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A comprehensive analysis of the acromial morphology and etiological factors for rotator cuff tears in Fosbury flop tears: bursal-sided partial-thickness tears versus full-thickness tears

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ABSTRACT

Fosbury flop tears (FFTs) are a type of rotator cuff tear characterized by the tendon flipping upon itself and adhering medially. These tears have been observed arthroscopically as either bursal-sided partial-thickness tears (BSPTTs) or full-thickness tears (FTTs), though the mechanism leading to FFTs in these tear types remains unclear. This study aimed to investigate the clinical features, acromial morphology, and treatment outcomes of FFTs, stratifying patients into BSPTT and FTT groups. We included patients with small-to-medium-sized supraspinatus tendon tears who underwent arthroscopic rotator cuff repair (ARCR). Those with BSPTTs were categorized as Group P, and those with FTTs as Group F. Variables such as age, sex, diabetes mellitus status, critical shoulder angle (CSA), lateral acromial angle (LAA), sagittal and coronal acromion morphologies, Japanese Orthopaedic Association (JOA) score, and retear rate were evaluated. Group P consisted of 13 patients, primarily younger males with traumatic tears, while Group F included 40 patients, with a higher proportion of females. There were no significant differences between the groups in CSA, LAA, JOA scores, or retear rates. Both groups had a high prevalence of double-floor type osteophytes in coronal acromial morphology. FFTs were frequently observed in both BSPTTs and FTTs, particularly in patients with double-floor osteophytes. BSPTTs with FFTs may be more common in younger patients with trauma. Overall, ARCR outcomes for FFTs were similar between BSPTTs and FTTs, suggesting similar efficacy in treatment across these tear types.

Keywords: acromial morphology, rotator cuff tear, Fosbury flop tear, bursal-side partial-thickness tear, full-thickness tear

Abbreviations:
FFT: Fosbury flop tear
BSPTT: bursal-sided partial-thickness tear
FTT: full-thickness tear
PTT: partial-thickness tear
ARCR: arthroscopic rotator cuff repair
AHD: acromiohumeral distance

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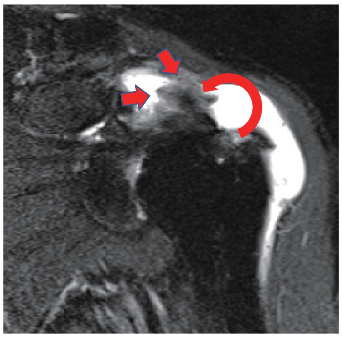
CSA: critical shoulder angle
LAA: lateral acromial angle
SD: standard deviation

INTRODUCTION

Arthroscopic rotator cuff repair (ARCR) for rotator cuff tears is an effective treatment for restoring shoulder joint function.[1-3] ARCR uses an arthroscope, which allows a detailed evaluation of the rotator cuff tear. In recent years, Lädermann et al[4,5] identified a novel rotator cuff tear pattern referred to as Fosbury flop tears (FFTs), characterized by the tendon flipping upon itself and adhering medially (Fig. 1). Recent literature has documented the clinical outcomes of ARCR for FFTs.[6,7] These studies have indicated that FFTs are associated with a high retear rate following ARCR. Rotator cuff tears are classified into partial-thickness tears (PTTs) and full-thickness tears (FTTs), and FFTs can manifest as either PTTs or FTTs. PTTs in FFTs typically occur as bursal-sided partial-thickness tears (BSPTTs). However, the mechanisms underlying the development of rotator cuff tears into PTTs or FTTs are not well understood. PTTs may progress to FTTs with enlargement, and FTTs are more prevalent in elderly patients compared to PTTs.[8] The retear rate after ARCR for rotator cuff tears tends to increase with tear size, resulting in poorer clinical outcomes.[9,10] Few studies are comparing the clinical outcomes of ARCR between PTTs and FTTs with matched tear widths. Chung et al[9] compared the clinical outcomes of 34 cases of PTTs and 21 cases of FTTs in patients with small rotator cuff tears. They reported a retear rate of 35.3% for PTTs and 14.3% for FTTs, with PTTs being more common. Peters et al[11] also compared PTTS and FTTs in patients with small-to-medium rotator cuff tears and found no significant difference in the retear rate. However, conclusive findings on the clinical outcomes between PTTs and FTTs remain elusive. Furthermore, to our knowledge, there have been no reports comparing the clinical outcomes of BSPTTs and FTTs specifically in FFT.

