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Partial rupture of the distal biceps brachii tendon: a magnetic resonance imaging analysis

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Background: This study is the largest cohort of partial distal biceps brachii tendon ruptures in the literature that was analyzed according to rupture morphology of the long and short tendon heads.

Methods: Patients with partial distal biceps tendon ruptures were identified using an institutional enterprise data warehouse query at a single institution. A retrospective chart review was performed to record patient demographics, past medical history, and injury mechanism for each patient. Each patient's magnetic resonance images were reviewed to determine injury patterns, specifically the extent of long head (LH) and short head (SH) tendon involvement, and associated injuries. Rupture morphologies were correlated with mechanism of injury, diabetes status, and smoking history.

Results: Seventy-seven patients were included in the study. The average age was 52 years (±11.9, range: 23-90 years); 67% were male, with an average body mass index of 28.3 (±4.3). A smoking history was reported in 31.2% of patients and 5.2% were diabetic. The partial ruptures were caused by a traumatic mechanism in 57.1% of cases, 23.4% were atraumatic, and 19.5% had an unknown mechanism. The most common injury morphology was a partial LH rupture with an intact SH tendon (33.8%). Isolated complete ruptures of the LH represented the least common injury morphology. Injury morphology was significantly related to mechanism ($P < .01$). Traumatic ruptures had a higher percentage of SH involvement compared with the atraumatic group (77.3% vs. 37.7%, respectively). In contrast, atraumatic ruptures involved the LH tendon in 89% of cases, with only 37.7% of cases involving the SH tendon. Patients with a history of smoking were more likely to have an atraumatic mechanism ($P = .01$). A history of diabetes was unrelated to mechanism ($P = .20$).

Conclusion: Partial ruptures of the distal biceps brachii tendon represent a spectrum of patterns with varying involvement of the LH and SH tendons. Injury morphology was significantly related to mechanism ($P < .01$). LH tendon involvement was seen in 88.9% of atraumatic cases, whereas SH tendon involvement was seen in 77.3% of traumatic cases. A more comprehensive understanding of partial rupture patterns is critical to further understand the risk factors that may preclude to worse clinical outcomes, and aid in deciding which patients would benefit from operative vs. nonoperative management.

Approval for this study was received from the Institutional Review Board Office of Northwestern University (STU00205161).

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The distal insertion of the biceps brachii tendon is vulnerable to both acute and chronic injuries. There is a large body of literature focused on acute and complete ruptures of the tendon and subsequent surgical management.[20] It is estimated that the rate of complete ruptures of the tendon is between 1.2 and 2.55 per 10,000 patient-years.[12,17] However, complete ruptures are thought to represent only 3% of all distal bicep pathologies, which include partial ruptures, chronic tendinosis, bicipitoradial bursitis, and ganglion cysts.[4,15] Relative to complete ruptures, there is a paucity of literature focused on partial ruptures of the distal bicep tendon, which are likely more common than their complete rupture counterparts.

Partial ruptures of the distal biceps are often difficult to diagnose. Many patients have nonspecific pain localized to the antecubital fossa, do not recall a specific trauma, and, on average, present 4.5 weeks after the onset of symptoms.[6,16,22] Physical examination findings normally positive in complete ruptures may also be difficult to interpret in the context of partial ruptures as ecchymosis, deformity from proximal tendon migration, and the hook sign may be negative. When a rupture of the distal biceps tendon is suspected, magnetic resonance imaging (MRI) has been proven to be a powerful investigative tool with a sensitivity and specificity of 100% and 82.8% for complete ruptures and 59.1% and 100% for partial ruptures, respectively.[9]

The muscle bellies of the biceps brachii, the long head (LH) and short head (SH), form 2 distinct distal tendon bundles that insert on the radial tuberosity. The anatomy of each tendon's insertional footprint has been well described; however, the pathomechanism and pattern of partial tendon ruptures are poorly understood. The goal of this study is to analyze the morphology of partial distal biceps ruptures using the largest cohort of partial ruptures assessed according to LH and SH tendon involvement, and identify factors predisposing patients to these different pattern types.

Materials and methods

Data collection

Institutional review board approval was obtained before the initiation of this study. Our institutional enterprise data warehouse (EDW) was queried for patients who presented to our hospital system with distal biceps brachii tendon injuries. Subjects were identified based on the International Statistical Classification of Diseases and Related Health Problems code: 10th Revision (S46.21, S46.29). The EDW search identified 571 patients for review. MRI reports available in the electronic medical record were retrospectively reviewed. Patients with reported complete ruptures, absence of an MRI, and those without report of a partial distal biceps tendon rupture were excluded from analysis. After exclusion, 79 patients remained for review. A retrospective chart review was then performed for the 79-patient cohort. Demographics were recorded, including age, sex, mechanism of injury, body mass index, diabetes status, and smoking history.

