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Risk factors for and prognosis of folded rotator cuff tears: a comparative study using propensity score matching

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Background: The prognosis of rotator cuff repair (RCR) may be affected by the shape and quality of the torn rotator cuff tendon. However, only a few studies have reported on folded rotator cuff tears (FCTs). Therefore, this study aimed to evaluate the prognostic factors for FCT and clinical outcomes of FCT repair.
Methods: Through propensity score matching (PSM), 200 (40 patients with FCTs and 160 controls) of 1927 patients who underwent RCR from 2010 to 2016 were included. The variables not used for PSM were compared. The anatomic and functional outcomes were assessed at the final follow-up (32.3 ± 21.2 months), and the related prognostic factors for FCTs were evaluated.
Results: The risk factors for FCT were heel-type spur (odds ratio [OR], 11.6; $P < .001$) and delamination (OR, 2.3; $P = .034$). Although the functional scores at the final follow-up for both groups improved postoperatively and were not significantly different, the visual analog scale scores for pain (1.9 ± 2.1 vs. 1.2 ± 1.7, $P = .034$) and American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) scores (83.1 ± 14.3 vs. 88.5 ± 12.2, $P = .018$) were significantly worse in the FCT group at 6 months postoperation. The retear rate was significantly higher in the FCT group (25.0 vs. 10.0%, $P = .018$). An FCT was a significant risk factor for retears (OR, 3.0; $P = .015$); however, a subgroup analysis revealed that the retear rate according to the management strategy for the folded portion (débridement of the folded portion vs. en masse repair including the folded portion) was not significantly different (26.7 vs. 24.0%, $P > .99$).
Conclusion: The risk factors for FCTs were heel-type spur and delamination. The retear rate was significantly higher for patients with FCTs. An FCT was indicative of poor quality of the remaining tendon; therefore, FCT may be a prognostic factor for worse functional outcomes during the early postoperative period and poor healing potential.
Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Rotator cuff tear; folded rotator cuff tear; arthroscopic rotator cuff repair

The prognosis of rotator cuff repair (RCR) may be affected by the morphologic pattern of the torn rotator cuff tendon. Several studies have presented different stress distribution and clinical outcomes based on the tear morphology.[1,13,26,27,29] Furthermore, the morphologic type of rotator cuff tears (RCTs) may affect the surgical

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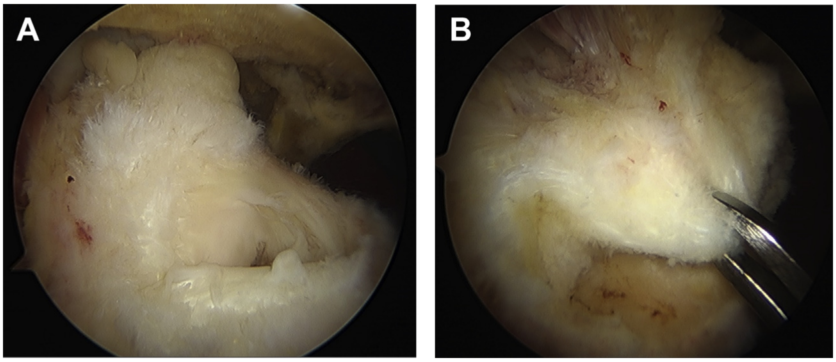

Figure 1 (**A**) A folded rotator cuff tear is defined when the torn end of the rotator cuff is folded owing to retraction in the superomedial direction. (**B**) It is returned to its anatomic position when the folded rotator cuff tear is pulled back with a tissue grasper.

technique used for RCR, including the type of surgical repair and number of suture anchors used.[26]

Several studies have reported on the morphologic aspects of RCTs, including the size, location, shape of the RCTs, and presence of delamination. In the clinical setting, we encounter many cases of folded rotator cuff tear (FCTs), in which the torn end of the rotator cuff is folded up owing to retraction in the superomedial direction (Fig. 1). We define the tear as an FCT when the following conditions are satisfied: (1) full-thickness RCT is noted and (2) the torn end of the rotator cuff tendons is everted or folded in the superomedial direction.

However, only a few studies have reported on FCTs. Therefore, the current study aimed to evaluate the risk factors for and prognosis of FCTs. We hypothesized that an FCT may be affected by subacromial attrition and that the prognosis may be worse than that for an RCT without a folded portion. To our knowledge, this is the first study evaluating the risk factors for FCTs and the prognosis of RCR in patients with full-thickness FCTs.