The objective of this study was to contrast the clinical profiles of small-to-medium FFTs involving BSPTTs and FTTs, investigate their etiological factor, and assess their clinical outcomes.

A



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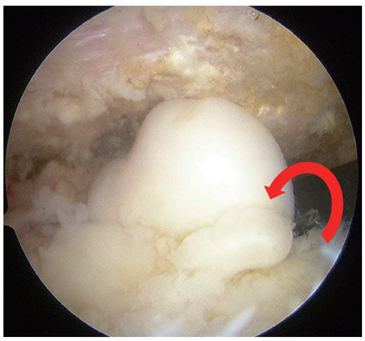

Fig. 1 FFT: a tear pattern wherein the stump of the rotator cuff is inverted more than 90° relative to the footprint

Fig. 1A: MRI
Fig. 1B: Arthroscopic view
FFT: Fosbury flop tear

MATERIALS AND METHODS

Patient selection

The ethics committee review of Ichinomiya Nishi Hospital approved this study and all patients provided consent for participation. We analyzed a database of patients who underwent ARCR performed by a single surgeon at Ichinomiya Nishi Hospital from 2015 to 2022. Among the 543 patients who had ARCR, we selected those with isolated small-to-medium tears of the supraspinatus tendon, measuring less than 3 cm as per the Cofield classification.[12] Patients with a supraspinatus tendon inverted ("flipped") more than 90° during arthroscopy were categorized as having FFT. Among these FFT cases, Group P included those with BSPTTs, while Group F included those with FTTs (Fig. 2).

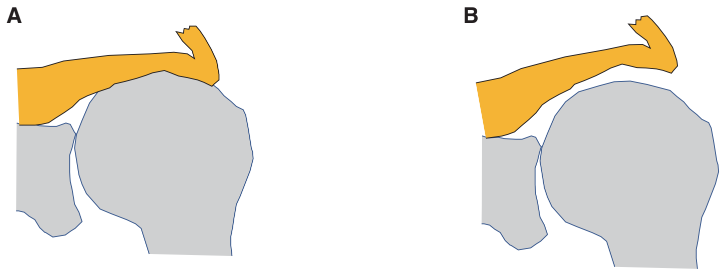

Fig. 2 Tear types of the FFT

Fig. 2A: Partial tear with FFT (Group P)

Fig. 2B: Complete tear with FFT (Group F)

FFT: Fosbury flop tear

Surgeries were carried out under general anesthesia with the addition of an interscalene nerve block. Patients were placed in the beach chair position. For patients with preoperative shoulder joint contracture, an arthroscopic pan-capsular release was performed. Additionally, subacromial decompression was carried out for those with subacromial spurs. In Group P, intact articular-side fibers of the greater tuberosity footprint were peeled using a radiofrequency device, resulting in a FTT, which was subsequently repaired. ARCR was performed via the suture-bridge technique. Medial anchors (Healix; DePuy-Mitek, Raynham, MA) were inserted just lateral to the cartilage of the humeral head. A suture from each anchor was passed through the tendon. Lateral anchors (Quatro Link knotless; Zimmer Biomet, Warsaw, IN) were placed approximately 5 mm distal to the lateral edge of the greater tuberosity.

Postoperative protocol

All patients adhered to a standardized rehabilitation protocol. The shoulder was immobilized using a sling and abduction pillow for 4 weeks. Range of motion exercises for the elbow, wrist, and fingers commenced immediately after surgery. Passive forward elevation exercises were initiated on the first postoperative day. Active-assisted motion exercises began at 4 weeks postoperatively, followed by active motion exercises at 6 weeks, and a strengthening exercise program was introduced at 8 weeks postoperatively.

Evaluation criteria

Age, sex, the presence of diabetes mellitus, traumatic tears, acromiohumeral distance (AHD),[13] critical shoulder angle (CSA),[14] lateral acromial angle (LAA),[15] sagittal and coronal morphologies of the acromion, Japanese Orthopaedic Association (JOA) scores, and the rate of rotator cuff retear were evaluated and compared between Group P and Group F.

AHD was previously defined by Moosikasuwan et al[13] (Fig. 3A). The CSA was defined as the angle between a line connecting the superior and inferior edges of the glenoid fossa and a line connecting the inferior edge of the glenoid with the most inferolateral edge of the acromion (Fig. 3B). The LAA was defined as the angle formed at the intersection of two lines: one representing the glenoid cavity and the other representing the inferior surface of the acromion (Fig. 3C). Standard anteroposterior radiographs were used to measure AHD, CSA, and LAA.

