

# What Influence Does Progression of a Nonhealing Rotator Cuff Tear Have on Shoulder Pain and Function?

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## Abstract

**Background** There have been numerous reports of clinical outcomes associated with tendon healing after repair that suggest a nonhealed tendon has a negative effect on postoperative clinical outcomes. However, to our knowledge, there has been no report on the relationship between tear size progression of nonhealed tendons and clinical outcomes.

**Questions/purposes** (1) Do patients with healed arthroscopic rotator cuff repairs have better outcomes, less pain, and more strength than patients whose repair did not heal? (2) In patients with nonhealed rotator cuff tendons, does tear size progression (increase or decrease) affect

outcomes, pain, and strength? (3) Is there continued improvement beyond 6 months in outcomes, pain, and strength; and how do the improvements differ based on whether the tear size has increased or decreased?

**Methods** Between May 2008 and December 2012, 647 patients underwent arthroscopic rotator cuff repair for full-thickness tears at our institution. Of those, 442 patients (68%) had all MRI and clinical information available to permit inclusion in this retrospective study at a minimum of 2 years followup (mean,  $33 \pm 4$  months; range, 24–43 months). Healing of the repaired tendon and tear size progression were assessed using MRI at 6 months postoperatively. Eighty-two of 442 tears (19%) were not healed. Of the nonhealed tears, 45 (55%) had a decrease and 37 (45%) had an increase in tear size. Shoulder function outcomes using the American Shoulder and Elbow Surgeon (ASES) and Constant scores and pain severity using VAS scores were evaluated preoperatively, at 6 months postoperatively, and at the latest followup. Isometric muscle strength was measured at 6 months postoperatively and at the latest followup.

**Results** Compared with patients with nonhealed tendons after arthroscopic rotator cuff repair, patients with healed repairs had improved ASES scores (healed,  $93 \pm 5$ ; nonhealed,  $89 \pm 8$ ; mean difference, 4; 95% CI, 3–5;  $p < 0.001$ ), better Constant scores (healed,  $91 \pm 5$ ; nonhealed,  $85 \pm 8$ ; mean difference, 6; 95% CI, 4–7;  $p < 0.001$ ), and greater strength ([flexion: healed,  $96\% \pm 7\%$ ; nonhealed,  $85\% \pm 12\%$ ; mean difference, 11%; 95% CI, 9%–13%;  $p < 0.001$ ]; [external rotation: healed,  $92\% \pm 8\%$ ; nonhealed,  $80\% \pm 12\%$ ; mean difference, 11%; 95% CI, 9%–14%;  $p < 0.001$ ]; [internal rotation: healed,  $97\% \pm 8\%$ ; nonhealed,  $92\% \pm 8\%$ ; mean difference, 5%; 95% CI, 3%–7%;  $p < 0.001$ ]); however there was no difference in pain level based on VAS scores (healed,  $0.9 \pm 0.8$ ; nonhealed,

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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$1.0 \pm 0.8$ ; mean difference, 0.2; 95% CI, 0.0–0.4;  $p = 0.226$ ). Compared with patients with increased tear size, patients with decreased tear size had better ASES scores (decreased,  $91 \pm 6$ ; increased,  $86 \pm 8$ ;  $p = 0.001$ ), improved Constant scores (decreased,  $88 \pm 6$ ; increased,  $82 \pm 9$ ;  $p = 0.003$ ), greater flexion strength (decreased,  $91\% \pm 9\%$ ; increased,  $78\% \pm 11\%$ ;  $p < 0.001$ ), and greater external rotation strength (decreased,  $86\% \pm 10\%$ ; increased,  $73\% \pm 11\%$ ;  $p < 0.001$ ). However, the difference does not seem to meet a minimal clinically important difference. Patients with increased tear size differed from those with decreased tear size with respect to flexion and external rotation strength where the former had no improvement. There was no improvement in flexion (6 months,  $78\% \pm 11\%$ ; latest followup,  $78\% \pm 11\%$ ;  $p = 0.806$ ) and external rotation strength (6 months,  $74\% \pm 12\%$ ; latest followup,  $73\% \pm 11\%$ ;  $p = 0.149$ ).