Materials and methods

We retrospectively reviewed the records of all arthroscopic RCR procedures performed for RCTs at the senior author's institution by a single surgeon (J.H.O.) between February 2010 and May 2016. Of 1927 consecutive arthroscopic RCR cases (patient with FCT-to-control ratio = 101:1826), patients with a partially repaired torn rotator cuff (0:4), concomitant subscapularis tear (11:305), isolated infraspinatus tear (0:7), revision surgery (0:19), or follow-up of less than 12 months (40:713) were excluded. Finally, there were 50 patients in the FCT group and 778 patients in the control group. To increase the statistical power, propensity score matching (PSM) at a ratio of 1:4 was performed with respect to age at surgery, sex, operated side (dominant or nondominant), duration of symptoms, tear characteristics (size and thickness), fatty infiltration of the rotator cuff muscles, and the presence of osteoporosis. Before PSM, a relatively lower percentage of the dominant operated side (64.0% vs. 77.0%, $P = .041$) and greater tear sizes in the mediolateral direction (retraction; 17.3 ± 7.6 vs. 14.7 ± 6.7 mm, $P = .016$) were observed in the FCT group. However, these mismatched variables were corrected after PSM (Table I).

The medical records, including the physician's admission and progress notes, operative records, anesthesia records, functional score outcomes, and radiologic images, were retrospectively reviewed. Data were collected for the following variables for analysis: patient demographic characteristics (age at surgery, sex, operated side [dominant or nondominant], time interval between symptom onset and surgery, follow-up period, intensity of sports and work activities, presence of osteoporosis and other comorbidities, history of steroid injection, traumatic events, and/or surgical history of the operated side); surgical factors (size and characteristics of the torn rotator cuff, quality of the remaining tendon, presence of delamination and/or FCTs, and management method for the delaminated and/or folded portion of the torn rotator cuff); functional outcomes (pain, subjective satisfaction, forward flexion, external rotation of the arm at the side, internal rotation of the arm at the back, power of the supraspinatus, the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form [ASES] score, the abbreviated version of the Disabilities of Arm, Shoulder, and Hand questionnaire [Quick-DASH] score, and the Simple Shoulder Test [SST] results); and radiologic factors (acromiohumeral distance [AHD], type and thickness of the acromion,[7,30] and presence and morphologic type of the subacromial spur[24]).

The range of motion (ROM) of the shoulder was evaluated preoperatively and at every follow-up visit. Forward flexion was measured in the neutral position using a goniometer. External rotation was measured using a goniometer with the arm at the patient's side. Internal rotation was measured at the height of the spinous process, which could be reached with the ipsilateral thumb. Forward flexion <120°, external rotation to the side <30°, and/or internal rotation to the back below L3 during passive ROM were considered indicative of preoperative stiffness.[25] The other functional scores were evaluated preoperatively, at 6 months postoperatively, and at the annual follow-up visits beginning at 1 year postoperatively by an independent clinical researcher who was blinded to the current study.

Magnetic resonance imaging (MRI) was performed preoperatively and at 1 year postoperatively. The coronal and sagittal oblique images were obtained with T2-weighted turbo spin echo (3-tesla Achieva and Ingenia; Philips, Best, the Netherlands;

Table I Post–propensity score matching demographic data

Variables	FCT	Control	*P* value
Age (yr)	60.1 ± 7.5	60.0 ± 8.4	.980
Sex (male-female)	16:24	60:100	.856
Duration of symptom (mo)	6.0 ± 5.6	5.8 ± 5.1	.822
Hand dominance (dominant-nondominant)	27:13	112:48	.848
Tear thickness (none–partial tear–full-thickness tear)			
Supraspinatus	0:2:38	0:9:151	>.99
Infraspinatus	40:0:0	159:0:1	>.99
Tear size (mm)			
Retraction	16.0 ± 6.6	16.2 ± 6.2	.783
Anteroposterior	15.5 ± 4.9	15.4 ± 5.1	.809
Presence of osteoporosis (yes-no)	8:32	30:130	>.99
Fatty degeneration (grade 0-1-2-3-4)*			
Supraspinatus	6:12:20:2:0	14:43:95:7:1	.685
Infraspinatus	7:30:3:0:0	20:120:20:0:0	.553
Subscapularis	12:26:2:0:0	46:102:12:0:0	.920

FCT, folded rotator cuff tear.
Data are presented as mean ± standard deviation or ratio.
* Goutallier-Fuchs grade.