Radiologic review

Injury MRIs for all 79 patients were then reviewed by a fellowship-trained musculoskeletal radiologist, who was blinded to the mechanism of injury and prior radiology report. The LH tendon, SH tendon, corresponding muscle bellies, lacertus fibrosus, radial tuberosity, bicipitoradial bursa, and surrounding muscles were independently assessed. The images were again blindly reviewed, 10 months later, by the same radiologist and a musculoskeletal radiology fellow to determine the intraobserver and interobserver reliability of each MRI variable. Radiology review resulted in 2 additional patients being excluded from analysis, 1 with a complete rupture and 1 with an intrasubstance rupture, resulting in 77 patients being included for analysis.

Radiologic definitions

The MRIs were interpreted according to a standardized protocol, which included review of the axial, sagittal, and coronal fat-suppressed, fluid sensitive images (T2-weighted turbo spin echo sequences) with respect to the long axis of the joint. Flexion abduction views were interpreted when available. The distal LH and SH tendon slips were analyzed at the radial tuberosity attachment and categorized as a bifid, non-bifid with 2 closely approximated tendon splits, or nondistinguishable slips inserting as a single unit. All insertion morphologies were included in the analysis. In cases where the tendon appeared as a single unit, the medial half of the tendon at the level of the myotendinous junction and extending to the level of the elbow joint was considered the SH, whereas the lateral half was considered the LH. Distally, the more anterior insertion of the tendon was considered the SH, whereas the posterior component of the tendon insertion was considered the LH. Partial ruptures were defined as any intact fibers of the LH or SH tendon slip that were still visible and taut. The degree of rupture was based on the approximate cross-sectional area of involvement compared with the expected area of involvement. The T2-weighted axial sequence was the sequence of choice to distinguish a full-thickness rupture from a partial-thickness rupture; the findings were confirmed on the sagittal and coronal images. Tendinopathy was defined as an abnormal caliber change of the tendon and/or abnormal signal intensity seen on T2-weighted images, generally best demonstrated on axial images.

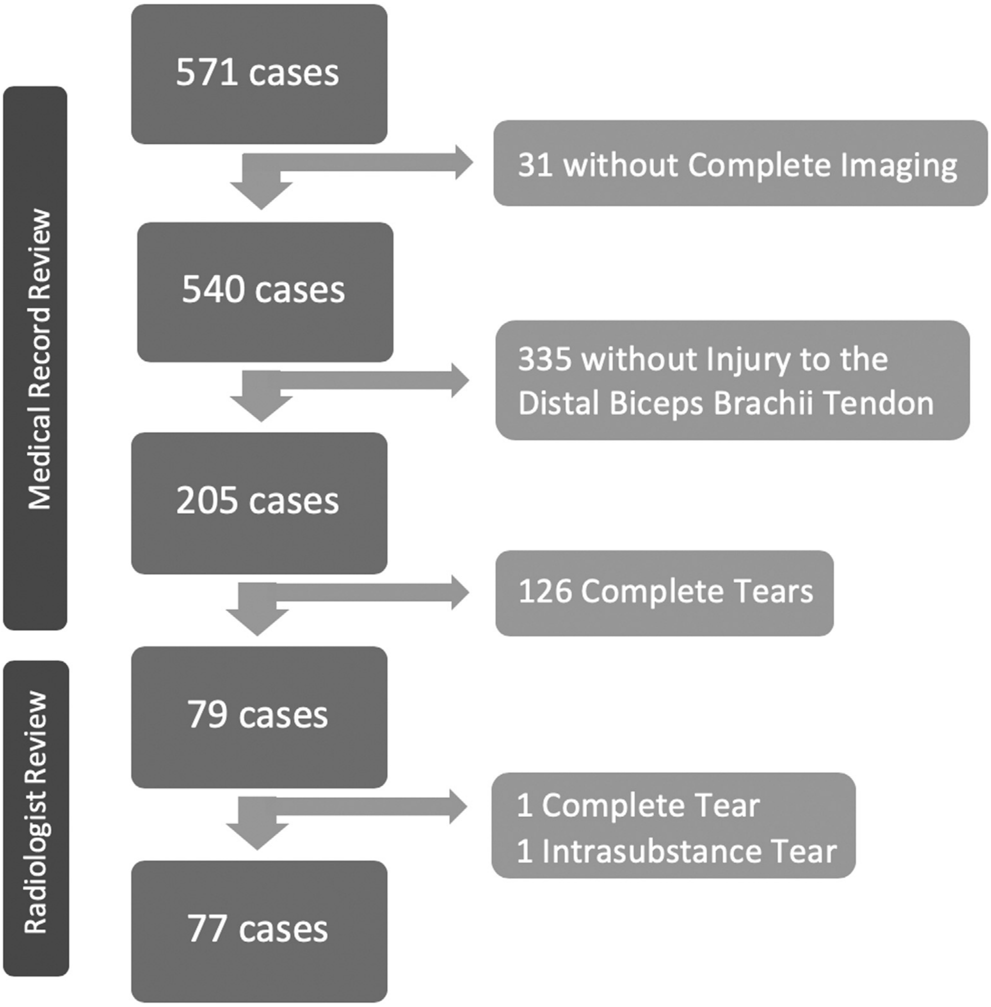

Figure 1 Flow diagram of cases included for analysis.