**Conclusions** Patients who had healed tendons after arthroscopic rotator cuff repair had better shoulder function than patients who had nonhealed tendons. Among patients with nonhealed rotator cuff tendons after surgery, those with decreased tear size, observed on their 6-month postoperative MRI, compared with their initial tear size, showed better shoulder function and muscle strength than those with increased tear size beyond 6 months. Although results are statistically different, they seem insufficient to achieve clinically important differences.

**Level of Evidence** Level III, therapeutic study.

## Introduction

Rotator cuff tears commonly are found in elderly patients and frequently lead to shoulder dysfunction, which is an important cause of missed work and pain. As many arthroscopic repair techniques using diverse combinations of suture configurations, anchor types, and number of sutures passing the tendon have been developed, satisfactory clinical outcomes have been reported after rotator cuff repair [10]. However, the retear rate of the rotator cuff after repair has been reported at approximately 20% despite various advanced arthroscopic surgical techniques to improve cuff healing [5, 9, 17].

Despite a high risk that a rotator cuff tear may not heal, studies disagree regarding whether this actually results in clinically important problems for patients, such as persistent pain or worsening shoulder dysfunction [4, 13, 20]. One meta-analysis regarding postoperative clinical outcomes in patients with nonhealed rotator cuff tendons showed a lack of correlation with rotator cuff integrity, and patients' shoulder function was improved after surgery compared with their preoperative status despite failure of

tendon healing [16]. Jost et al. [13] reviewed their patients who had structural failure of the rotator cuff after repair at an average of 8 years. They likewise reported clinically important improvements in their patients compared with before surgery. By contrast, others have found that a lack of tendon healing after surgery is associated with persistent pain and shoulder dysfunction [6, 21]. Therefore the relationship between the clinical outcomes after rotator cuff repair and postoperative integrity of the repaired tendons remains open to debate. However, the effect of tear size progression of a nonhealed tendon on the postoperative clinical outcomes remains to be discussed.

Therefore we asked: (1) Do patients with healed arthroscopic rotator cuff repairs have better outcomes, less pain, and more strength than patients whose repairs did not heal? (2) In patients with nonhealed rotator cuff tendons, does tear size progression (increase or decrease) affect outcomes, pain, and strength? (3) Is there continued improvement beyond 6 months in outcomes, pain, and strength, and how do the improvements differ based on whether the tear size has increased or decreased?

## Patients and Methods

From May 2008 to December 2012, 647 patients with a symptomatic full-thickness rotator cuff tear and arthroscopic complete repair of a torn tendon over the anatomic insertion area of the greater tuberosity were identified for study. The institutional review board approved the study protocol, and informed consent was obtained from all participants. A total of 97 patients (15%) were excluded for missing the 6-month postoperative MRI. Also excluded were patients who underwent revision shoulder surgery, with isolated subscapularis tears, tears associated with glenohumeral arthritis, stiffness or instability, with symptomatic acromioclavicular joint disorders, concomitant labral tears, and those with workers' compensation claims (together, those exclusions represented 39 patients [6%] of the original 647). Finally 69 patients (11%) were lost to followup before 2 years, leaving 442 patients for analysis. There were 209 men and 233 women with a mean age of  $55 \pm 7$  years (range, 46–75 years). The average followup was  $33 \pm 4$  months (range, 24–43 months) (Table 1).