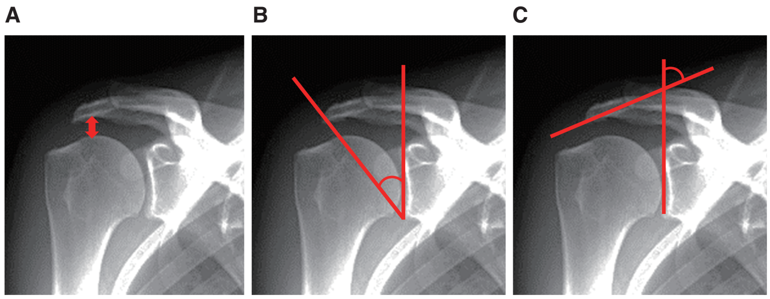

Fig. 3 Standard anteroposterior radiographs of the AHD, CSA, and LAA

Fig. 3A: The AHD is defined as the distance from the inferior surface of the acromion to the apex of the humeral head.

Fig. 3B: The CSA is defined as the angle between a line intersecting the superior and inferior edges of the glenoid fossa and another line intersecting the inferior edge of the glenoid with the most inferolateral edge of the acromion.

Fig. 3C: The LAA is defined as the intersection of two lines representing the glenoid cavity and the inferior surface of the acromion.

AHD: acromiohumeral distance
CSA: critical shoulder angle
LAA: lateral acromial angle

The sagittal acromial morphology was classified according to a method described by Bigliani et al.[16] Assessments were made on scapular Y radiographs and classified as Type 1 (flat), Type 2 (curved), or Type 3 (hooked) acromia. Coronal acromial morphology was classified by computed tomography (CT) or magnetic resonance imaging (MRI) using the following classification: flat type refers to the absence of osteophytes, beak type involves lateral osteophytes, and double-floor type features inferior osteophytes of the acromial center[6] (Fig. 4).

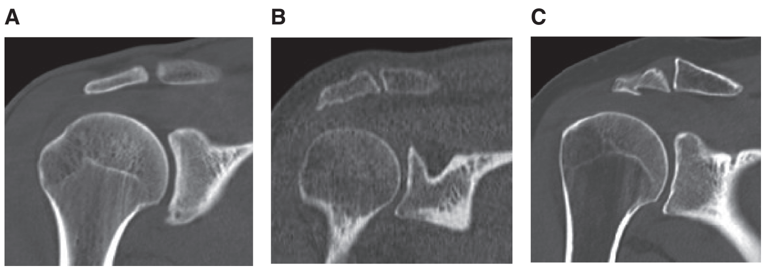

Fig. 4 Acromial morphology

Fig. 4A: Flat type, no osteophytes
Fig. 4B: Beak type, lateral osteophytes
Fig. 4C: Double-floor type, inferior osteophytes of the acromial center

MRI examination

MRI scans were conducted using a 3-tesla closed-type scanner (MRT-2000/V2, Toshiba, Tokyo, Japan). The structural integrity of the repairs was assessed using oblique coronal, oblique sagittal, and axial T2-weighted images. MRI evaluations were performed preoperatively and at 6, 12, and 24 months postoperatively. Repair integrity was classified according to the 5-category Sugaya classification system.[17] Postoperative retears were identified as those falling under Sugaya Type IV or Type V.

Statistical analysis

All statistical analyses were performed using SPSS software (version 18.0, SPSS Inc, Chicago, IL). The t-test and Fisher's exact test were utilized, with statistical significance defined as $P < 0.05$.

RESULTS

This study included 13 patients in Group P and 40 patients in Group F. The mean ages were 57.8 ± 9.0 years (standard deviation [SD]) for Group P and 65.6 ± 9.4 years (SD) for Group F. Group P comprised 11 males and 2 females, whereas Group F included 15 males and 25 females. Diabetic complications were present in 2 patients (15.4%) in Group P and 10 patients (25.0%) in Group F. There were 7 patients (53.8%) with a history of trauma in Group P and 9 patients (22.5%) in Group F. Group P was significantly younger, had a higher rate of traumatic tears, and had a higher proportion of males compared to females (Table 1).

