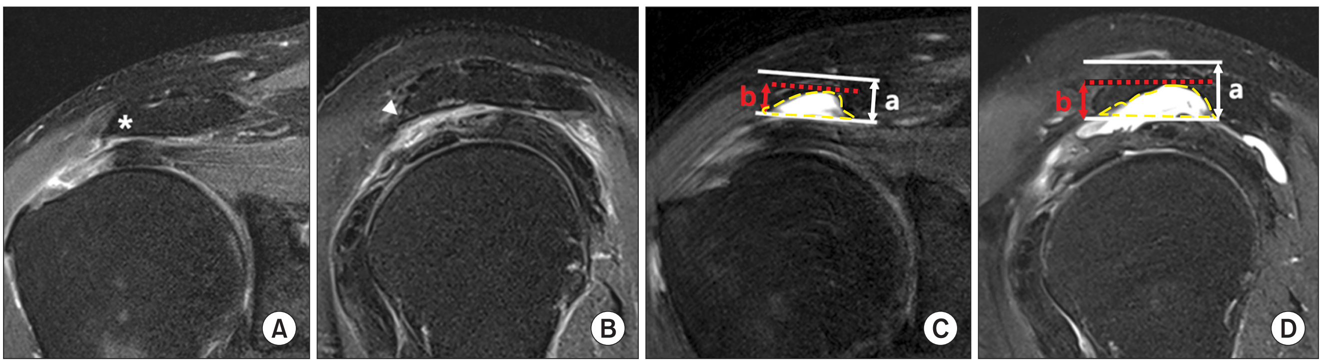

Fig. 5. Severe acromial cupping of the acromial undersurface. (A) Preoperative T2-weighted oblique coronal magnetic resonance (MR) image showing a mild lateral traction type spur (asterisk). (B) Preoperative T2-weighted oblique sagittal MR image showing an anterior bird beak spur (arrowhead). (C) Postoperative T2-weighted oblique coronal MR image showing severe acromial cupping (yellow dotted line). The depth of acromial cupping (b) versus acromial height (a) was ≥ 1/3. (D) Postoperative T2-weighted oblique sagittal MR image showing severe acromial cupping (yellow dotted line).

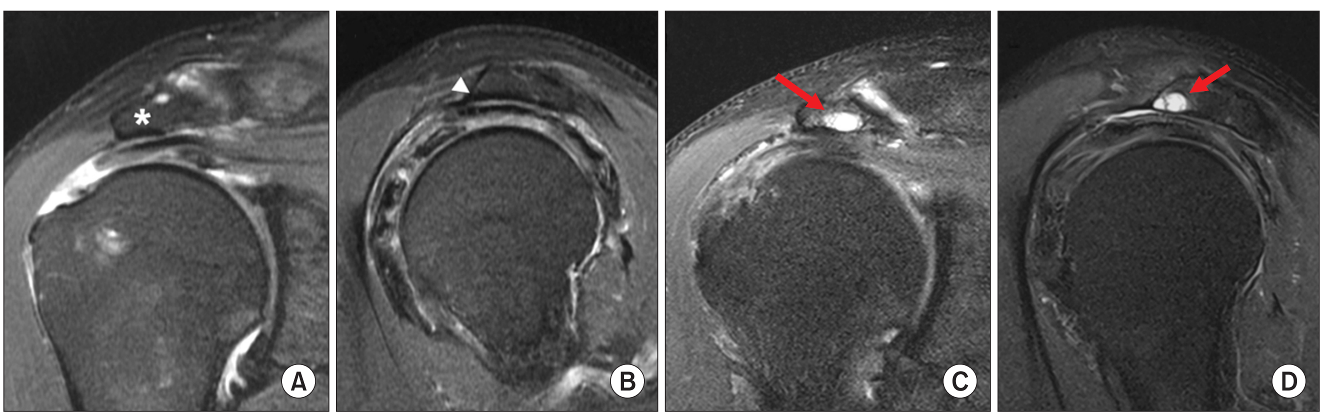

Fig. 6. Cyst in the acromion. (A) Preoperative T2-weighted oblique coronal magnetic resonance (MR) image showing no high signal intensity lesion in the acromion (asterisk). (B) Preoperative T2-weighted oblique sagittal MR image showing a mild anterior spur (arrowhead). (C) Postoperative T2-weighted oblique coronal MR image showing a high signal intensity cystic lesion (arrows) in the acromion. (D) T2-weighted oblique sagittal MR image.