Rotator cuff tears in all patients were confirmed by preoperative MRI, and the characteristics of the rotator cuff tendon were evaluated. All patients underwent 1.5-T MRI with a shoulder array coil, at the same institution. The slice thickness was 3 mm, with an interslice gap of 0.3 mm. Patients were categorized based on tear size in small (< 1 cm), medium (1–3 cm), and large to massive (> 3 cm) tear groups by the longest medial to lateral length on the coronal image and anterior to posterior width on the

**Table 1.** Comparison of patient demographics

Demographic	Patients who achieved healing (n = 360)	Patients who did not achieve healing (n = 82)	p Value
Age (years)*	55 ± 6	58 ± 7	< 0.001
Sex (men:women)	178:182	31:51	
Followup (months)	33 ± 4	32 ± 5	0.623
Dominant arm*	288 (80%)	54 (66%)	0.006
Tear size category			
Small to medium	317	50	
Large to massive	43	32	

Values are mean ± SD; \*statistically significant difference.

sagittal image of the preoperative MR images. Arthroscopic single-row repair was done in patients with small to medium rotator cuff tears, and transosseous-equivalent suture bridge repair was performed in patients with large to massive rotator cuff tears.

Patients were placed in the lateral decubitus position. After interscalene nerve block and induction of general anesthesia, a subacromial bursectomy was performed routinely in all patients. However, an acromioplasty was performed only on hook-type acromions or acromions with a prominent osteophyte that could induce impingement. The single-row repair technique was performed using one or two double-loaded absorbable suture anchors. The transosseous-equivalent suture bridge repair was performed using two or three double-loaded absorbable suture anchors in the medial row and two suture anchors in the lateral row. After the medial-row suture was tied horizontally, two lateral anchors were inserted in the lateral cortex of the proximal humerus to make a suture-bridge configuration using the tied suture limb. All operations were performed by one experienced surgeon (S-JS).

All patients underwent a standard rehabilitation program of stretching exercise training according to the size of the tear. For patients with small to medium tears, a shoulder brace with 0° external rotation and 15° abduction was applied for 4 weeks. The patients with large to massive tears were allowed to wear a brace for an additional 2 weeks. The patients with small to medium rotator cuff tears were allowed to engage in passive ROM exercises when it was tolerable; however, 6 weeks was required for those with large to massive tears. Active shoulder motion exercises were allowed after 3 months postoperatively in all patients. Simultaneously, strengthening exercises were conducted using an elastic band that allowed forward flexion and internal and external rotation. Return to sports and heavy labor were allowed 6 months postoperatively for all patients. All patients participated in a daily home exercise program. Rehabilitation instructions were reiterated at every followup, and patients were actively encouraged to maintain their daily home exercise program.

**Table 2.** Comparison of patient demographics

Demographic	Decreased tear size (n = 45)	Increased tear size (n = 37)	p Value
Age (years)	57 ± 6	58 ± 7	0.397
Sex (men:women)	20:25	11:26	
Followup (months)	32 ± 5	33 ± 5	0.822
Dominant arm	32 (71%)	22 (59%)	0.268
Tear size category			
Small to medium	29	21	
Large to massive	16	16	

Values are mean ± SD.

Tendon integrity was evaluated on postoperative MR images, and a healed tendon was defined as one of homogeneous low intensity and of full-thickness continuity with the bone. Nonhealed tendons were involved in the presence of fluid signal intensity in any rotator cuff tendon and complete discontinuity of the tendon in at least two planes. Of the total 442 patients, 360 patients (81%) had a healed tendon and the remaining 82 patients (19%) had a nonhealed rotator cuff.

Among the patients with a nonhealed tendon after failure of the repair, the sizes of the preoperative and postoperative tears were determined by measuring the longest distance from the tip of greater tuberosity to the lateral edge of the retracted tendon or torn tendon gap on the coronal images, or the widest gap of the torn tendon on sagittal MR images, in millimeters [3]. Preoperative and postoperative MR images were interpreted by an expert musculoskeletal radiologist (J-YH) and an orthopaedic surgeon (T-HK) blinded to patient history. The actual measurement of the tear size from the MR image was performed and averaged independently by two orthopaedic surgeons (JHA and SWC) blinded to patient information.

