Evaluation of Radiographic Changes 5 Years After Arthroscopic Rotator Cuff Repair

Ryogo Furuhata,* MD, PhD, Noboru Matsumura,*† MD, PhD, Tomoki Matsuo,* MD, Hiroo Kimura,* MD, PhD, Taku Suzuki,* MD, PhD, Masaya Nakamura,* MD, PhD, and Takuji Iwamoto,* MD, PhD

Investigation performed at the Department of Orthopaedic Surgery, Keio University School of Medicine, Tokyo, Japan

Background: Radiographic changes in the glenohumeral joint often occur after rotator cuff repair; however, the details of the progression and underlying causes remain unknown.

Purpose: To retrospectively evaluate the timing and frequency of radiographic changes after arthroscopic rotator cuff repair and to clarify the predictive factors that affect the onset of such changes using multivariate analysis.

Study Design: Case-control study; Level of evidence, 3.

Methods: We retrospectively reviewed 100 patients with 5 years of follow-up after arthroscopic rotator cuff repair and evaluated the postoperative shift in radiographic findings on plain radiographs every year during follow-up. Factors related to osteoarthritis, acromial spur re-formation, and greater tuberosity resorption at 5 years after surgery were evaluated using logistic regression analyses. Explanatory variables included preoperative factors, intraoperative factors, and postoperative retear. Baseline variables significant in the univariate analyses were included in the multivariate models.

Results: Of the 100 patients, 12 developed osteoarthritis, 26 developed acromial spur formation, and 16 developed greater tuberosity resorption at 5 years after surgery. The incidence and grade of osteoarthritis and acromial spur gradually increased over time postoperatively. On the other hand, greater tuberosity resorption developed within 2 years after surgery but did not progress later. Multivariate analysis showed that a larger anteroposterior tear size (odds ratio [OR], 1.09; 95% CI, 1.01-1.17; \(P = .037\)) was a risk factor for postoperative osteoarthritis. Early retear (OR, 10.26; 95% CI, 1.03-102.40; \(P = .047\)) was a risk factor for acromial spur re-formation. Roughness of the greater tuberosity (OR, 9.07; 95% CI, 1.13-72.82; \(P = .038\)) and larger number of suture anchors (OR, 3.34; 95% CI, 1.66-6.74; \(P = .001\)) were risk factors for greater tuberosity resorption.

Conclusion: Our study showed that radiographic changes occurred in 40% of patients within 5 years after arthroscopic rotator cuff repair. While the osteoarthritic changes and acromial spur re-formation gradually progressed postoperatively, the greater tuberosity resorption stopped within 2 years after surgery. Tear size, morphology of the greater tuberosity, and the number of suture anchors can affect radiographic changes. Furthermore, this study suggested that acromial spur re-formation may be an indicator of early retears.

Keywords: acromial spur; arthroscopy; bone resorption; osteoarthritis; radiographic change; rotator cuff repair

Arthroscopic rotator cuff repair for rotator cuff tears provides favorable long-term clinical outcomes.\(^{18,26,38}\) However, postoperative radiographic changes, such as osteoarthritis of the glenohumeral joint,\(^{1,12,16,25,28,29,36,53}\) re-formation of the acromial spur,\(^{3,13}\) and bone resorption of the greater tuberosity,\(^{4}\) frequently occur after rotator cuff repair. Postoperative glenohumeral osteoarthritis has been reported to be associated with retear and poor long-term clinical outcomes after rotator cuff repair.\(^{12,16}\) Although the effect of acromial spur re-formation on long-term postoperative outcomes is unclear, there are some reports that acromial spur re-formation after acromioplasty causes shoulder pain or symptoms of subacromial impingement.\(^{3,13}\) Bone resorption of the greater tuberosity may lose biomechanical fixation for possible revision or resurgery, while rotator cuff repair using biodegradable anchors has the advantage of preserving bone stock after rotator cuff repair.\(^{22,23,37}\) Several studies to date have reported that bone resorption around the suture anchor has no significant effect on postoperative clinical outcomes\(^{23,27,37}\); however, there is 1 report showing the association of this radiological finding with the retear rate.\(^{39}\)

Previous studies have shown that the frequency of osteoarthritis of the glenohumeral joint >5 years after rotator cuff repair was 17% to 29%,\(^{1,12,16,25,28}\); however, the timing...
of its appearance has not been well-documented. The frequency and pathogenesis of re-formation of an acromial spur remain poorly understood. Osteolysis around the suture anchors, which may be a precursor of greater tuberosity resorption, has been reported to occur gradually from 3 months postoperatively and increase up to 2 years postoperatively; however, no studies have evaluated the long-term change of osteolysis around the anchors or greater tuberosity resorption. In addition, few studies have examined the risk factors for glenohumeral osteoarthritis after rotator cuff repair, and factors affecting the re-formation of an acromial spur and bone resorption of the greater tuberosity remain unknown. Therefore, it is important to identify the timing of the appearance of these radiographic changes following rotator cuff repair and the risk factors for radiographic changes.