repetition time / echo time, 3700-4400/80-100 ms; slice thickness, 2 mm; interslice gap, 0.2 mm). Ultrasonography was performed at 3 and 6 months postoperatively and at the annual follow-up visit beginning 1 year postoperatively to evaluate the status and/or repair integrity of the torn rotator cuff. Preoperative plain radiographs, including Grashey, lateral, axial, supraspinatus outlet, and 30° caudal tilt views, and MRI scans were used to evaluate the type and thickness of the acromion and the presence and morphologic type of the subacromial spur. The thickness of the acromion was measured in the portion just lateral to the acromioclavicular joint in the oblique sagittal images, and the subacromial spur was classified as heel, traction, birdbeak, or medial type (Fig. 2).[24] AHD was measured preoperatively with radiographic plain imaging using the Grashey view. Repair integrity, type and thickness of the acromion, and presence and morphologic classification of the subacromial spur were evaluated by a musculoskeletal radiologist with more than 10 years of experience.

Surgical technique and rehabilitation protocol

All operative procedures were performed with the patient under general anesthesia and in the lateral decubitus position with the Spider Limb Positioning System (Smith & Nephew, Andover, MA). Arthroscopic glenohumeral inspection was conducted using a 30° arthroscope via a standard posterior portal to evaluate the lesion of the long head of the biceps brachii tendon, labrum, capsule, and rotator cuff. The subacromial space was inspected using a 30° arthroscope to evaluate the subacromial-subdeltoid bursa and presence of the subacromial spur. Acromioplasty was performed when the subacromial spur was present and/or the thickness of the acromion was greater than 7 mm, according to the preoperative MRI scan.[28] The tear size was measured mediolaterally (retraction) and anteroposteriorly using a probe with a 70° arthroscope, and the RCT was classified according to the Cofield classification.[4] Subsequently, the retracted torn tendon was pulled by a tissue grasper to evaluate the tissue quality and measure the tension in the retracted tendon. If the torn tendon was thin and/or friable, then the tissue quality was considered poor; if the thickness of the tendon was uneven but the tendon was not friable, then the tissue quality was considered fair; finally, if the tendon was thick and robust, then the tissue quality was considered good. The tissue quality was evaluated intraoperatively by a single surgeon (J.H.O., senior author of this study).

The repair method was selected based on the size and tension in the retracted tendon.[11] In general, a small RCT was repaired using the modified Mason-Allen technique, and tears larger than medium-size were repaired according to the tension in the retracted torn rotator cuff tendons. If the torn rotator cuff tendons could be pulled through to the insertion site of the greater tuberosity without resistance, a double-row suture bridge technique was used. Otherwise, a single-row technique was used.

The delaminated portion of the torn rotator cuff was repaired using an en masse technique; however, the folded portion was managed by débridement or en masse repair, based on the surgeon's clinical discretion. If the folded portion was thin or fragile and repair could not be guaranteed, débridement was performed. However, in the case of a remaining tendon of relatively better quality, the folded portion was repaired using an en masse repair method.

Postoperatively, all patients wore an abduction brace, and the immobilization period was determined according to the size of the RCTs.[19] Immobilization was for 4 weeks for small tears, 5 weeks for medium tears, and 6 weeks for large-to-massive tears. After the immobilization period, the patients were educated about active assisted ROM exercises. At 3 months postoperatively, the active ROM of the shoulder was assessed. If the active ROM of the shoulder had recovered to ≥80% of that of the opposite arm, the patients were educated regarding strengthening exercises, including forward flexion, abduction, and external and internal rotation using resistance rubber bands. Various types of activities,

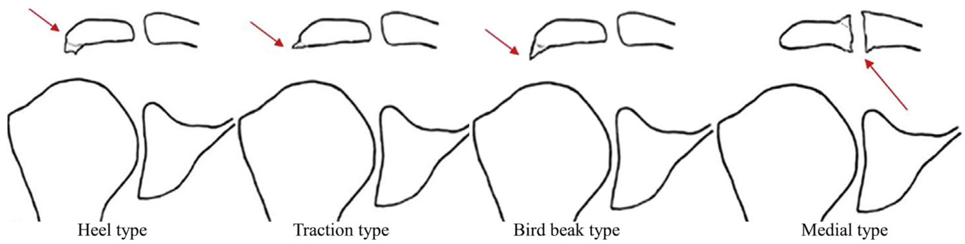

Figure 2 The subacromial spurs were classified into 4 subtypes according to the morphology. (Adapted from Oh et al.[24])

including sports, were usually permitted at 6 months after the surgery.