Of the 82 patients with a nonhealed tendon after rotator cuff repair, 45 patients (55%) had decreased tear size compared with the initial defect and 37 patients (45%) had an increased tear size observed on the 6-month postoperative MR images (Table 2). The mean lengths of the

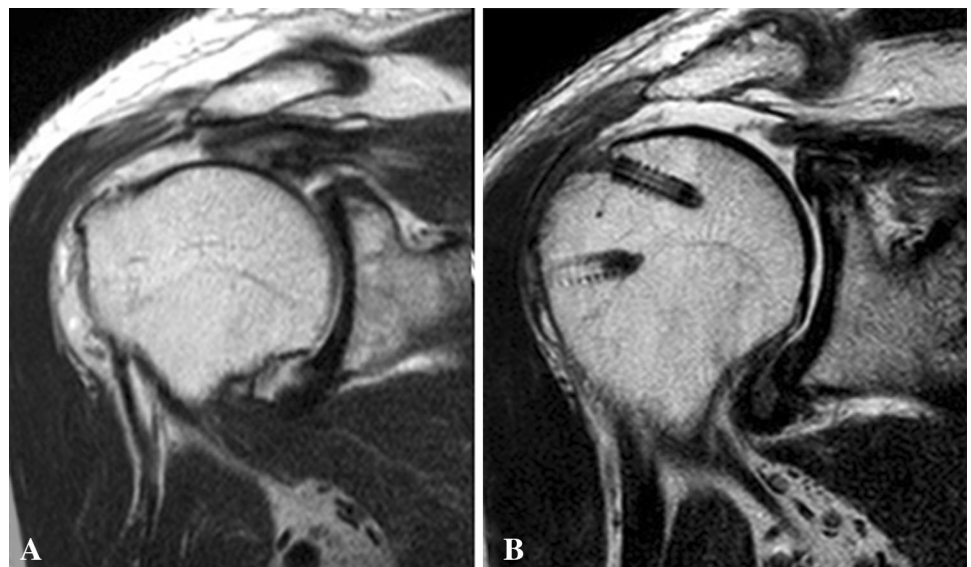
preoperative and postoperative tears, when an increase was observed, were  $28 \pm 13$  mm and  $32 \pm 13$  mm, respectively. In terms of decreased sizes of tears, the mean lengths of the preoperative and postoperative tears were  $23 \pm 13$  mm and  $16 \pm 11$  mm, respectively. Of 45 patients with decreased nonhealed tendons, 29 patients (64%) had small to medium tears preoperatively, and of 37 patients with increased nonhealed tendons, 16 patients (43%) had large to massive tears preoperatively. There were no statistical differences in the proportion of preoperative rotator cuff tear size between the two groups ( $p = 0.105$ ).

The shoulder functional outcomes were evaluated at 6 months postoperatively and at the latest followup. For the clinical comparison after arthroscopic rotator cuff repair, based on MR images obtained at 6 months postoperatively, all patients were divided into groups with a healed tendon or a nonhealed tendon. For the clinical comparison based on tear size progression after tendon repair failure in patients with confirmed nonhealed rotator cuff tendons, patients were divided into groups with a decreased tear size compared with the preoperative tear size (Fig. 1) or an increased tear size (Fig. 2). In patients with a nonhealed

**Fig. 1A–B** (A) An oblique coronal MR image of the preoperative medium-size rotator cuff tear is shown. (B) A postoperative oblique coronal MR image of the left shoulder obtained at the 6-month followup after repair shows a decreased tear size.



**Fig. 2A–B** (A) An oblique coronal MR image of the right shoulder obtained before surgery is shown. (B) A postoperative oblique coronal MR image obtained 6 months after repair shows increased tear size.





tendon, clinical outcomes at 6 months postoperatively were compared with those at the latest followup to assess functional improvement according to tear progression. A goniometer was used to measure preoperative and postoperative ranges of shoulder motion at the point of pain. The American Shoulder and Elbow Surgeons (ASES) and Constant scores [2] were used to evaluate shoulder functional outcomes. The VAS score was used to evaluate pain after surgery.