The purpose of this study was to determine the timing and frequency of these radiographic changes after arthroscopic rotator cuff repair and to clarify whether these changes progress over time. Further, we examined the factors affecting postoperative radiographic changes using multivariate analysis.

METHODS

Patient Selection

The study protocol was approved by the independent ethics committee of our hospital. This retrospective study involved patients who underwent arthroscopic rotator cuff repair between 2013 and 2017. We included patients who underwent arthroscopic rotator cuff repair for posterosuperior rotator cuff tears. Patients with subscapularis tendon tears were treated by open rotator cuff repair and were not included in this study. In addition, we excluded patients who were unable to continue follow-up with plain radiographs immediately after surgery and every year (once a year) for 5 years after surgery, patients who had undergone surgery of the affected upper extremity, and patients who had preoperative osteoarthritic changes in the glenohumeral joint (Samilson-Prieto grade ≥2). There were no age-related restrictions; however, the indication for surgery was a healthy patient who could be administered general anesthesia.

We identified 159 patients who met the inclusion criteria. Of these, we excluded 54 patients without follow-up every year for 5 years after surgery, 2 patients with a history of the affected upper limb surgery, and 3 patients with preoperative glenohumeral osteoarthritis. As a result, only 100 patients could be followed up with plain radiographs every year during the 5 years after surgery and were included in this study.

Surgical Procedure and Rehabilitation

Surgery was performed by a single orthopaedic surgeon (N.M.) with over 10 years of experience in shoulder surgery and over 500 surgeries for arthroscopic rotator cuff repair. All patients were placed in the beach-chair position under general anesthesia. First, intra-articular arthroscopy was performed. None of the patients had obvious cartilage lesions in the glenohumeral joint. Degeneration of the long head of biceps brachii was observed in 18 patients; however, additional biceps tenotomy or tenodesis was not performed for any of these patients. The subscapularis tendon was intact in all patients. The coracoacromial release was performed in all cases, regardless of the acromial type, and then the acromion spur was shaved until the trabecular bone was visible under the subacromial bursa view. Footprint preparation was limited to the removal of soft tissue remnants using a sharp curette and did not involve using a burr to shave cortical bone or create bone vents. In all cases, rotator cuff repair was performed using double-row technique with bioinductive suture anchors (Healix Advance BR Anchor; Mitek). None of the patients underwent a transition from arthroscopic to open rotator cuff repair. The mean number of suture anchors used for surgery was 3.3 ± 1.5 (range, 2-8). The number of suture anchors was determined by the respective size of rotator cuff tear.

Postoperatively, the arm was immobilized in a brace for 1 month. Passive range of motion training was commenced 1 month after surgery, and active range of motion training was allowed 2 months after surgery. The patients were allowed to return to recreational activity with high demands on the shoulder or manual labor 6 months after surgery. To assess postoperative retear of the repaired rotator cuff, magnetic resonance imaging (MRI) scans were taken at 6, 12, and 24 months after surgery. To assess the radiographic progression of the glenohumeral joint, plain radiographs of the shoulder including anteroposterior and scapular-Y directions were taken immediately (within 2 weeks) and every year for 5 years after surgery. No revision surgery was needed or performed in the present cases.

Outcome Measures

We evaluated the postoperative change in glenohumeral osteoarthritis, acromial spur (anterior spur or lateral spur) re-formation, and bone resorption of the greater tuberosity on plain radiographs immediately and every year during the 5 years after surgery. Osteoarthritis of the
TABLE 1
Patient Demographics (N = 100)†

| Characteristic                        | Value             |
|--------------------------------------|-------------------|
| Age, years                           | 63.3 ± 8.3 (46-87)|
| Female sex                           | 38                |
| Dominant arm affected                | 69                |
| Duration of symptoms (years)         | 1.8 ± 3.4 (0.1-20) |
| History of trauma                    | 73                |
| History of smoking                   | 46                |
| Diabetes                             | 13                |
| Preoperative osteoarthritis‡         | 0                 |
| Length of acromial spur, mm          |                   |
| Anterior                             | 2.3 ± 3.7 (0-17)  |
| Lateral                              | 1.2 ± 1.7 (0.8)   |
| Morphology of greater tuberosity     |                   |
| Sclerosis                            | 35                |
| Spur                                 | 7                 |
| Roughness                            | 11                |
| Femoralization                       | 8                 |
| Superior migration of humeral head   | 12                |
| Tear size, cm                        |                   |
| Anteroposterior                      | 1.6 ± 1.1 (0-4.8) |
| Mediolateral                         | 2.0 ± 1.4 (0-4.9) |

†Data are presented as mean ± SD (range) or No. of patients.
‡Modified Samilson-Prieto grade ≥2.