Clinical Evaluation

Functional outcomes were evaluated by the pre- and postoperative visual analog scale (VAS) for pain, American Shoulder and Elbow Surgeons (ASES) score, simple shoulder test (SST), and Constant-Murley score. Functional scores were assessed and determined by a clinical research assistant (YHJ and SYO) with 7 years of experience.

Statistical Analysis

Statistical analysis was performed using IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA). All reported *p*-values are two sided, and statistical significance was accepted for $p < 0.05$. Interobserver reliability for grading of acromial cupping between two fellow trained orthopedic surgeons (YHJ and SYO) was calculated using kappa coefficients, which were interpreted as described by Landis and Koch.[21] The Student *t*-test and analysis of variance test were used for parametric variables and the Mann-Whitney *U*-test for nonparametric variables to compare outcomes between groups. The chi-square test or Fisher's exact test were used to compare discrete variables. A paired *t*-test was used to compare pre- and postoperative means.

RESULTS

One hundred and ten patients were enrolled; 85 patients received arthroscopic rotator cuff repair with acromioplasty (group A), and 25 patients underwent arthroscopic rotator cuff repair only (group N). Demographic data of both groups are summarized in Table 1. Baseline demographic data did not differ significantly between the two groups.

Prevalence and Severity of Acromial Cupping According to Acromioplasty

The prevalence of acromial cupping and acromial cysts among the 110 study subjects were 36.4% (40/110) and 6.4% (7/110), respectively. The prevalence of mild acromial cupping, severe acromial cupping, and acromial cysts in group A (with acromioplasty) was 28.2% (24/85), 15.3% (13/85), and 5.9% (5/85), respectively. In group N, the prevalence of mild cupping and acromial cysts was 12.0% (3/25) and 8.0% (2/25), respectively, and there was no case of severe cupping. Interobserver reliability for the classification of the severity of acromial cupping was excellent (kappa value = 0.869). The prevalence ($p = 0.012$) and severity ($p = 0.033$) of acromial cupping were significantly higher in group A, but the prevalence of acromial cysts was similar in the two groups ($p = 0.703$).

Clinical and Radiologic Results According to Severity of Cupping

We also classified patients into 3 groups according to the severity of acromial cupping (no cupping, mild cupping and severe cupping). In 103 of the 110 study subjects without acromial cysts, 61.1% (63/103) had no acromial cupping, 26.2% (27/103) showed mild cupping, and 12.6% (13/103) had severe cupping. Preoperative demographic

Table 1. Comparison of Demographic Data between Acromioplasty vs. Non-acromioplasty Group

Variable	Group A (n = 85)	Group N (n = 25)	*p*-value
Sex (male : female)	32 : 53	8 : 17	0.101
Age (yr)	60.84 ± 6.30	61.96 ± 6.84	0.491
Site of operation (Rt : Lt)	68 : 17	18 : 7	0.395
Number of anchors	1.82 ± 0.44	1.88 ± 0.53	0.753
Spur type (minimal : lateral traction : bird beak : heel type)	38 : 23 : 2 : 22	16 : 2 : 2 : 5	0.055
FI of supraspinatus muscle	1.24 ± 0.61	1.64 ± 0.49	0.068
CSA (°)	35.00 ± 3.55	35.72 ± 4.74	0.065
BMD	–1.10 ± 1.10	–0.85 ± 1.34	0.591
Tear size (AP dimension, mm)	11.86 ± 3.66	11.12 ± 3.90	0.817
Retraction (mm)	15.61 ± 8.99	18.47 ± 9.64	0.810

Values are presented as mean ± standard deviation. Group A: acromioplasty group, Group N: non-acromioplasty group.
Rt: right, Lt: left, FI: fatty infiltration, CSA: critical shoulder angle, BMD: bone mineral density, AP: anteroposterior.