Isometric muscle strength was measured using the Nottingham Myometer (Mecmesin Co, Nottingham, UK) by the same examiner (M-RK) preoperatively, at 6 months postoperatively, and at the latest followup. The contralateral shoulder was tested in an identical manner for comparison. The strength of the forward flexion, internal rotation, and external rotation was calculated as a percentage of the contralateral shoulder strength. The muscle strength was recorded during tests, and instructions were given to patients to elevate or rotate with maximal strength. The muscle strength of the affected shoulder was calculated as a percentage of the contralateral shoulder strength.

All clinical evaluations were performed by the examiner (M-RK) who was not involved in this study. In addition, preoperative demographic factors such as age, gender, and dominant shoulder were recorded.

#### Statistical Analysis

Comparisons between patients with healed and nonhealed tendons for clinical outcomes were performed using Student's t-test. Clinical comparison based on the progression of rotator cuff tear size between 6 months postoperatively and latest followup was performed using a paired t-test. Comparisons among the categorical variables were performed using a chi-square test for distribution of preoperative tear size and progression of tear size. Statistical analysis was performed using SPSS software (Version 18.0; SPSS Inc, Chicago, IL, USA) with a 95% CI.

#### Results

Compared with patients with nonhealed tendons after arthroscopic rotator cuff repair, patients with healed repairs had improved ASES scores (healed,  $93 \pm 5$ ; nonhealed,  $89 \pm 8$ ; mean difference, 4; 95% CI, 3–5;  $p < 0.001$ ), better Constant scores ( $91 \pm 5$  versus  $85 \pm 8$ ; mean difference, 6; 95% CI, 4–7;  $p < 0.001$ ), and greater strength ([flexion,  $96\% \pm 7\%$  versus  $85\% \pm 12\%$ ; mean difference, 11%; 95% CI, 9%–13%;  $p < 0.001$ ]; [external rotation,  $92\% \pm 8\%$  versus  $80\% \pm 12\%$ ; mean difference, 11%; 95% CI, 9%–14%;  $p < 0.001$ ]; [internal rotation,  $97\% \pm 8\%$  versus  $92\% \pm 8\%$ ; mean difference, 5%; 95% CI, 3%–7%;  $p < 0.001$ ]), but there was no difference in pain level based on VAS scores ( $0.9 \pm 0.8$  versus  $1.0 \pm 0.8$ ; mean difference, 0.2; 95% CI, 0.0–0.4;  $p = 0.226$ ) (Table 3). Two of the patients with nonhealed tendons (two of 82; 2%) underwent revision surgery owing to pain and motion impairment, whereas there were no revision procedures in patients with healed tendons during the followup period.

Compared with patients with an increased tear size, those with decreased tear sizes had few, if any, clinically important differences. Compared with patients with increased tear size, patients with decreased tear sizes had better ASES scores (decreased,  $91 \pm 6$ ; increased,  $86 \pm 9$ ; mean difference, 5; 95% CI, 2–9;  $p = 0.001$ ), improved Constant scores ( $88 \pm 6$  versus  $82 \pm 9$ ; mean difference, 5; 95% CI, 2–9;  $p = 0.003$ ), greater flexion strength ( $91\% \pm 9\%$  versus  $78\% \pm 11\%$ ; mean difference, 13%; 95% CI, 8%–17%;  $p < 0.001$ ), and greater external rotation strength ( $86\% \pm 10\%$  versus  $73\% \pm 11\%$ ; mean difference, 12%; 95% CI, 7%–17%;  $p < 0.001$ ) (Table 4). There were no differences in VAS pain scores ( $1.0 \pm 0.8$  versus  $1.1 \pm 0.9$ ; mean difference, 0.1; 95% CI, –0.5 to 0.3;  $p = 0.590$ ) and internal rotation strength ( $93\% \pm 8\%$  versus  $90\% \pm 8\%$ ; mean difference, 3%; 95% CI, –1% to 6%;  $p = 0.124$ ).