The normal distal biceps muscle bellies have a tapered, smooth appearance on long axis MRI of the elbow; muscle bellies with a globular, rounded morphology and proximal migration of the myotendinous junction were defined as retracted. The radial tuberosity is normally smooth with a thin enthesis, and entheseal irregularity was defined as a jagged, pitted, or discontinuous enthesis associated with spurring or marrow edema, which was best identified on T2-weighted fat-suppressed sequences.

Categorical data were compared with the χ^2 test. Pearson correlation coefficients were reported. Continuous variables were compared using Student's *t*-test. An alpha level of <0.05 was set. Kappa-coefficients (κ) were calculated for the intraobserver and interobserver correlations. All data and statistical analyses were performed using JMP Pro (version 13.0; SAS, Cary, NC, USA).

Results

A total of 571 patients were identified by the EDW based on International Statistical Classification of Diseases and Related Health Problems: 10th Revision codes. After review of the medical record, 31 patients had incomplete imaging, 335 did not have a rupture of the distal biceps brachii tendon, and 126 had complete ruptures—these cases were excluded. Two additional patients were excluded after radiologic review, 1 for a complete rupture and 1 for an intrasubstance rupture (Fig. 1). The remaining 77 patients were included in the study. The average age of the sample population was 52 years (±11.9, range: 23-90 years); 67% were male, with an average body mass index of 28.3 (±4.3). A smoking history was reported in 31.2% of the patients and 5.2% were diabetic (Table I). A 3-Tesla MRI was used in 40 cases (51.9%), and the arm was in a flexion abduction view in 4 cases (5.3%).

The most common injury morphology was a partial LH rupture with an intact SH insertion (33.8%). Isolated complete ruptures of the LH (3.9%) were the least common. Isolated complete SH tendon ruptures occurred more frequently in 11.7% of cases (Fig. 2). The overall rate of partial LH ruptures was 68.9%; complete LH ruptures (11.7%) and intact LH tendons (11.7%) were less

Table I Patient demographics

Patient factor	Mean (n)	95% CI, %
Age	52	±11.9
BMI	28.3	±4.3
Male sex	67	87.0%
Diabetes	4	5.2%
Smoking history	24	31.2%

BMI, body mass index; *CI*, confidence interval.

Figure 2 T2 sagittal magnetic resonance imaging sequence demonstrating a complete short head (SH) tendon rupture with an intact long head (LH) tendon inserting on the radial tuberosity (RT).

commonly seen. Intact SH tendons were most common (37.7%), followed by partial SH ruptures (32.5%) and complete SH ruptures (29.9%) (Fig. 3). There were 11 cases (14.3%) with a bifid distal biceps tendon (Fig. 4). A subgroup analysis was performed; the bifid tendons demonstrated no significant difference in partial rupture morphology when compared with non-bifid tendons (P = .32) (Table II).

Injury morphology was significantly related to mechanism ($P < .01$). A majority of the partial ruptures occurred after a traumatic event (57.1%). The most common injury mechanism was lifting an object (28.6%) (Table III, Fig. 5). Isolated partial ruptures of the LH tendon were the most common pattern in the atraumatic group with a rate of 66.5%, compared with 20.4% in the traumatic group ($P <$ .01) (Fig. 6). The LH tendon was affected in 88.9% of atraumatic cases compared with the SH tendon in 27.8%. Compared with the atraumatic group, SH tendon injuries occurred more frequently in the traumatic group (77.3%). In addition, morphologies involving a complete LH or complete SH rupture were very rare in the atraumatic group; only 1 case (5.6%) occurred (Table IV).

Associated tendinopathy was common; 62.3% of cases demonstrated LH and SH tendinopathy on MRI (Fig. 7). Tearing of the lacertus fibrosis was uncommon (5.2%) (Fig. 8). Muscle retraction was found in 24.7%, and atrophy was demonstrated in 6.5% of cases (Table V). An osseous avulsion was only seen in 1 case (1.3%), and tuberosity abnormalities including entheseal irregularity (44.2%) and subentheseal marrow edema (27.3%) were more common. Subentheseal marrow edema was independently related to diabetes, where it was found in 75% of diabetics compared with 4.1% of nondiabetics ($P < .01$). Tendinopathy ($P = .01$), lacertus fibrosis injuries ($P < .01$), and muscle strains ($P < .01$) were more common in cases with a traumatic mechanism (Table VI). Patients with a history of smoking were more likely to have an atraumatic mechanism ($P = .01$). A history of diabetes was unrelated to mechanism ($P = .20$) (Table VII).