The mean patient age at the time of surgery was 63.3 ± 8.3 years, with 38 women and 62 men. The mean time from onset of symptoms to surgery was 1.8 ± 3.4 years. Overall, 73 patients had a history of trauma to the affected shoulder (Table 1).

The preoperative radiographic findings are presented in Table 1. Of the 100 patients, none had osteoarthritic changes in the glenohumeral joint that were higher than Samilson-Prieto grade 1. A preoperative anterior spur ≥5 mm was observed in 23 patients, and a lateral spur ≥3 mm was observed in 19 patients. Early retears (within 2 years after surgery) developed in 7 patients.
Five years after arthroscopic rotator cuff repair, osteoarthritis (Figure 1); anterior spur re-formation (Figure 2); lateral spur re-formation (Figure 3); and bone resorption of the greater tuberosity (Figure 4) occurred in 12, 21, 14, and 16 patients, respectively, and at least 1 of these aforementioned radiographic changes occurred in 40 patients. The incidence of osteoarthritis gradually increased from 1 year postoperatively, as indicated by the proportion of patients with Samilson-Prieto grades 3 or 4. At 5 years postoperatively, 7 patients were classified as having Samilson-Prieto grade 2, 2 patients as grade 3, and 3 patients as grade 4 (Figure 5A).

There were no patients with anterior spur ≥5 mm or lateral spur ≥3 mm immediately after surgery; however, the incidence of acromial spur re-formation increased gradually from the second postoperative year, and the frequency and mean length of the spur increased over time (Figure 5, B and C). Of the patients with acromial spur at 5 years postoperatively, 15 of 21 (71%) had a larger anterior spur than preoperatively, and 6 of 14 (43%) had a larger lateral spur than preoperatively. The incidence of osteoarthritis and anterior spur increased significantly at 4 years after surgery compared with immediately after surgery (P < .001) (Figure 5, A and B). The incidence of lateral spur increased significantly at 3 years after surgery compared with immediately after surgery (P < .001) (Figure 5C). Bone resorption of the greater tuberosity developed within 2 years after surgery, but it did not progress after the first 2 postoperative years (Figure 5D).

Risk Factors of Postoperative Osteoarthritis

Univariate analyses demonstrated that older age (P = .050), larger anteroposterior tear size (P = .004), larger
mediolateral tear size \( (P = .004) \), and a larger number of suture anchors \( (P = .043) \) were significantly associated with postoperative osteoarthritis after rotator cuff repair. Multivariate analysis showed that a larger anteroposterior tear size (odds ratio \([OR]\), 1.09; 95\% CI, 1.01-1.17; \( P = .037 \)) was a risk factor for postoperative osteoarthritis. The Hosmer-Lemeshow goodness-of-fit test showed no significant difference from the good model fit \( (P = .471) \) (Table 2).

**Figure 3.** Plain radiographs of the right shoulder of a 50-year-old woman who underwent arthroscopic repair for supraspinatus tear (A) before, (B) 2 years after, and (C) 5 years after surgery. These radiographs show formation of the acromial lateral spur at 2 years postoperatively.

Risk Factors for Acromial Spur Re-formation (Anterior or Lateral)

Univariate analyses showed that the roughness of the greater tuberosity \( (P = .032) \), larger anteroposterior tear size \( (P < .001) \), larger mediolateral tear size \( (P < .001) \), a larger number of suture anchors \( (P < .001) \), and early retear \( (P = .001) \) were significantly associated with acromial spur formation after rotator cuff repair. Multivariate analysis showed that early retear \( (OR, 10.26; 95\% CI, 1.03-102.40, P = .047) \) was a risk factor for acromial spur. The Hosmer-Lemeshow goodness-of-fit test showed no significant difference from the good model fit \( (P = .419) \) (Table 3).

**Figure 4.** Plain radiographs of the left shoulder of a 51-year-old man who underwent arthroscopic repair for supraspinatus and infraspinatus tears using 6 suture anchors (A) before, (B) 1 year after, and (C) 5 years after surgery. These radiographs show bone resorption of the greater tuberosity at 1 year after surgery, with no further progression at 5 years postoperatively.