Patients with increased tear size differed from those with decreased tear size with respect to flexion and external rotation strength, where the former had no improvement

**Table 3.** Comparison of the final clinical outcomes of patients

Variable	Patients who achieved healing (n = 360)	Patients who did not achieve healing (n = 82)	Mean difference (95% CI)	p Value
ASES score*	$93 \pm 5$	$89 \pm 8$	4 (3–5)	< 0.001
Constant score*	$91 \pm 5$	$85 \pm 8$	6 (4–7)	< 0.001
VAS for pain	$0.9 \pm 0.8$	$1.0 \pm 0.8$	0.2 (0.0–0.4)	0.226
Muscle strength* (%)				
Flexion	$96 \pm 7$	$85 \pm 12$	11 (9–13)	< 0.001
External rotation	$92 \pm 8$	$80 \pm 12$	11 (9–14)	< 0.001
Internal rotation	$97 \pm 8$	$92 \pm 8$	5 (3–7)	< 0.001

Values are mean  $\pm$  SD; \*statistically significant difference; ASES = American Shoulder and Elbow Surgeons.

**Table 4.** Comparison of the final clinical outcomes of patients

Variable	Decreased tear size (n = 45)	Increased tear size (n = 37)	Mean difference (95% CI)	p Value
ASES score*	91 ± 6	86 ± 9	5 (2–9)	0.001
Constant score*	88 ± 6	82 ± 9	5 (2–9)	0.003
VAS for pain	1.0 ± 0.8	1.1 ± 0.9	0.1 (–0.5–0.3)	0.590
Muscle strength (%)				
Flexion*	91 ± 9	78 ± 11	13 (8–17)	< 0.001
External rotation*	86 ± 10	73 ± 11	12 (7–17)	< 0.001
Internal rotation	93 ± 8	90 ± 8	3 (–1–6)	0.124

Values are mean ± SD; \*statistically significant difference; ASES = American Shoulder and Elbow Surgeons.

**Table 5.** Clinical comparison of patients with a decreased size of nonhealed tendon

Variable	Postoperative 6 months	Latest followup	Mean difference (95% CI)	p Value
ASES score*	89 ± 7	91 ± 6	3 (2–4)	< 0.001
Constant score*	85 ± 7	88 ± 6	3 (2–4)	< 0.001
VAS for pain*	1.7 ± 0.9	1.0 ± 0.8	0.8 (0.5–1.0)	< 0.001
Muscle strength (%)				
Flexion*	89 ± 10	91 ± 9	2 (1–4)	0.004
External rotation*	82 ± 11	86 ± 10	3 (1–5)	0.003
Internal rotation*	91 ± 7	93 ± 8	2 (1–3)	0.004

Values are mean ± SD; \*statistically significant difference; ASES = American Shoulder and Elbow Surgeons; p value = results between 6 months and latest followup.

**Table 6.** Clinical comparison of patients with an increased size of nonhealed tendon

Variable	Postoperative 6 months	Latest followup	Mean difference (95% CI)	p Value
ASES score*	80 ± 8	86 ± 9	6 (4–7)	< 0.001
Constant score*	75 ± 9	82 ± 9	7 (5–9)	< 0.001
VAS for pain	1.8 ± 1.0	1.1 ± 0.9	0.7 (0.4–1.0)	< 0.001
Muscle strength (%)				
Flexion	78 ± 11	78 ± 11	0 (–1–1)	0.806
External rotation	74 ± 12	73 ± 11	1 (0–3)	0.149
Internal rotation*	88 ± 8	90 ± 8	2 (1–2)	< 0.001

Values are mean ± SD; \*statistically significant difference; ASES = American Shoulder and Elbow Surgeons; p values = results between 6 months and latest followup.