The interobserver and intraobserver reliability for each MRI variable were measured. The most reliable measurement was muscle belly retraction, which demonstrated an almost perfect intrauser reliability ($\kappa = 0.83$, $P < .0001$) and a substantial interuser reliability ($\kappa = 0.64$, $P < .0001$). The least reliable interpretation was the assessment of the tuberosity, which demonstrated a fair intrauser reliability ($\kappa = 0.35$, $P < .0001$) and fair interuser reliability ($\kappa = 0.28$, $P < .0001$) (Table VIII).

Discussion

The majority of cases involved a partial rupture of the LH (68.8%), and the most common injury morphology was an isolated partial LH rupture without SH involvement (33.8%). Multiple studies have suggested that distal tendon ruptures typically involve the SH of the biceps.[2,6,10,16,22] Many of these studies, however, have been considered underpowered due to small cohorts of less than 30 patients. We separated our cohort into traumatic and atraumatic groups and analyzed the differences. Traumatic ruptures were more common overall (57.1%) and had a higher percentage of SH involvement compared with the atraumatic group (77.3% vs. 37.7%, respectively). This makes sense pathomechanically. The most common mechanism of injury was lifting an object (28.6%), where the more distal insertion of the SH tendon experiences greater tensile force during an eccentric load.[11] Of complete SH ruptures, 100% occurred via a traumatic mechanism. These findings suggest that injuries resulting from an eccentric load are more likely to involve the SH tendon.

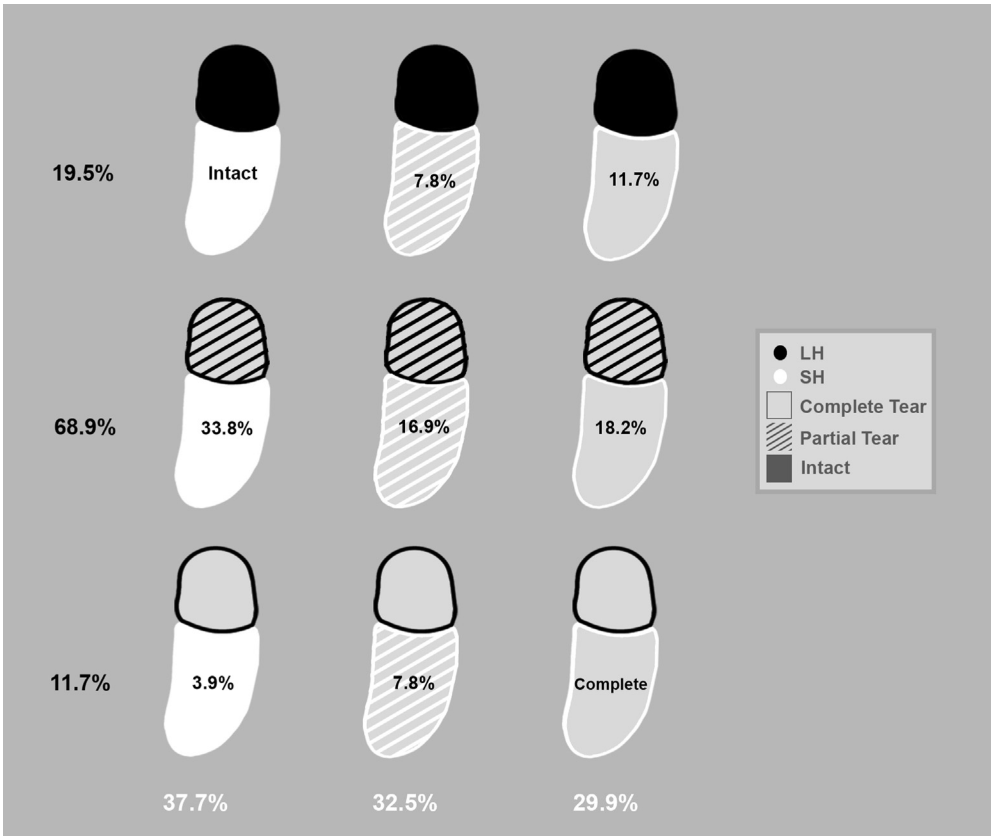

Figure 3 Schematic of the partial rupture patterns in the 77-patient cohort, organized by long head (LH) and short head (SH) rupture morphologies, including complete ruptures, partial ruptures, and absence of rupture. Rows were organized by LH morphologies (black) and columns were organized by SH morphologies (white).