Risk Factors of Bone Resorption of the Greater Tuberosity

Univariate analyses showed that the roughness of the greater tuberosity \( (P < .001) \), larger anteroposterior tear size \( (P < .001) \), larger mediolateral tear size \( (P < .001) \), and a larger number of suture anchors \( (P < .001) \) were significantly associated with bone resorption of the greater tuberosity after rotator cuff repair. Multivariate analysis showed that the roughness of the greater tuberosity \( (OR, 9.07; 95\% CI, 1.13-72.82; P = .038) \) and a larger number of suture anchors \( (OR, 8.13; 95\% CI, 1.01-65.03; P = .048) \) were risk factors for bone resorption.

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anchors (OR, 3.34; 95% CI, 1.66-6.74; \( P = .001 \)) were risk factors for bone resorption of the greater tuberosity. The Hosmer-Lemeshow goodness-of-fit test showed no significant difference from the good model fit (\( P = .741 \)) (Table 4).

Risk Factors of Early Retear

Univariate analyses showed that a shorter duration of symptom (\( P = .005 \)), superior migration of humeral head (\( P = .036 \)), larger anteroposterior tear size (\( P = .029 \)), larger mediolateral tear size (\( P = .001 \)), and a larger number of suture anchors (\( P = .011 \)) were significantly associated with early retear after rotator cuff repair. Multivariate analysis showed that a larger mediolateral tear size (OR, 1.17; 95% CI, 1.01-1.35; \( P = .035 \)) was a risk factor for early retear. The Hosmer-Lemeshow goodness-of-fit test showed no significant difference from the good model fit (\( P = .244 \)) (Table 5).

DISCUSSION

In this study, we investigated the changes in plain radiographic findings during the 5 years after arthroscopic rotator cuff repair and conducted multivariate analyses to identify factors affecting these radiographic changes. As a result, we made 2 important clinical observations. First, osteoarthritis and acromial spurs appeared gradually and progressed after rotator cuff repair, whereas bone resorption of the greater tuberosity occurred within 2 years after rotator cuff repair and did not progress thereafter. Second, these radiographic changes showed significant associations with preoperative bone morphology of the greater tuberosity, tear size of the rotator cuff, the number of suture anchors used in surgery, and the presence of early retear. This study demonstrated that osteoarthritis after rotator cuff repair developed gradually over time. Moreover, osteoarthritis in 11% of the patients progressed to Samilson-Prieto classification grade C2 at 5 years postoperatively. Our results concurred with those of previous studies that evaluated short-term radiological outcomes after rotator cuff repair and which indicated that osteoarthritis develops in 4% to 17% of patients during a follow-up period of 3.6 to 7 years after surgery.\(^2^8,2^9,5^3\) In addition, previous studies that evaluated radiological outcomes for >10 years after surgery showed an increase in the incidence of osteoarthritis (up to 19%-29%) 10 to 20 years after surgery,\(^1,1^2,1^6,2^5\) suggesting that the frequency and grade of osteoarthritis after rotator cuff repair may increase over time, even 5 years postoperatively.

To date, the relationship between osteoarthritis after rotator cuff repair and postoperative outcomes has not been fully clarified, and no case required additional surgery in the present study. However, some studies have reported...
### TABLE 2
Univariate and Multivariate Predictors of Osteoarthritis After Rotator Cuff Repair

| Variable                        | Osteoarthritis (+) (n = 12) | Osteoarthritis (-) (n = 88) | P    | OR [95% CI] | P       |
|---------------------------------|-----------------------------|-----------------------------|------|-------------|---------|
| Age, years                      | 68 [62-74]                  | 63 [61-65]                  | .050 | 1.08 [0.98-1.18] | .141   |
| Female sex                      | 5 (42)                      | 33 (37)                     | .762 | -           | -       |
| Dominant arm affected           | 9 (75)                      | 60 (68)                     | .760 | -           | -       |
| Duration of symptoms, y         | 2.5 [0-5.0]                 | 1.7 [1.0-2.4]               | .991 | -           | -       |
| Trauma                          | 9 (75)                      | 64 (73)                     | ≥.999| -           | -       |
| Smoking                         | 5 (42)                      | 41 (47)                     | ≥.999| -           | -       |
| Diabetes                         | 2 (17)                      | 11 (13)                     | .563 | -           | -       |

| Morphology of greater tuberosity |                          |                            |     |             |         |
| Sclerosis                       | 7 (58)                     | 28 (32)                    | .105| -           | -       |
| Spur                            | 1 (8)                      | 6 (7)                      | ≥.999| -           | -       |
| Roughness                       | 2 (17)                     | 9 (10)                     | .618| -           | -       |
| Femoralization                  | 0 (0)                      | 8 (9)                      | .591| -           | -       |
| Superior migration of humeral head | 1 (8)                   | 11 (13)                     | ≥.999| -           | -       |