(Table 5). Patients with decreased tear size had improved ASES scores (6 months, 89 ± 7; latest, 91 ± 6; mean difference, 3; 95% CI, 2–4;  $p < 0.001$ ), Constant scores (6 months, 85 ± 7; latest, 88 ± 6; mean difference, 3; 95% CI, 2–4;  $p < 0.001$ ), and VAS pain scores (6 months, 1.7 ± 0.9; latest, 1.0 ± 0.8; mean difference, 0.8; 95% CI, 0.5–1.0;  $p < 0.001$ ). Patients with increased tear size also had improved ASES scores (6 months, 80 ± 8; latest, 86 ± 9; mean difference, 6; 95% CI, 4–7;  $p < 0.001$ ), Constant scores (6 months, 75 ± 9; latest, 82 ± 9; mean difference, 7; 95% CI, 5–9;  $p < 0.001$ ), and VAS pain scores (6

months, 1.8 ± 1.0; latest, 1.1 ± 0.9; mean difference, 0.7; 95% CI, 0.4–1.0;  $p < 0.001$ ) (Table 6). However, although patients with decreased tear size had continued improvement in strength of flexion (89% ± 10% to 91% ± 9%; mean difference, 2%; 95% CI, 1%–4%;  $p = 0.004$ ), external rotation (82% ± 11% to 86% ± 10%; mean difference, 3%; 95% CI, 1%–5%;  $p = 0.003$ ), and internal rotation (91% ± 7% to 93% ± 8%; mean difference, 2%; 95% CI, 1%–3%;  $p = 0.004$ ), patients with increased tear size improved only in strength of internal rotation (88% ± 8% to 90% ± 8%; mean difference, 2%; 95% CI, 1%–2%;  $p$

< 0.001) but not flexion ( $78\% \pm 11\%$  to  $78\% \pm 11\%$ ; mean difference, 0%; 95% CI,  $-1\%$  to  $1\%$ ;  $p = 0.806$ ) and external rotation ( $74\% \pm 12\%$  to  $73\% \pm 11\%$ ; mean difference, 1%; 95% CI,  $0\%$ – $3\%$ ;  $p = 0.149$ ).

## Discussion

Despite satisfactory shoulder function outcomes after rotator cuff repair according to the evolvement of surgical techniques and instruments [10], the high nonhealing rate of repaired tendons is still a concern. Several studies have investigated the relationship between the clinical outcomes after rotator cuff repair and postoperative integrity of the repaired tendons [6, 13, 16]. However, to our knowledge, there are no studies analyzing the clinical outcome according to the progression of re-tear size compared with the initial defect. In this study, we analyzed how tear size progression influenced the clinical outcome for patients with nonhealed rotator cuff tendons. The most important finding was that for patients with nonhealed tendons, those with increased tear size differed in shoulder function and muscle strength from those with decreased tear size.

Our study has several limitations. First, patients who had a concomitant partial thickness subscapularis tear were included in the study. Although the presence of the subscapularis tear may have a confounding effect on the results, such as postoperative pain and internal rotation deficits, only patients with partial thickness tears that were less than half the amount of the subscapularis tendon thickness were included. Second, there might be potential bias when interpreting the results because the total numbers of patients in the two groups were uneven. The number of patients with small to medium tears was greater than the number of patients with large to massive tears because only medium or smaller tears have a high chance of having complete repair of the torn tendon over the anatomic insertion area of the greater tuberosity. Numerous exceptions were made in selecting patients with large to massive tears. In patients of advanced age with large to massive tears, most with severe retraction of the rotator cuff beyond the glenoid level underwent reverse shoulder arthroplasty. Third, postoperative MRI was performed to identify the integrity of the repaired rotator cuff tendon at 6 months postoperatively. Although, to our knowledge, there is no consensus regarding appropriate timing for postoperative MRI to confirm tendon healing, we evaluated tendon integrity on 6-month postoperative MR images, based on studies that showed healing of the repaired tendon was nearly complete within 6 months after repair [8, 22]. Furthermore, re-tear of the repaired tendon has been reported to occur most frequently within 6 months after surgery [11, 14]. Koh et al. [14] reported that the integrity or re-tear