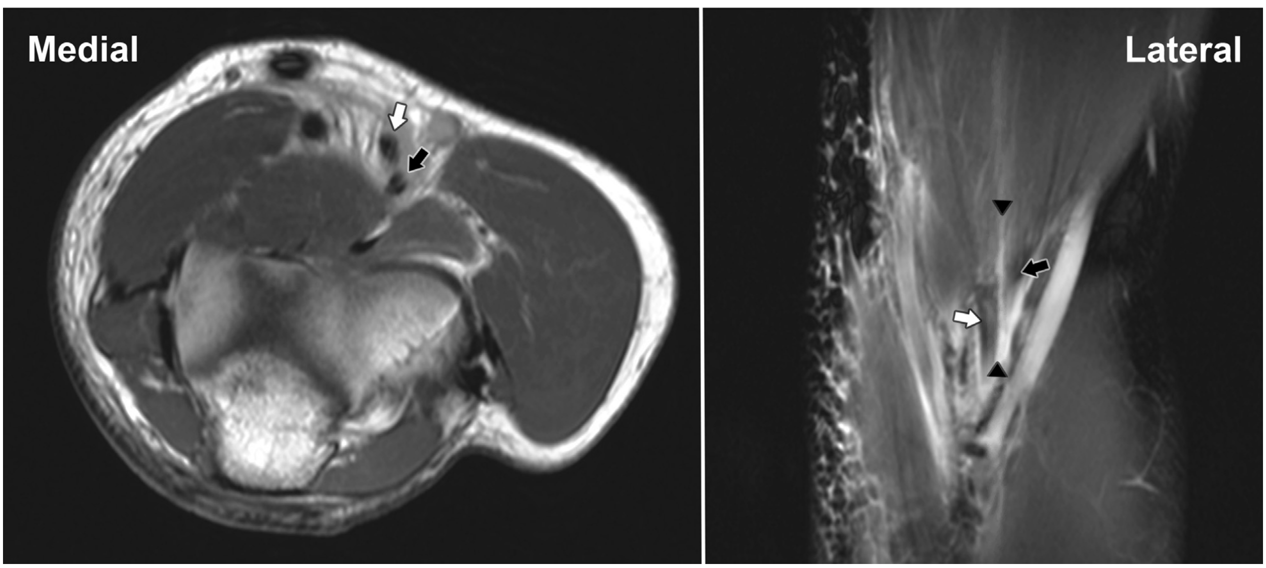

Figure 4 Bifid distal biceps tendon morphology on axial proton density (left) and coronal T2 fat saturated (right) series demonstrating clearly divided short head (white arrow) and long head (black arrow) tendon slips separated by an intervening connective tissue septum (arrow heads) arising from the myotendinous junction and extending to the tendon insertion.

Table II Bifid tendon vs. partial rupture morphology

Partial rupture morphology		Bifid	Non-bifid	
Long head	Short head	n (%)	n (%)	
Partial	–	4 (36.4)	22 (33.3)	
Partial	Complete	3 (27.3)	11 (16.7)	
–	Complete	3 (27.3)	6 (9.1)	
Complete	Partial	1 (9.1)	5 (7.6)	
Partial	Partial	0 (0)	13 (19.7)	
–	Partial	0 (0)	6 (9.1)	
Complete	–	0 (0)	3 (4.5)	$P = .32$

Table III Mechanism of injury

Mechanism	n (%)
Traumatic	
Lifting an object	22 (28.6)
Sport	11 (14.3)
Weight training	7 (9.1)
Polytrauma	4 (5.2)
Total	44 (57.1)
Atraumatic	18 (23.4)
Unknown	15 (19.5)

The contrary is true for atraumatic ruptures. Atraumatic ruptures involved the LH tendon in 89% of cases, with only 37.7% of cases involving the SH tendon. The relatively low rate of SH involvement suggests a different mechanism of injury in the atraumatic group. Atraumatic ruptures are likely the result of attritional tendon injury from repetitive supination, in contrast to an acute eccentric force where the SH is preferentially loaded. This explains why a higher proportion of the atraumatic injuries involved a partial LH rupture with no SH involvement (66.5%). It was also noted that complete ruptures of either the LH or SH were rare in the atraumatic cohort, accounting for only 1 case (5.6%). This suggests that injuries predominately involving the LH tendon are more likely a result of a chronic attritional mechanism. Common rupture morphologies of these injuries are poorly understood and may be important for guiding treatment.

The anatomy of the distal biceps brachii tendon is well described. The LH and SH form 2 tendon bundles approximately 7 cm proximal to the radius.[1,5,8,11,13,14] Proximal to the elbow joint, the SH tendon lies medial to the LH tendon in the coronal plane and serves as the origin for the lacertus fibrosis.[1] The LH and SH tendons travel together through the cubital tunnel lateral to the median nerve and brachial artery, and deep to the radial recurrent vessels.[23] The 2 tendons externally rotate 90° as they travel toward the radius, such that the SH tendon lies distal to the LH tendon in the sagittal plane.[1,8,11,13] The tendons of both the LH and SH insert posteriorly to the radial protuberance, providing a cam mechanism to increase supination torque.[19] At their insertion on the radial tuberosity, the 2 tendons each occupy their own orientation on the footprint and are easily separated in 59%-67% of patients.[8,11,18,21] The footprint on the radial tuberosity is oval and measures 21 mm in the longest dimension. The SH occupies the distal 12 mm with an oval footprint and the LH inserts along the proximal 9 mm in a radial-based crescent (Fig. 9).[7,11,21]

The anatomic position of each tendon's insertion carries significant biomechanical implications. Eames et al,[8] who dissected 17 cadaver elbows, were the first to suggest that the SH is a more powerful flexor and the LH is a more powerful supinator based on each tendons' relative anatomy on the radial tuberosity. Jarrett et al[11] conducted a biomechanical study demonstrating that the SH is a more efficient flexor, particularly when the elbow is in 90° of flexion. In a neutral pronated arm, Jarrett et al[11] determined that the SH was a more efficient supinator, and only with the arm in a supinated position was the LH more efficient at supination.