Statistical analysis

All statistical analyses were performed using the SPSS statistics software package (version 20.0; IBM Corp., Armonk, NY, USA), except for PSM. PSM was performed by the statistician at the senior author's institution. The Kolmogorov-Smirnov normality test was used for continuous variables. Subsequently, an independent *t* test or Mann-Whitney *U* test was performed, and Pearson or Spearman correlation analysis was used to evaluate the correlation between the variables. These statistical methods were selected according to the results of the normality test. For nominal variables, the chi-square or Fisher exact test was used to determine the differences, and the phi or Cramer V correlation coefficient was used to evaluate the correlation between the variables. Multiple variable logistic regression analysis was performed to evaluate the causal relationships. All statistical tests were 2-sided and had a significance level of .05.

Results

Risk factors for folded rotator cuff tears

The mean follow-up duration was 32.3 ± 21.2 months. There was no statistical difference in the follow-up period of the FCT and control groups (33.0 ± 20.4 vs. 32.1 ± 21.5 months, $P = .423$). The total number of steroid injections (0.9 ± 1.4 vs. 1.1 ± 1.8, $P = .745$), presence of comorbidities (47.5% vs. 48.8%, $P > .99$), and incidence of traumatic events involving the ipsilateral shoulder (17.5% vs. 18.8%, $P > .99$) were not significantly different between the groups. Furthermore, the intensity of sports activity was not significantly different (high-middle-low = 0:9:30 vs. 4:64:92, $P = .078$) between the groups; however, the intensity of work activity was higher for the control group (high-middle-low = 0:14:25 vs. 16:69:75, $P = .034$).

The acromiohumeral distance ($P = .976$), morphologic type ($P = .263$), and thickness of the acromion ($P = .514$) were not statistically different between the groups (Table II). A subacromial spur was significantly more commonly noted in the FCT group ($P = .002$), and the morphologic subanalysis revealed that heel-type spurs were more frequently observed in the FCT group in both the coronal ($P < .001$) and sagittal ($P = .034$) views (Table II). The ratio of delaminated tears was also higher in the FCT group ($P = .006$; Table II).

The correlation analyses revealed that FCTs were correlated with heel-type spurs ($r = 0.436$, $P < .001$) and delamination ($r = 0.204$, $P = .006$). Subsequently, multivariate regression analysis was performed to evaluate the causal relationship with FCTs. Finally, a heel-type spur in the coronal view (odds ratio [OR], 11.6; $P < .001$) and delamination (OR, 2.3; $P = .034$) were identified as the risk factors for FCTs.

Prognosis of folded rotator cuff tears

The mean operative time was statistically longer for the FCT group than for the control group ($P = .008$; Table II). However, the repair method ($P = .511$), total number of suture anchors ($P = .975$), and failed suture anchors during surgery ($P = .952$) were not significantly different (Table II). Tissue quality was worse in the FCT group than in the control group ($P = .021$; Table II), and it was also correlated with the presence of an FCT ($r = 0.200$, $P = .025$) and delamination ($r = 0.186$, $P = .027$).

A subgroup analysis according to the management methods used for the folded portion was conducted. Débridement was performed in 15 cases (37.5%), and en masse repair was performed in 25 cases (62.5%). Débridement was performed more often than en masse repair for poor-quality tendons (good-fair-poor = 1:7:7 vs. 0:20:5, $P = .047$); however, the tear size (retraction: 15.5 ± 7.6 vs. 16.4 ± 6.1 mm, $P = .684$; anteroposteriorly: 15.8 ± 6.0 vs. 15.4 ± 4.3 mm, $P = .785$), repair methods (single-row–double-row suture bridge–modified Mason-Allen = 0:8:7 vs. 0:19:6, $P = .175$), and operative time (92.0 ± 25.6 vs. 91.6 ± 19.5 minutes, $P = .956$) did not differ significantly according to the management method used for the folded portion. Furthermore, the retear rate (26.7% vs. 24.0%, $P > .99$) was not significantly different between the groups.