The mean AHD, CSA, and LAA in Groups P and F were as follows: AHD, 10.3 ± 1.1 and 9.8 ± 1.5 mm (SD); CSA, 34.4 ± 3.6 and 34.3 ± 4.5 degrees (SD); LAA, 82.7 ± 10.6 and 82.7 ± 8.8 degrees (SD). No significant differences were observed between the two groups in AHD, CSA, or LAA (Table 2).

Table 1 Patient demographics

	Group P	Group F	*P* Value
Number of patients	13	40	
Age (years)	57.8 ± 9.0	65.6 ± 9.4	0.018
Sex (male/female)	11/2	15/25	0.071
Diabetes [%]	2 [15.4%]	10 [25.0%]	0.47
History of trauma [%]	7 [53.8%]	9 [22.5%]	0.032

Table 2 Results of the CSA, LAA, and AHD

	Group P	Group F	*P*-value
AHD (mm)	10.3 ± 1.1	9.8 ± 1.5	0.16
CSA (°)	34.4 ± 3.6	34.3 ± 4.5	0.93
LAA (°)	82.7 ± 10.6	82.7 ± 8.8	0.99

CSA: critical shoulder angle
LAA: lateral acromial angle
AHD: acromiohumeral distance

Table 3 Results of acromial morphology

		Group P	Group F	*P*-value
Acromial morphology of the sagittal plane (Bigliani classification)	Type 1	3 (23.1%)	14 (35.0%)	0.58
	Type 2	8 (61.5%)	17 (42.5%)	
	Type 3	2 (15.4%)	9 (22.5%)	
Acromial morphology of the coronal plane	Flat type	2 (15.4%)	7 (17.5%)	0.55
	Beak type	2 (15.4%)	2 (5.0%)	
	Double-floor type	9 (69.2%)	31 (77.5%)	

Table 4 Clinical results

		Group P	Group F	*P* Value
JOA score	Pre-op	64.7 ± 13.8	61.9 ± 12.0	0.60
	Post-op 12 mo	85.6 ± 6.6	86.0 ± 8.2	0.90
	Post-op 24 mo	93.4 ± 6.7	93.9 ± 5.1	0.81
Retear rate		2/11 (22.2%)	5/35 (14.3%)	0.79

JOA: Japanese Orthopaedic Association
Pre-op: preoperative
Post-op: postoperative

The sagittal acromial morphology was classified according to the Bigliani classification. In Group P, 3 patients had Type 1, 8 had Type 2, and 2 had Type 3. In Group F, there were 14 cases of Type 1, 17 cases of Type 2, and 9 cases of Type 3. No significant difference was observed between the two groups (P = 0.58).

The coronal acromial morphology consisted of flat, beak, and double-floor types. In Group P, there were 2 patients with flat-type, 2 with beak-type, and 9 with double-floor-type acromia. In Group F, there were 7 flat-type, 2 beak-type, and 31 double-floor-type acromia. Double-floor-type acromia were more common in both groups, and there was no significant difference between the two groups (P = 0.55; Table 3).

The preoperative, 12-month postoperative, and 24-month postoperative JOA scores were 64.7 ± 13.8 points, 85.6 ± 6.6 points, and 93.4 ± 6.7 points, respectively, for Group P, and 61.9 ± 12.0 points, 86.0 ± 8.2 points, and 93.9 ± 5.1 points respectively, for Group F. Both groups demonstrated significant improvement at 12 months post-surgery. No significant difference was found between the two groups from pre-surgery to 24 months post-surgery.

The retear rate was 22.2% in Group P and 14.3% in Group F. No significant difference was found between the two groups (P = 0.79; Table 4).