of rotator cuffs maintains the same status from 6 months to 19 months postoperatively and the structural status of repaired rotator cuff tendons can be assessed at 6 months after surgery. Therefore, assessment of secure tendon healing was performed at 6 months after surgery, and the clinical analysis based on the integrity and progression of the size of the tendon defect at 6 months postoperatively was considered to be appropriate. Finally, there is another concern regarding the accuracy of measuring rotator cuff tears using MRI. MR arthrography or ultrasonography might be a more accurate tool to evaluate the postoperative status of repaired tendons. However, MR arthrography needs an invasive additional procedure such as an injection. Furthermore, according to a recent systematic review, MRI and MR arthrography provided good accuracy, with no differences in the diagnosis of rotator cuff tears [18]. Ultrasonography was performed regularly after surgery. However, ultrasonography is an examination with flexible results depending on the examiner or the proficiency of the examiner. Therefore, we performed MRI to improve the patients' compliance and for consistency of evaluation.

We found that successful repair of rotator cuff tears was generally superior to failure of repair, especially in terms of shoulder function and muscle strength. Boileau et al. [1] reported that the absence of repaired tendon healing was associated with inferior muscle strength. In particular, they found that mechanical defects of the rotator cuff would induce muscle weakness and eventually cause functional impairment of the shoulder. Contrary to the inferior muscle strength recovery in our patients with a nonhealed rotator cuff, both groups of patients with healed and nonhealed tendons had pain relief after surgery, regardless of postoperative tendon integrity. Intraoperative subacromial bursectomy may have contributed to the decreased pain intensity in both groups of patients because the suprascapular nerve endings are responsible for proprioception and nociception of the subacromial bursa [12].

Tear size progression of the rotator cuff tendon after repair was associated with postoperative shoulder function in our study patients; however the differences observed often were small, and many might have been below the minimum clinically important difference for the outcomes tools used. Patients with an increased size of tear from the initial defect showed inferior clinical scores and muscle strength compared with those from patients with a decreased tear size. Sugaya et al. [21] reported that patients with a major discontinuity observed on the postoperative MR images, suggesting a medium or large nonhealed tendon after arthroscopic rotator cuff repair, showed poorer functional outcomes than patients with an intact tendon or a small nonhealed tendon. Function of the rotator cuff to stabilize the glenohumeral joint was well preserved, even in the patients with small nonhealing tendons [15]. If

biomechanical stability of the rotator cuff is maintained by some means after surgery, the rotator cable and transverse plane force couple will be restored for proper function of the repaired rotator cuff tendon. Therefore, attempts to decrease the initial rotator cuff tear size for rebuilding the force couple might lead to restoration of rotator cuff function, especially for preoperative large to massive tears.

In this study, muscle strength was improved from 6 months postoperatively to the latest followup even in the patients with nonhealed tendons when the nonhealed tendon showed a decreased size from the original size. However, muscle strength of patients with an increased size of nonhealed tendons showed no improvement after 6 months of tendon repair. Similarly, Shin et al. [19] reported that muscle strength of patients with a healed tendon after arthroscopic rotator cuff repair showed continuous progression until 18 months after surgery. An animal study showed that muscle atrophy after rotator cuff tendon tear was restored to some degree by providing continuous traction to a retracted tendon [7]. In the current study, continuous traction forces were applied on partially healed tendons in patients with decreased size of the nonhealed tendon. This might lead to partial recovery of muscle atrophy and restoration of muscle strength in the patients with decreased size of nonhealed tendons

Patients with healed tendons after arthroscopic rotator cuff repair have better shoulder function than patients with nonhealed tendons. Patients without healing of the repaired rotator cuff tendon with an increase in the size of their tear, as measured at 6 months after surgery, experienced better shoulder function and muscle strength from those with decreased tear size when followed beyond 6 months. Although results are statistically different, they seem to be insufficient to achieve clinically important differences.

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