Preoperative pain, ROM, power of the supraspinatus, and ASES scores were not different according to the

Table II Comparison between the folded rotator cuff tear group and control group

	FCT	Control	P value
Acromiohumeral distance (mm)	8.3 ± 1.8	8.3 ± 1.9	.976
Acromion			
Type (flat-curved-hooked-convex)*	21:17:1:1	91:63:6:0	.263
Thickness (mm)	8.3 ± 1.7	8.1 ± 1.6	.514
Subacromial spur (yes-no)			
Overall	39:1	119:41	.002†
Coronal view	39:1	94:66	<.001†
Sagittal view	34:6	102:58	.013†
Subacromial spur, coronal view‡			
Heel type	34/40	50/160	<.001†
Traction type	5/40	41/160	.094
Birdbeak type	0/40	1/160	>.99
Medial type	0/40	2/160	>.99
Subacromial spur, sagittal view‡			
Heel type	12/40	23/160	.034†
Traction type	14/40	67/160	.475
Birdbeak type	6/40	10/160	.097
Medial type	2/40	2/160	.179
Tissue quality (good-fair-poor)	1:27:12	5:136:19	.021†
Delamination (yes-no)	24:16	56:104	.006†
Operation time (min)	91.8 ± 21.7	82.0 ± 21.6	.008†
Repair method (SR-DRSB-mMA)	0:27:13	6:102:52	.511
Number of suture anchors			
Total	3.3 ± 1.5	3.2 ± 1.5	.975
Failed	0.1 ± 0.3	0.1 ± 0.4	.952

FCT, folded rotator cuff tear; *SR*, single-row technique; *DRSB*, double-row suture bridge technique; *mMA*, modified Mason-Allen technique.
Data are presented as mean ± standard deviation, ratio, or proportion.
* Bigliani classification for acromial type.
† Statistically significant.
‡ Subacromial spur was classified as heel, traction, birdbeak and medial type according to morphology.[8]

presence of an FCT (all $P > .05$; Table III); however, the QuickDASH scores ($P = .003$) and SST scores ($P = .033$) were worse for the FCT group than for the control group (Table III). All functional outcomes improved postoperatively after surgery in both groups (all $P < .05$), with no significant differences between the groups (all $P > .05$), except for pain ($P = .034$) and ASES score ($P = .018$), which were worse in the FCT group at 6 months postoperatively (Table III).

The retear rate at the final follow-up was statistically higher in the FCT group (25.0% vs. 10.0%, $P = .018$). Therefore, subgroup analyses were performed to eliminate the effects of the confounding factors and to investigate the risk factors for retear. An FCT was more frequently observed ($P = .018$) and the tissue quality of the tendons was worse ($P = .020$) in the retear group (Table IV). However, the other demographic characteristics, radiologic factors, and surgical factors were not significantly different (all $P > .05$; Table IV). Although the proportions of both FCTs and poor-quality tendons were significantly higher in the retear group, a statistically significant correlation was observed between the variables ($r = 0.200$, $P = .025$). Therefore, logistic regression analysis was performed using FCT alone to eliminate the bias based on the multicollinearity between 2 variables, and the presence of an FCT was a significant risk factor for retear (OR, 3.0; $P = .015$). At the final follow-up, the QuickDASH scores ($P = .037$) and visual analog scale scores for satisfaction ($P = .014$) were significantly worse for the retear group (Table IV).

Discussion

Several previous studies have analyzed RCTs according to the morphologic pattern; however, to our knowledge, previous studies have not reported on full-thickness FCTs. We hypothesized that an FCT may be affected by subacromial attrition and that the prognosis might be worse than that for an RCT without a folded portion. We found that the presence of heel-type subacromial spurs in the coronal view and delaminated tears were the risk factors for FCTs. Furthermore, although the functional outcomes were not

Table III Comparison of functional scores between folded rotator cuff tear and control group