| Length of subacromial spur, mm  |                          |                            |     |             |         |
| Anterior                        | 2.7 [0-5.4]                | 2.3 [1.5-3.1]              | .832| -           | -       |
| Lateral                         | 1.8 [0.5-3.2]              | 1.1 [0.8-1.4]              | .178| -           | -       |

| Tear size, cm                   |                          |                            |     |             |         |
| Anteroposterior                 | 2.7 [2.1-3.3]             | 1.4 [1.2-1.6]              | .004 | 1.09 [1.01-1.17] | .037 |
| Mediolateral                    | 3.1 [2.6-3.5]             | 1.9 [1.6-2.2]              | .004 | 1.01 [0.95-1.08] | .714 |
| Suture anchors used in surgery  | 4.0 [3.3-4.7]             | 3.3 [2.9-3.7]              | .043 | 0.98 [0.59-1.63] | .940 |
| Early retear                    | 1 (8)                     | 6 (7)                      | ≥.999| -           | -       |

**a** Values are presented as % [95%CI] or No. (%). Dashes indicated no analyses performed. OR, odds ratio.

**b** Statistically significant (P ≤ .05).

### TABLE 3
Univariate and Multivariate Predictors of Acromial Spur Re-formation After Rotator Cuff Repair

| Variable                        | Spur (+) (n = 26) | Spur (-) (n = 74) | P    | OR [95% CI] | P       |
|---------------------------------|------------------|------------------|------|-------------|---------|
| Age, years                      | 65 [62-68]       | 63 [61-65]       | .311 | -           | -       |
| Female sex                      | 9 (35)           | 39 (53)          | .170 | -           | -       |
| Dominant arm affected           | 18 (69)          | 51 (69)          | ≥.999| -           | -       |
| Duration of symptoms (years)    | 2.0 [0.5-3.4]    | 1.7 [0.9-2.4]    | .169 | -           | -       |
| Trauma                          | 22 (85)          | 51 (69)          | .198 | -           | -       |
| Smoking                         | 14 (54)          | 32 (43)          | .370 | -           | -       |
| Diabetes                         | 5 (19)           | 8 (11)           | .321 | -           | -       |

| Morphology of greater tuberosity |                          |                            |     |             |         |
| Sclerosis                       | 8 (31)            | 27 (36)            | ≥.999| -           | -       |
| Spur                            | 3 (12)            | 4 (5)              | .372 | -           | -       |
| Roughness                       | 6 (23)            | 5 (7)              | .032 | 2.44 [0.57-10.42] | .229 |
| Femoralization                  | 2 (8)             | 6 (8)              | ≥.999| -           | -       |
| Superior migration of humeral head | 6 (23)            | 6 (8)              | .074 | -           | -       |
| Length of subacromial spur, mm  |                          |                            |     |             |         |
| Anterior                        | 3.4 [1.7-5.2]     | 1.9 [1.2-2.6]     | .661 | -           | -       |
| Lateral                         | 1.4 [0.9-2.1]     | 1.1 [0.8-1.5]     | .843 | -           | -       |

| Tear size, cm                   |                          |                            |     |             |         |
| Anteroposterior                 | 2.0 [1.6-2.4]          | 1.3 [1.0-1.6]           | <.001 | 0.98 [0.92-1.05] | .624 |
| Mediolateral                    | 2.9 [2.3-3.5]         | 1.7 [1.4-2.0]          | <.001 | 1.05 [0.99-1.11] | .099 |
| Suture anchors used in surgery  | 4.2 [3.4-5.0]         | 3.0 [2.7-3.3]          | <.001 | 1.19 [0.80-1.79] | .393 |
| Early retear                    | 6 (23)               | 1 (1)                | .001 | 10.26 [1.03-102.40] | .047 |