DISCUSSION

In 2015, Lädermann et al[4,5] introduced the FFT, a new rotator cuff tear pattern characterized by an inverted tendon stump. However, its incidence has been reported to be 5–7.9% of patients who undergo ARCR, suggesting that this condition is not uncommon.[6,7] The etiological factor of FFT development remains unclear. In addition, the etiological factor of PTTs and FTTs in the rotator cuff remain unclear. In this study, we investigated the etiological factors of BSPTTs and FTTs associated with FFTs. BSPTTs associated with FFTs tended to occur relatively frequently after trauma in young male patients, whereas FFT associated with FTTs tended to occur atraumatically in female patients. Research indicates that the prevalence of PTTs is approximately twice that of FTTs.[18] PTTs can sometimes cause more pain and dysfunction than FTTs. Ellman classified PTTs based on their location within the articular, bursal, and intratendinous regions.[19] Although the specific pathogenesis of PTTs is not completely understood, previous reports have suggested the involvement of intrinsic and extrinsic factors.[20-22] The most significant intrinsic factors contributing to rotator cuff tears are degenerative changes, hypovascularity, and microstructural collagen fiber abnormalities.[20,21] Extrinsic factors may include subacromial impingement due to chronic repetitive use and tensile overload.[22] Articular-sided tears are associated with degenerative changes in the supraspinatus tendon and are reported to be more common in elderly patients.[23] On the other hand, Kim et al[24] reported that bursal-sided tears are primarily caused by impingement of the underside of the acromion and the rotator cuff. They compared bursal-sided tears with articular-sided tears, and concluded that they are more likely to occur in relatively young patients who are more likely to elevate their shoulder joints. The results of this study suggest that the underlying cause of nontraumatic FTTs with FFT in elderly women may be the presence of degenerative changes in the supraspinatus tendon.

In this study, we investigated CSA, LAA, and sagittal acromial morphology. Previous studies have suggested that CSA ≥ 35 degrees, LAA < 70 degrees, and Type 3 acromial morphology according to the Bigliani classification are associated with the occurrence of rotator cuff tears.[13-15] In this study, the CSA was less than 35 degrees in both groups, the LAA was more than 70 degrees, and Type 3 Bigliani classification was rare. This may be because the subjects examined in this study primarily had small-to-medium tears of the supraspinatus tendon alone. Furthermore, the lack of significant differences between the two groups in CSA, LAA, or sagittal acromial morphology suggests that these factors may not play a role in the etiological factors of occurrence of PTTs and FTTs.

In this study, the number of patients with double-floor type subacromial osteophytes was significantly greater in both the BSPTT group with FFT and the FTT group with FFT. In a previous report, Jeong et al[7] reported that there is a relationship between subacromial osteophytes and FFT, and we believe that the occurrence of FFT is related to double-floor type subacromial osteophytes. According to the results of this study, BSPTTs with FFTs were often observed after trauma in relatively young patients; however, it is unlikely that double-floor type osteophytes appeared after trauma. We believe that patients with double-floor type osteophytes before trauma suffer PTTs as a result of the trauma and develop FFT due to the presence of double-floor type osteophytes. However, since imaging tests were not performed prior to the trauma, this is only a speculation. In this study, all BSPTTs with FFT were observed arthroscopically, with more than 50% damage to the footprint of the greater tuberosity, including cases where damage extended from the medial to the lateral portion of the footprint. In cases where the damage caused by BSPTTs to the footprint of the greater tuberosity was less than 50%, the volume of the rotator cuff stump was small, and we believe that FFT is unlikely to occur. In this study, all BSPTTs with FFTs were repaired using the suture-bridge technique after FTTs before repair, and there was no significant difference in the clinical outcomes or retear rate between Group P and Group F. There are two methods for repairing rotator cuffs for BSPTTs: in situ repair and repair after tear completion. Zhuo et al[25] compared the range of motion, Visual Analogue Scale (VAS) score, American Shoulder and Elbow Surgeons (ASES) score, and retear rate in 28 cases that underwent in situ repair and 30 cases that underwent repair after tear completion, and they reported no significant differences. Similarly, Shin et al[26] compared 47 cases that underwent in situ repair with 37 cases that underwent repair before tear completion, and they reported no significant differences in the VAS score, ASES score, or retear rate between the two groups. Regarding the repair method for BSPTTs with FFTs, we created FTTs before repair, but the clinical outcomes may have been equivalent if in situ repair had been performed.

This study has several limitations. First, this was a retrospective study. Second, the sample size in both groups was relatively small. Third, the follow-up period was not long enough to draw definitive conclusions. Future research should include a prospective randomized controlled trial with a larger sample size and a longer follow-up period to obtain more comprehensive results. Lastly, although this study suggested that osteophytes on the subacromial surface may have an effect on the development of FFT, it is unclear whether osteophyte formation or the development of FFT occurred first, because imaging tests were not performed prior to the rotator cuff tear.

CONCLUSION

FFTs frequently occur in patients with double floor-type osteophytes on the subacromial surface of both BSPTTs and FTTs. BSPTTs with FFTs may occur in young patients. The treatment outcomes of ARCR for BSPTTs with FFT were comparable to those for FTTs.

CONFLICTS OF INTEREST STATEMENT

None.

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