Follow-up period	FCT	Control	*P* value
Pain (VAS)			
Preoperative	5.8 ± 2.3	6.2 ± 2.4	.359
PO 6 mo	1.9 ± 2.1	1.2 ± 1.7	.034*
PO 1 yr	0.8 ± 1.8	0.6 ± 1.2	.744
Final follow-up	1.0 ± 1.9	0.5 ± 1.3	.148
P value	<.001*	<.001*	
Forward flexion (°)			
Preoperative	148.9 ± 21.4	147.0 ± 24.3	.798
PO 6 mo	162.2 ± 10.2	164.3 ± 10.7	.301
PO 1 yr	166.5 ± 7.8	168.7 ± 9.9	.060
Final follow-up	165.3 ± 8.8	167.7 ± 9.0	.160
P value	<.001*	<.001*	
External rotation (°)†			
Preoperative	54.5 ± 12.9	51.8 ± 18.0	.390
PO 6 mo	69.9 ± 15.7	64.4 ± 16.7	.070
PO 1 yr	73.2 ± 11.8	71.7 ± 16.4	.646
Final follow-up	71.9 ± 12.9	70.7 ± 17.1	.928
P value	<.001*	<.001*	
Internal rotation (level of vertebra)‡			
Preoperative	T9.9 ± 2.3	T9.9 ± 3.3	.430
PO 6 mo	T8.3 ± 2.3	T9.1 ± 2.1	.839
PO 1 yr	T8.5 ± 1.9	T8.6 ± 4.7	.709
Final follow-up	T8.0 ± 1.7	T8.2 ± 4.5	.773
P value	<.001*	<.001*	
Power of supraspinatus			
Preoperative	4.6 ± 0.4	4.5 ± 0.4	.434
PO 6 mo	4.9 ± 0.3	4.8 ± 0.3	.836
PO 1 yr	4.9 ± 0.2	4.9 ± 0.3	.606
Final follow-up	4.9 ± 0.2	4.9 ± 0.2	.928
P value	<.001*	<.001*	
ASES score			
Preoperative	50.7 ± 18.1	58.9 ± 18.9	.070
PO 6 mo	83.1 ± 14.3	88.5 ± 12.2	.018*
PO 1 yr	92.9 ± 12.9	95.0 ± 8.8	.727
Final follow-up	92.2 ± 14.2	95.5 ± 9.9	.754
P value	<.001*	<.001*	
QuickDASH			
Preoperative	44.9 ± 20.3	31.1 ± 20.4	.003*
PO 6 mo	7.1 ± 5.8	9.0 ± 11.3	.805
PO 1 yr	4.1 ± 6.7	4.2 ± 9.1	.569
Final follow-up	4.0 ± 7.0	3.3 ± 7.7	.445
P value	<.001*	<.001*	
Simple Shoulder Test			
Preoperative	3.7 ± 2.6	5.3 ± 3.2	.033*
PO 6 mo	9.5 ± 2.4	9.6 ± 2.6	.822
PO 1 yr	11.0 ± 2.4	11.1 ± 1.6	.797
Final follow-up	11.0 ± 2.2	11.2 ± 1.6	.827
P value	<.001*	<.001*	
Satisfaction (VAS)			
PO 6 mo	8.0 ± 2.3	8.1 ± 1.7	.566
PO 1 yr	9.0 ± 0.8	8.7 ± 1.4	.563
Final follow-up	9.3 ± 1.0	9.1 ± 1.3	.457
P value	<.001*	<.001*	

(*continued on next page*)

Table III Comparison of functional scores between folded rotator cuff tear and control group (*continued*)

Follow-up period	FCT	Control	*P* value
Retear rate (yes-no)			
PO 6 mo	2:38	3:157	.585
PO 1 yr	7:33	15:145	.159
Final follow-up	10:30	16:144	.018*

VAS, visual analog scale; *PO*, postoperative; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *QuickDASH*, abbreviated version of the Disabilities of the Arm, Shoulder, and Hand questionnaire; *FCT*, folded rotator cuff tear.
Data are presented as mean ± standard deviation or ratio.
* Statistically significant.
† External rotation was measured using a goniometer with the arm at the patient's side.
‡ Internal rotation was measured as the height of the spinous process which that be reached with the ipsilateral thumb.

significantly different between the groups, the retear rate was significantly higher for patients with FCTs.

In the current study, the presence of a heel-type spur was noted more frequently in the FCT group. Furthermore, a heel-type spur was considered a predictive factor for FCTs. Previous studies[17,18,23,24] have reported that the subacromial spur is correlated with the development of an RCT. Although the debate regarding the causal relationship between the subacromial spur and RCTs is ongoing, the extrinsic mechanism theory, which suggests that impingement causes tearing of the rotator cuff tendon, has been supported by several previous reports that have indicated that the subacromial spur is relatively more commonly noted in patients with bursal-side partial-thickness RCTs than in those with articular-side trears.[12,18,23] Furthermore, Kim et al[17] previously reported similar results for partial-thickness tears. They analyzed the everted type of bursal-side RCTs, which are morphologically similar to FCTs but not full-thickness tears. In their study, a hat-type spur, which is similar to a heel-type spur but with a projection in the medial and lateral directions, was a risk factor for an everted-type bursal-side RCT. Despite the differences between partial-thickness and full-thickness tears, this finding was consistent with that of the present study.