**a** Values are presented as % [95%CI] or No. (%). Dashes indicated no analyses performed. OR, odds ratio.

**b** Statistically significant (P ≤ .05).
### TABLE 4
Univariate and Multivariate Predictors of Greater Tuberosity Bone Resorption After Rotator Cuff Repair

| Variable                               | Univariate Predictors | Multivariate Predictors |
|----------------------------------------|------------------------|-------------------------|
|                                        | Resorption (\(+\))    | OR [95% CI]             |
|                                        | (n = 16)               |                         |
|                                        | Resorption (-)         |                         |
|                                        | (n = 84)               |                         |
|                                        | P                      |                         |
| **Variable**                           | **Resorption (\(+\))** | **Resorption (-)**      |
| **(n = 16)**                           | **(n = 84)**           |                         |
|                                        | **P**                  | **OR [95% CI]**         |
| **(n = 84)**                           |                         |                         |
| **P**                                  | **OR [95% CI]**        |                         |
| Age, years                             | 62 [57-67]             | 64 [62-66]              | .605 | - |
| Female sex                             | 6 (38)                 | 32 (38)                 | ≥.999 | - |
| Dominant arm affected                   | 8 (50)                 | 23 (27)                 | .084 | - |
| Duration of symptoms, years            | 1.6 [0.2-3.0]          | 1.8 [1.0-2.6]           | .702 | - |
| Trauma                                 | 13 (81)                | 60 (71)                 | .547 | - |
| Smoking                                | 8 (50)                 | 38 (45)                 | .789 | - |
| Diabetes                               | 4 (25)                 | 9 (11)                  | .215 | - |
| Morphology of greater tuberosity       |                        |                         |     |     |
| Sclerosis                              | 4 (25)                 | 31 (37)                 | .409 | - |
| Spur                                   | 3 (19)                 | 4 (5)                   | .079 | - |
| Roughness                              | 7 (44)                 | 4 (5)                   | <.001<sup>b</sup> | 9.07 [1.13-72.82] | .038<sup>b</sup> |
| Femoralization                         | 0 (0)                  | 8 (10)                  | .438 | - |
| Superior migration of humeral head      | 4 (25)                 | 8 (10)                  | .098 | - |
| **Length of subacromial spur, mm**     |                        |                         |     |     |
| Anterior                               | 1.5 [0-3.0]            | 2.5 [1.7-3.3]           | .180 | - |
| Lateral                                | 0.3 [0-0.5]            | 1.3 [1.0-1.7]           | .080 | - |
| **Tear size, cm**                      |                        |                         |     |     |
| Anteroposterior                        | 2.6 [2.0-3.2]          | 1.4 [1.2-1.6]           | <.001<sup>b</sup> | 1.06 [0.97-1.15] | .125 |
| Mediolateral                           | 3.2 [2.8-3.6]          | 1.8 [1.5-2.1]           | <.001<sup>b</sup> | 0.97 [0.90-1.06] | .530 |
| Suture anchors used in surgery         | 5.5 [5.0-6.0]          | 2.9 [2.6-3.2]           | <.001<sup>b</sup> | 3.34 [1.66-6.74] | .001<sup>b</sup> |
| Early retear                           | 2 (13)                 | 5 (6)                   | .311 | - |

<sup>a</sup>Values are presented as % [95%CI] or No. (%). Dashes indicated no analyses performed. OR, odds ratio.

<sup>b</sup>Statistically significant (P ≤ .05).

### TABLE 5
Univariate and Multivariate Predictors of Early Retear After Rotator Cuff Repair

| Variable                               | Univariate Predictors | Multivariate Predictors |
|----------------------------------------|------------------------|-------------------------|
|                                        | Early retear (\(+\))  | OR [95% CI]             |
|                                        | (n = 7)                |                         |
|                                        | Early retear (-)       |                         |
|                                        | (n = 93)               |                         |
|                                        | P                      |                         |
| **Variable**                           | **Early retear (\(+\))** | **Early retear (-)**      |
| **(n = 7)**                            | **(n = 93)**           |                         |
|                                        | **P**                  | **OR [95% CI]**         |
| **(n = 93)**                           |                         |                         |
| **P**                                  | **OR [95% CI]**        |                         |
| Age, years                             | 63 [58-69]             | 63 [62-65]              | .882 | - |
| Female sex                             | 3 (43)                 | 35 (38)                 | ≥.999 | - |
| Dominant arm affected                   | 5 (71)                 | 64 (69)                 | ≥.999 | - |
| Duration of symptoms, years            | 0.4 [0.3-0.6]          | 1.9 [1.2-2.6]           | .005<sup>b</sup> | 0.00 [0.00-5.90] | .125 |
| Trauma                                 | 7 (100)                | 66 (71)                 | .185 | - |
| Smoking                                | 4 (57)                 | 42 (45)                 | .234 | - |
| Diabetes                               | 1 (14)                 | 12 (13)                 | ≥.999 | - |
| Morphology of greater tuberosity       |                        |                         |     |     |
| Sclerosis                              | 2 (29)                 | 33 (35)                 | ≥.999 | - |
| Spur                                   | 0 (0)                  | 7 (8)                   | ≥.999 | - |
| Roughness                              | 2 (29)                 | 9 (10)                  | .17  | - |
| Femoralization                         | 0 (0)                  | 8 (9)                   | ≥.999 | - |
| Superior migration of humeral head      | 3 (43)                 | 9 (10)                  | .036<sup>b</sup> | 5.33 [0.44-64.12] | .187 |
| **Length of subacromial spur, mm**     |                        |                         |     |     |
| Anterior spur                          | 3.3 [1.4-5.2]          | 2.3 [1.5-3.0]           | .057 | - |
| Lateral spur                           | 0.4 [-0.5 to 1.3]      | 1.2 [0.9-1.6]           | .146 | - |
| **Tear size, cm**                      |                        |                         |     |     |
| Anteroposterior                        | 2.3 [1.9-2.8]          | 1.6 [1.3-1.8]           | .029<sup>b</sup> | 0.89 [0.77-1.04] | .137 |
| Mediolateral                           | 3.7 [3.2-4.2]          | 1.9 [1.6-2.2]           | .001<sup>b</sup> | 1.17 [1.01-1.35] | .035<sup>b</sup> |
| Suture anchors used in surgery         | 5.1 [3.5-6.7]          | 3.2 [2.9-3.4]           | .011<sup>b</sup> | 1.54 [0.76-3.11] | .234 |