In the majority of cases, the distal biceps tendon appeared as a single unit or 2 closely apposed tendon slips with predictable positions of the LH and SH fibers. At their insertion on the radial tuberosity, the individual tendon slips may be separate. Although it is seen in a minority of cases, a bifid tendon can be diagnosed on imaging when the distal biceps tendon is clearly divided into separate LH and SH tendon slips separated by an intervening connective tissue septum arising from the myotendinous junction and extending to the tendon insertion. In clinical practice, the interdigitations between the tendon slips of a bifid tendon may occur but are not routinely assessed or documented. For the purpose of this study, we have elected to report bifid tendons together with single tendons. Bifid tendons are relatively uncommon; further research is required to establish a larger cohort of bifid tendons and study this specific morphology's effect on injury and outcome.

Current literature on partial ruptures of the distal biceps tendon focuses primarily on the surgical management of the injury.[2,4] The natural history and best treatment strategies are poorly defined, and thus, management is controversial. An operative indication of ruptures larger than 50% is commonly cited, but this guideline is controversial.[2,8] In a recent systematic review by Behun et al,[4] 19 articles were reviewed, and the authors concluded that managing partial ruptures with tear completion and anatomic repair led to satisfactory results with predictable outcomes. The authors also explain that nonsurgical management can be an appropriate option; however, consensus on treatment regimen and duration is lacking.[4] More recently, Bauer et al[3] conducted a study that collected patient-reported outcomes on 74 patients with partial distal biceps ruptures; they concluded that the failure rate of nonoperative management was 56%. On the basis of their evidence, Bauer et al[3] considered it reasonable to pursue early surgical

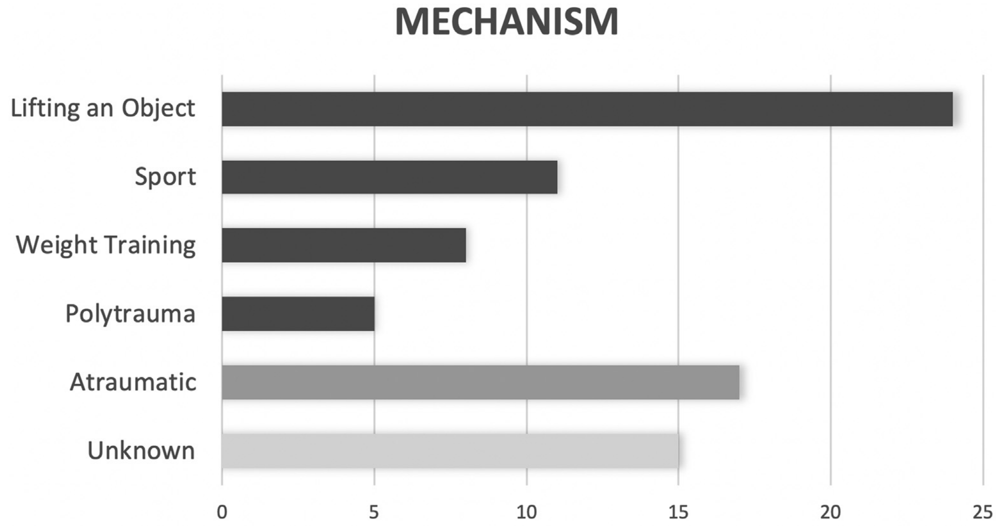

Figure 5 Bar graph of partial biceps brachii tendon ruptures by mechanism.

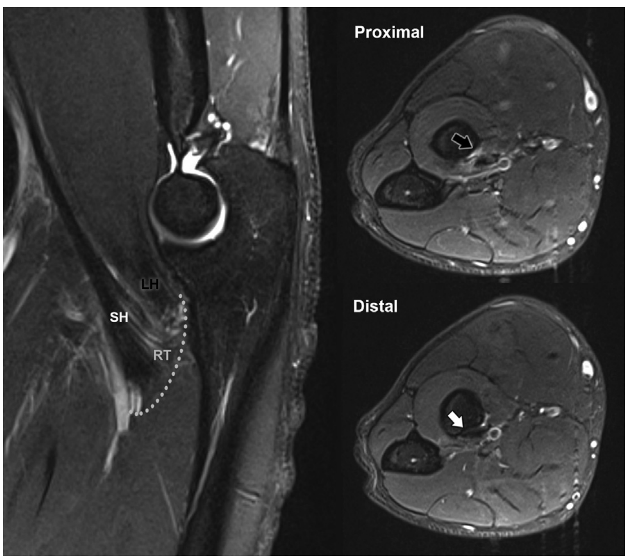

Figure 6 Representative sagittal (left) and axial (right) T2 fat-saturated magnetic resonance imaging sequences demonstrating a partial long head (LH) (black arrow) tear at its insertion on the radial tuberosity (RT) and an intact short head (SH) insertion (white arrow).