Table 2. Comparison of Demographic Data According to the Severity of Acromial Cupping

Variable	No cupping (n = 63)	Mild cupping (n = 27)	Severe cupping (n = 13)	*p*-value
Sex (male : female)	24 : 39	6 : 21	6 : 7	0.736
Age (yr)	61.29 ± 6.72	62.43 ± 5.64	60.85 ± 5.93	0.669
Number of anchors	1.93 ± 0.42	1.80 ± 0.55	1.77 ± 0.44	0.101
Goutallier grade	1.32 ± 0.58	1.37 ± 0.72	1.23 ± 0.60	0.677
CSA (°)	35.15 ± 4.11	35.17 ± 3.81	34.31 ± 3.30	0.605
BMD	–1.08 ± 1.35	–1.31 ± 1.03	–0.67 ± 0.95	0.148
Tear size (AP dimension, mm)	11.66 ± 3.81	11.70 ± 4.21	11.89 ± 3.96	0.410
Retraction (mm)	16.64 ± 8.76	18.02 ± 10.77	12.91 ± 7.14	0.290

Values are presented as mean ± standard deviation.
CSA: critical shoulder angle, BMD: bone mineral density, AP: anteroposterior.

Table 3. Comparison of Preoperative and Postoperative Functional Evaluations According to the Severity of Acromial Cupping

Variable	Non cupping (n = 63)	Mild cupping (n = 27)	Severe cupping (n = 13)	*p*-value
VAS pain score				
Preoperative	4.30 ± 2.47	4.16 ± 3.11	4.06 ± 1.57	0.956
Postoperative	1.65 ± 1.75	1.11 ± 1.41	1.56 ± 1.13	0.464
ASES score				
Preoperative	19.16 ± 7.49	19.22 ± 8.08	19.44 ± 6.04	0.994
Postoperative	26.38 ± 5.17	25.72 ± 5.46	26.33 ± 5.22	0.902
SST score				
Preoperative	4.73 ± 2.73	5.18 ± 2.88	4.75 ± 3.01	0.850
Postoperative	9.00 ± 2.41	8.65 ± 2.60	8.50 ± 3.25	0.816
Constant-Murley score				
Preoperative	62.98 ± 17.79	63.76 ± 12.70	62.89 ± 15.22	0.985
Postoperative	84.84 ± 12.50	80.35 ± 5.89	89.56 ± 9.07	0.117

Values are presented as mean ± standard deviation.
VAS: visual analog scale, ASES: American Shoulder and Elbow Surgeons, SST: simple shoulder test.

data (Table 2) and functional scores (VAS, $p = 0.956$; ASES, $p = 0.994$; SST, $p = 0.850$; and Constant-Murley score, $p = 0.985$) were not significantly different in these groups (Table 3). There was no statistically significant difference in postoperative functional outcomes (Table 3) and retear rates (no cupping group, 6.3% [4/63)]; mild cupping group, 11.1% [3/27]; and severe cupping group, 7.7% [1/13]; $p = 0.726$) among patients with different cupping severities.

DISCUSSION

The principal finding of this study is that acromial cupping after arthroscopic rotator cuff repair was common (36.4%). Neither prevalence nor severity of acromial cupping was related to other preoperative or intraoperative variables, which include the number of anchors used, tear size, and BMD. Only related factor was whether concomitant acromioplasty was performed or not. Acromial cupping was observed in 43.5% (37/85) in group A and in 12.0% (3/25) in group N, which supports our first hypothesis. In addition, severe acromial cupping involving more than 1/3 thickness of the acromion was only observed in group A. However, cupping of the acromion did not affect the healing rate of the repaired cuff and functional scores, which contradicts our second hypothesis. Acromial cysts were also found after arthroscopic rotator cuff repair in 6.4% (7/110) of the study subjects, but no intergroup difference in prevalence was found according to whether acromioplasty was performed.