<sup>a</sup>Values are presented as % [95%CI] or No. (%). Dashes indicated no analyses performed. OR, odds ratio.

<sup>b</sup>Statistically significant (P ≤ .05).
that postoperative osteoarthritis is associated with poor functional outcomes. Therefore, it is important to identify factors affecting the onset of postoperative osteoarthritis. Our study showed that only the tear size of the rotator cuff was a risk factor for osteoarthritis 5 years after surgery. The results were similar to those of previous studies in which tear severity factors, such as massive rotator cuff tears and muscle atrophy, affected the progression of postoperative osteoarthritis. Further, multivariate analysis performed in the present study showed that the anteroposterior tear size, but not mediolateral tear size, was significantly associated with postoperative osteoarthritis, suggesting that the anteroposterior dimension of tear length has a greater influence on the development of postoperative osteoarthritis than the mediolateral dimension. The number of suture anchors used, which is considered highly correlated with tear size, was also significantly associated with postoperative osteoarthritis in the univariate analysis, but not in the multivariate analysis. This suggests that tear size is a greater contributor to the development of postoperative osteoarthritis than the number of suture anchors. Early retears, older age, and male sex were also identified as risk factors for postoperative osteoarthritis in previous studies; however, multivariate analysis of the present study showed no significant association between these factors and postoperative osteoarthritis. This may be due to the difference in the follow-up period of the patients between this study and the previous studies and the fact that the results of the previous studies were based on univariate analysis only.

Acromial anterior spurs are thought to be traction spurs that developed at the insertion of the coracoacromial ligament to the acromion, whereas lateral spurs are thought to result from mechanical stress caused by impingement of the greater tuberosity on the middle fiber of deltoid. Both spurs have been associated with the presence of acromial impingement and rotator cuff tears. However, the frequency of re-formation of an acromial spur after rotator cuff repair and its risk factors remain unclear. This study revealed that most acromial spurs gradually appeared since the third postoperative year and that the frequency at 5 years after surgery was 26%. In addition, this study showed an association between re-formation of acromial spurs and early retears within 2 years after surgery. To date, no study has evaluated the mechanism of acromial spur re-formation in patients who experienced retears. Previous studies have shown that patients with retears after rotator cuff repair exhibit a significant decrease in acromiobursal distance. This superior migration of the humeral head causes frequent acromial impingement, which may be the underlying mechanism of acromial spur re-formation. While acromial anterior spurs measuring ≥5 mm or lateral spurs measuring ≥3 mm have been reported to be a diagnostic indicator of rotator cuff tears, the present study highlighted the possibility that re-formation of acromial spurs after rotator cuff repair may be a result of early retears.

In addition, we found that 16% of patients experienced bone resorption of the greater tuberosity after rotator cuff repair, most of which appeared within 1 year after surgery. A previous study reported that the greater tuberosity presents with flattened and abnormal morphology after rotator cuff repair. However, the pathogenesis of such radiographic changes in the greater tuberosity has not yet been clarified. We have 2 hypotheses regarding the development of greater tuberosity resorption, the first being inflammatory response to biodegradable anchors that is reflected in T2 signal hyperintensity around the suture anchor in the greater tuberosity on MRI. This response lasts postoperatively and is thought to cause the osteolysis around suture anchors. This bone reaction to suture anchors may have contributed to the resorption of the greater tuberosity in the early postoperative period. Our second hypothesis concerns reduction in bone mineral density of the greater tuberosity in patients with rotator cuff tears. In these patients, the activation of osteoclasts, reduced mechanical stress by the rotator cuff tear, caused greater tuberosity osteopenia, which may have contributed to the onset of bone resorption after surgery. The present study showed that the number of suture anchors used in surgery was significantly related to bone resorption in the greater tuberosity. In the cases that required more suture anchors, the bone reaction to suture anchors may have been stronger, which may have affected the greater tuberosity resorption.