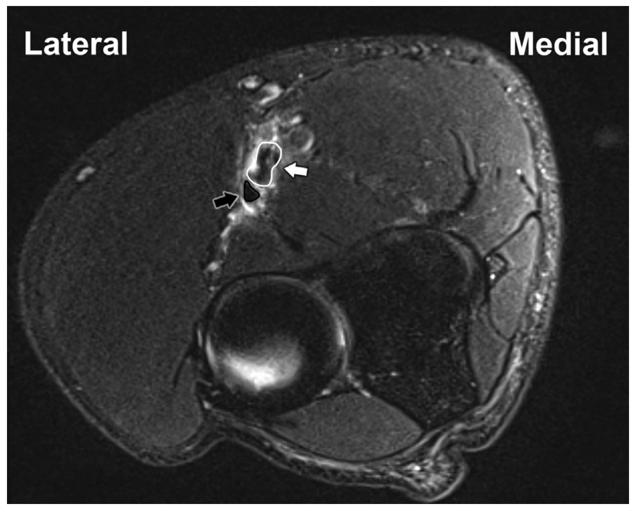

Figure 7 Representative axial T2 fat-saturated magnetic resonance imaging of short head (SH) tendinopathy (white arrow) relative to a normal long head tendon (black arrow); the SH demonstrates abnormal caliber change and abnormal signal intensity.

Table IV Traumatic and atraumatic mechanisms vs. partial rupture morphology

Partial rupture morphology		Traumatic (n = 44)	Atraumatic (n = 18)	*P* value
Long head	Short head			
Partial	–	9 (20.4%)	12 (66.5%)	
Partial	Complete	13 (29.6%)	0	
Partial	Partial	8 (18.2%)	3 (16.7%)	
–	Complete	7 (15.9%)	0	
–	Partial	2 (4.5%)	2 (11%)	
Complete	Partial	4 (9.1%)	0	
Complete	–	1 (2.3%)	1 (5.6%)	$<.01$

intervention on high-demand laborers with >50% tendon involvement.

Partial ruptures of the distal biceps tendon are rarely subclassified into atraumatic vs. traumatic ruptures in articles discussing treatment strategies and outcomes. This study highlights how atraumatic and traumatic mechanisms result in different partial rupture morphologies. Atraumatic partial ruptures predominately involve the LH tendon and may require a different treatment algorithm compared with their traumatic counterparts with more SH tendon involvement. Furthermore, various partial rupture morphologies may result in different symptom profiles and functional deficits if treated conservatively. Further

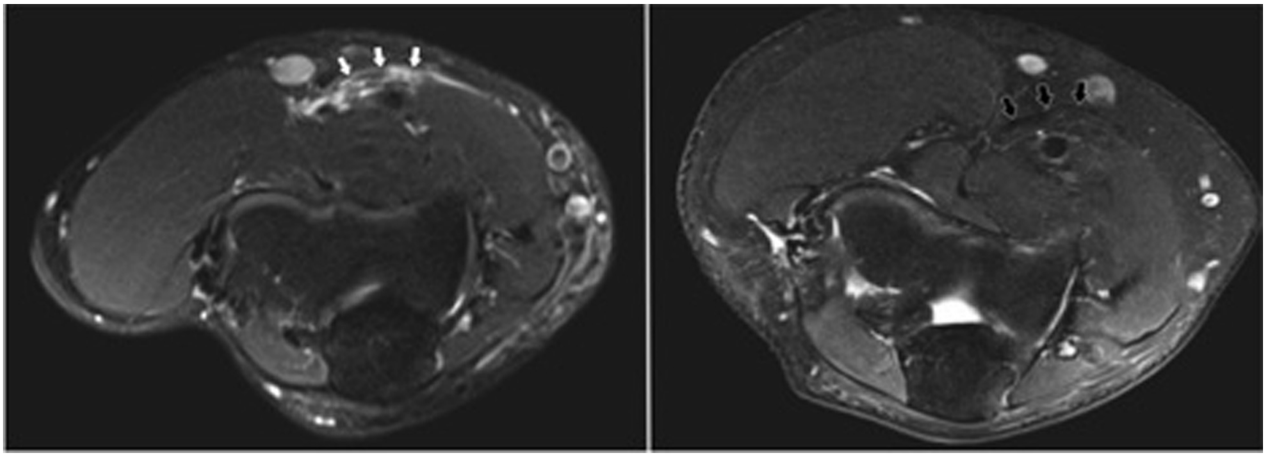

Figure 8 Lacertus fibrosus tear (white arrows) demonstrated on an axial T2-weighted magnetic resonance imaging sequence of a patient with a partial distal biceps rupture, with comparison with an intact lacertus fibrosus (black arrows) demonstrated in a different patient with a partial distal biceps rupture.