Acromial osteolysis after arthroscopic rotator cuff repair has received little attention and its mechanism has not been established. Only two case series have been published. Hotta and Yamashita[15] reported nine cases of osteolysis in the inferior surface of the acromion after surgery, which represented a prevalence of 2.1%. They considered it to have been caused by the impingement of knots in the suture thread. However, Park et al.[14] reported that the prevalence of acromial erosion was similar between the single- and double-row repair techniques (1.0% in a single-row repair group and 1.7% in a suture-bridge group) and thus concluded acromial erosion is not associated with knot impingement. In the present study, the prevalence of acromial cupping was greater than that in the two previous studies, and we found no significant relation between acromial cupping and the number of anchors ($p = 0.101$), which involves placement of more knots in the subacromial space. The higher prevalence in our study may be attributable to our failure to notice mild cases as this phenomenon has been neither reported nor given much attention. In fact, we had not noticed and been interested in this phenomenon until we encountered some severe cases. In terms of the mechanism of occurrence, we failed to show any other related variables but acromioplasty. The possible reason for the higher prevalence and severity in the acromioplasty group is bone resorption in the exposed weak cancellous undersurface as a result of decortication. Since there is no hard cortical bone, it is exposed to subacromial pressure and impingement. Although acromial cupping was not found to affect clinical outcomes or cuff healing, a thin acromion may increase the risk of an acromial fracture, especially after a reverse total shoulder arthroplasty in the future. Therefore, long-term consequences of acromial cupping need to be further investigated. Although it may be possible for acromioplasty to contribute to the development of acromial cupping, we believe there are still benefits of acromioplasty in rotator cuff repair in patients with impingement symptoms and subacromial spurs; acromioplasty is still performed in the authors' current practice.

Our study has some weaknesses that should be considered. First, the indications for acromioplasty were not uniform; acromioplasty was performed selectively. It was performed only when both acromial spurs and impingement symptoms were present. In addition, since acromioplasty could violate the coracoacromial arch, it was avoided in massive rotator cuff tears even if spurs were present. Therefore, we excluded massive tears from our analysis. Second, the follow-up was relatively short (approximately 12 months), and thus the long-term results of acromial cupping, especially regarding severe osteolysis, could not be ascertained. It is difficult to predict for now whether the results of a reverse total shoulder arthroplasty and the risk of postoperative fracture would be affected by acromial cupping. Therefore, its effect on subsequent procedures should be investigated in further research. Third, a considerable number of patients (n = 229) were excluded due to the unavailability of postoperative MR images; many patients were reluctant to bear the cost of an MRI evaluation after symptoms had subsided. We are uncertain whether this introduced selection bias. However, there was no clinical difference between those who had an MRI and those who did not. Fourth, some may argue that acromial cupping is an iatrogenic lesion created during acromioplasty. However, we performed acromioplasty in the standard fashion and avoided making a dome-shaped acromion. Since acromial cupping was defined as bone loss over the reference line, which was drawn in line with the flat undersurface of the acromion, there was no way to make a crescent undersurface during surgery. Although we performed immediate postoperative X-ray, it would have been better if special imaging, such as MRI or computed tomography, had been carried out in the immediate postoperative period; however, it is practically impossible in ordinary practice due to cost and ethical considerations. Finally, the depth of acromial cupping measured on sagittal and coronal MR images may differ from the actual depth.

The incidence and severity of acromial cupping were significantly greater in patients who underwent rotator cuff repair with acromioplasty. Acromial cupping was a relatively common phenomenon, especially after acromioplasty. However, neither the existence nor severity of acromial cupping affected functional outcomes or healing rates.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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