Delamination was also a risk factor for FCTs in this study. Previous studies have presented different stress distributions according to the pattern of tear shape.[1,13,26,27,29] Iwashita et al[10] argued that delamination is caused by the partial tear of each side of the rotator cuff that occurs at different time points. They insisted that if the partial tear occurred on one side of the rotator cuff first, there is increased stress concentration on the opposite side. Although we could not measure the tensional force in each delaminated portion of the rotator cuff, if the tear first occurred on the bursal side, it may be assumed that stress concentration was higher on the articular side. Sequentially, this change in stress concentration triggers an FCT by retraction of the tendon. We assumed that this was related to a subacromial spur. If subacromial impingement, which originated from the subacromial spur, induced the development of the bursal-sided partial tear, it may induce delamination and development of FCTs, which progressed in response to the increased stress concentration. Therefore, we considered FCT as a spectrum of delaminated RCTs induced by subacromial impingement.

Pain, shoulder ROM, and ASES scores were not significantly different between the 2 groups preoperatively; however, QuickDASH and SST scores were worse in the FCT group. These differences may be attributable to the different structure of these functional scores. Fifty percent of the overall ASES score reflects pain; however, the QuickDASH and SST scores focus on the ability to perform activities of daily living. We considered that aggravated subacromial impingement between the acromion and folded portion of the FCT may lead to worse functional outcomes. In contrast, the FCT group presented with worse pain and ASES scores at 6 months postoperatively. We could not accurately explain the reason for the worse functional outcomes during the early postoperative period; however, relatively higher levels of remnant inflammatory cytokines after RCR may account for the worse functional outcomes during the early postoperative period. Although we did not measure the levels of inflammatory cytokines, exacerbated subacromial impingement caused by the folded portion of a torn rotator cuff and remaining tendons of relatively poor quality may have induced the expression of inflammatory cytokines more frequently in the FCT group.

The retear rate at the final follow-up was also significantly higher in the FCT group. As is generally known, the poor tissue quality of a torn rotator cuff makes repair difficult, and many surgical techniques have been attempted to manage poor-quality tendons.[3,5] Previous studies have reported a correlation between the tissue quality of the tendon and healing potential after RCR.[2,6,9,22,31] Nho et al[22] assessed the tissue quality using the thickness of the remaining tissue and ease of mobilization of the torn tendon, and the retear rate was higher in the patients with worse-quality remaining tissue. Similarly, Wu et al[31] evaluated the tendon quality intraoperatively and found that the retear rate was correlated with tissue quality and mobility.

Table IV Comparison of risk factors and functional outcomes at the final follow-up according to the occurrence of retear

	Retear	Intact	*P* value
Age (yr)	62.6 ± 6.9	59.6 ± 8.4	.090
Sex (male-female)	14:12	62:112	.086
Duration of symptoms (mo)	5.6 ± 4.1	5.9 ± 5.3	.741
Hand dominance (dominant-nondominant)	18:8	121:53	>.99
History of steroid injection (no. of injections)	1.5 ± 2.1	1.0 ± 1.6	.408
Sports level (high-middle-low)	1:14:11	3:59:111	.060
Work level (high-middle-low)	2:16:8	14:67:92	.086
Comorbidity (yes-no)	10:16	87:87	.300
History of traumatic event (yes-no)	6:20	31:143	.588
Presence of osteoporosis (yes-no)	4:22	34:140	.791
Fatty degeneration (grade 0-1-2-3-4)*			
Supraspinatus	4:3:18:1:0	16:52:97:8:1	.254
Infraspinatus	3:22:1:0:0	24:128:22:0:0	.460
Subscapularis	5:20:1:0:0	53:108:13:0:0	.384
Tear thickness (none–partial tear–full-thickness tear)			
Supraspinatus	0:2:24	0:9:165	.639
Infraspinatus	26:0:0	173:0:1	>.99
Tear size (mm)			
Retraction	17.7 ± 6.1	16.0 ± 6.3	.173
Anteroposterior	16.6 ± 4.4	15.2 ± 5.1	.123
Acromion			
Type†	11:13:2:0	101:67:5:1	.248
Thickness (mm)	8.0 ± 1.8	8.2 ± 1.6	.623
Subacromial spur (yes-no)			
Overall	22:4	136:38	.608
Coronal view	19:7	114:60	.511
Sagittal view	20:6	116:58	.371
Tissue quality (good-fair-poor)	0:17:9	6:146:22	.020‡
Delamination (yes-no)	15:11	65:109	.056
Folded cuff tear (yes-no)	10:16	30:144	.018‡
Operation time (min)	87.6 ± 22.1	83.5 ± 21.9	.312
Repair method (SR-DRSB-mMA)	0:20:6	6:109:59	.310
Number of suture anchors			
Total	3.7 ± 1.5	3.2 ± 1.5	.079
Failed	0.0 ± 0.2	0.1 ± 0.4	.402
Pain (VAS)	1.0 ± 1.7	0.6 ± 1.5	.084
Forward flexion (°)	165.0 ± 11.9	167.4 ± 8.5	.459
External rotation (°)§	64.0 ± 21.7	71.9 ± 15.2	.092
Internal rotation (level of vertebra)‖	T8.3 ± 1.3	T8.1 ± 4.3	.083
Power of supraspinatus	4.8 ± 0.4	4.9 ± 0.2	.093
ASES score	91.6 ± 13.4	95.3 ± 10.6	.091
QuickDASH	4.8 ± 6.9	3.3 ± 7.6	.037‡
Simple shoulder test	10.7 ± 2.4	11.3 ± 1.7	.095
Satisfaction (VAS)	8.6 ± 1.4	9.2 ± 1.2	.014‡