Osteopenic changes in the greater tuberosity have been reported to be significantly remarkable in patients with moderate-to-severe retraction of the rotator cuff. This low bone density of the greater tuberosity may be also related to postoperative bone resorption, as more suture anchor is required in cases with severe tendon retraction. In addition, the present study showed a significant association between the bone morphology of the greater tuberosity and greater tuberosity resorption. In patients with rotator cuff tears, chronic tensile overload and heterogeneous strain from the rotator cuff tendons are thought to lead to the formation of spurs and sclerosis of the greater tuberosity. Furthermore, when the rotator cuff is torn, erosion of bone spurs or the sclerotic cortex gradually progresses due to acromial impingement, resulting in cortical surface roughness. Our study, along with earlier studies, has raised the possibility that this erosion of the greater tuberosity may be further stimulated by inflammation associated with suture anchors, resulting in the progression of bone resorption. Although this bone reaction has been reported to occur in absorbable anchors more frequently than in nonabsorbable anchors, the type of suture anchor (bioinductive anchor) has little influence on the results of this study. However, further studies are needed to clarify the effects of bone morphology of the greater tuberosity on postoperative bone resorption.

References 4, 22, 23, 27, 37, 39, 42, 44, 45.
Despite concerns about the adverse effects of greater tuberosity osteopenia and postoperative bone resorption on tendon healing, the present study revealed that, unlike osteoarthritic changes or acromial spur re-formation, progression of bone resorption stopped 1 to 2 years after surgery and showed no significant association with early retears, suggesting that the number of suture anchors and bone morphology of the greater tuberosity may not adversely affect the postoperative outcomes.

Regarding early retear, contrary to the risk factor for postoperative osteoarthritic, mediolateral tear size, but not anteroposterior tear size, were identified as significant risk factors in the multivariate analysis results, which is consistent with previous reports. It has been thought that rotator cuff retraction increases tension on the repaired tendon, resulting in poor footprint coverage, or reflects longer and worse tendon quality. The results of this study suggest that patients with a large, intraoperatively observed mediolateral tear should be followed up with caution for retears.

Strengths and Limitations

This study has 2 major strengths. First, assessment of postoperative radiographic changes over time following rotator cuff repair was feasible in this study because imaging evaluation was performed every year for 1 to 5 years after surgery. Most of the previous studies examining radiographic outcomes after rotator cuff repair evaluated patients only at 1 point in the postoperative period. Second, this study is novel in that it involved only patients who underwent arthroscopic rotator cuff repair using bioinductive anchors, while most of the previous studies only evaluated cases of open rotator cuff repair and mixed cases of open and arthroscopic rotator cuff repair.

This study had several limitations. First, this was an observational study; therefore, the results could be affected by residual confounding bias as the result of differences in factors that were not measured. For example, the shape of the tear (crescent tear, L- or U-shaped tear, or massive contracted tear) and muscle atrophy of the torn tendon can also influence the postoperative radiographic outcome; however, we could not evaluate these factors in this study. Second, we did not evaluate postoperative functional outcomes in this study. Since no patient with postoperative radiographic changes required reoperation, statistical significance may not imply clinical significance. Thus, the association between postoperative radiologic changes and functional outcomes remains unclear. Third, 54 patients were excluded because of inadequate follow-up, which may have affected the results of this study. Fourth, rotator cuff tears are generally atraumatic degenerative tears, however, 73 cases in this study had a history of trauma. Although most of the traumas were minor, they may reduce the generalizability of the results. Fifth, identifying immediate postoperative radiographic changes suggestive of early retears would also be significant clinically, but we could not evaluate them due to a lack of frequent follow-up with plain radiography immediately after surgery (especially within 2 years postoperatively).

CONCLUSION

The results of our study showed that radiographic changes occurred in 40% of patients within 5 years after arthroscopic rotator cuff repair. While the osteoarthritic changes and acromial spur re-formation gradually progressed postoperatively, the greater tuberosity resorption stopped within 2 years after surgery. Tear size, the morphology of the greater tuberosity, and the number of suture anchors can affect radiographic changes. Furthermore, this study suggested that acromial spur re-formation may be an indicator of early retears.

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