SR, single-row technique; *DRSB*, double-row suture bridge technique; *mMA*, modified Mason-Allen technique; *VAS*, visual analog scale; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *QuickDASH*, abbreviated version of the Disabilities of the Arm, Shoulder, and Hand questionnaire.

Data are presented as mean ± standard deviation or ratio.

* Goutallier-Fuchs grade.

† Bigliani classification for acromial type (flat-curved-hooked-convex).

‡ Statistically significant.

§ External rotation was measured using a goniometer with the arm at the patient's side.

‖ Internal rotation was measured as the height of the spinous process that could be reached with the ipsilateral thumb.

Furthermore, Chillemi et al[2] evaluated the torn rotator cuff histopathologically using biopsy samples; in their study, healing of the repaired torn rotator cuff tendon was affected by the histologic quality of the tissue. Although a histologic evaluation was not performed in this study, based on the higher prevalence of concomitant delaminated tears, we assumed that the higher retear rate in the FCT group could be accounted for by the poor quality of the remaining tendon.[8,15]

Delamination was not a significant risk factor for retears. Although the delamination rate tended to be higher in the retear group, a statistically significant difference was not noted in the current study. As of this writing, there is a debate regarding the effects of delamination on RCTs; however, several studies[16,20] have reported that delamination is not a negative prognostic factor for RCR. As previously mentioned, we considered FCT to be a spectrum disease of delaminated RCTs. Therefore, delamination may be a subclinical form of an FCT or a confounding factor affecting rotator cuff healing.

Limitations

There are several limitations of this study. First, the inherent bias associated with retrospective studies could not be excluded. FCTs are relatively rare, and some patients with FCTs who underwent RCR dropped out. Therefore, we had to include patients with relatively short follow-up periods to perform statistical analyses. However, many previous studies have indicated that repaired rotator cuffs biologically healed within 1 year postoperation.[14,21,32] Furthermore, we performed PSM to decrease the effects of the confounding factors, and the matched data indicated no significant differences between the groups. Second, histologic evaluations were not performed. However, biopsy is not commonly performed during RCR; there are ethical concerns that it could cause additional damage to the torn rotator cuff. Therefore, to elucidate the correlation between histologic characteristics and prognosis of FCTs, further research, specifically large prospective cohort studies, is required. Third, validation of the reliability of the FCT diagnosis, including inter- and intraobserver correlations, was not performed. Although the concept of an FCT was first presented in this study, an FCT has very distinctive arthroscopic features. Furthermore, the diagnosis of FCT included not only inspection but also pulling of the folded and retracted tendon using a tissue grasper. Therefore, inter- and intraobserver correlations could not be measured. Finally, we did not perform inter- and intraobserver correlation analyses to assess the reliability of the postoperative evaluation of retears. Generally, postoperative MRI scans are difficult to interpret because of the presence of implant-related artifacts. However, we used standardized MRI sequences that would have minimized the implant-related artifacts, and the analysis of MRI data was based on formal reading of the scans by musculoskeletal radiologists with more than 10 years of experience and who were not involved in this study. Therefore, we considered that evaluation of the retears by experienced musculoskeletal radiologists could guarantee neutrality and consistency in the analysis of MRI data.

Conclusions

The risk factors for FCTs were heel-type spur and delamination. The retear rate was significantly higher for patients with FCTs. An FCT was indicative of poor quality of the remaining tendon; therefore, FCT may be a prognostic factor for worse functional outcomes during the early postoperative period and poor healing potential.

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