Table V Associated MRI findings

Associated injury	n (%)
Tendinopathy	
LH/SH	48 (62.3)
LH	19 (24.7)
SH	9 (11.7)
None	1 (1.3)
Lacertus fibrosis	
Edema	17 (22.1)
Wave	9 (11.7)
Tear	4 (5.2)
Muscle bellies	
Retraction	19 (24.7)
Grade 1 strain	15 (19.5)
Grade 2 strain	7 (9.1)
Atrophy	5 (6.5)
Tuberosity	
Entheseal irregularity	34 (44.2)
Subentheseal marrow edema	21 (27.3)
Osseous avulsion	1 (1.3)
Bicipitoradial bursitis	53 (68.8)

MRI, magnetic resonance imaging; *LH*, long head; *SH*, short head.

Table VI Traumatic and atraumatic mechanisms vs. associated MRI findings

Associated findings	Traumatic N (%)	Atraumatic n (%)	*P* value
Tendinopathy			
LH/SH	33 (75.0)	8 (44.4)	**.01**
LH	5 (11.4)	9 (50.0)	
SH	5 (11.4)	1 (5.6)	
None	1 (2.3)	0 (0.0)	
Lacertus fibrosis			
No injury	20 (45.4)	17 (94.4)	**<.01**
Edema	14 (31.8)	0 (0.0)	
Wave	6 (13.6)	1 (5.6)	
Tear	4 (9.0)	0 (0.0)	
Muscle bellies			
No retraction	31 (70.4)	16 (88.9)	.12
Retraction	13 (29.6)	2 (11.1)	
No strain	26 (59.1)	18 (100.0)	**<.01**
Grade 1 strain	11 (25.0)	0 (0.0)	
Grade 2 strain	7 (15.9)	0 (0.0)	
No atrophy	41 (93.2)	17 (94.4)	.85
Atrophy	3 (6.8)	1 (5.6)	
Tuberosity			
Entheseal irregularity	11 (25.0)	8 (44.4)	.49
Subentheseal marrow edema	11 (25.0)	4 (22.2)	
Osseous avulsion	1 (2.3)	0 (0.0)	
Bicipitoradial bursitis			
Present	30 (68.2)	13 (72.2)	.75
Absent	14 (31.8)	5 (27.8)	

MRI, magnetic resonance imaging; *LH*, long head; *SH*, short head.

understanding and characterization of partial ruptures is critical to determine optimal treatment strategies and improve outcomes. The mechanism and morphology of partial ruptures of the distal biceps tendon may prove to be a better guide for treatment strategies than percent tendon involvement as currently cited.

The primary limitation of this study was its retrospective design. Only the information available in the electronic medical record could be assessed. Therefore, we were unable to draw conclusions regarding specific occupations, sport participation, or other patient risk factors, and 19.5% of our cases were missing a mechanism of injury. We omitted the unknown cases from our analysis. Although this study reports demographic, epidemiologic, and anatomic information characterizing various partial rupture morphologies, our data do not provide insight on outcomes or treatment recommendations. We are also limited by the reliability of each MRI interpretation; we are, however, the

Table VII Mechanism of injury vs. smoking history and diabetes

	Traumatic	Atraumatic	*P* value
	n (%)	n (%)	
Smoking history	9 (24.3)	12 (57.1)	
Nonsmoker	28 (75.6)	9 (42.8)	**.01**
Diabetes	1 (2.2)	2 (11.1)	
Nondiabetic	43 (97.7)	16 (88.8)	.20

Table VIII Intraobserver and interobserver reliability of each MRI finding

Variable	Intraobserver κ-coefficient	*P* value	Interobserver κ-coefficient	*P* value
Morphology	0.46	<.0001	0.6	<.0001
Tendinopathy	0.63	<.0001	0.57	<.0001
Lacertus fibrosis	0.41	<.0001	0.5	<.0001
Muscle bellies	0.51	<.0001	0.49	<.0001
Atrophy	0.32	.005	0.88	<.0001
Retraction	0.83	<.0001	0.64	<.0001
Tuberosity	0.35	<.0001	0.28	<.0001
Bicipitoradial bursitis	0.75	<.0001	0.76	<.0001

MRI, magnetic resonance imaging.

first to report interobserver and intraobserver reliability for many of the variables included in our study.

Conclusion

Partial ruptures of the distal biceps brachii tendon represent a spectrum of patterns with varying involvement of the LH and SH tendons. Injury morphology was significantly related to mechanism ($P < .01$). LH tendon involvement was seen in 88.9% of atraumatic cases, whereas SH tendon involvement was seen in 77.3% of traumatic cases. A more comprehensive understanding of partial rupture patterns is critical to further understand the risk factors that may preclude to worse clinical outcomes, and aid in deciding which patients would benefit from operative vs. nonoperative management.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

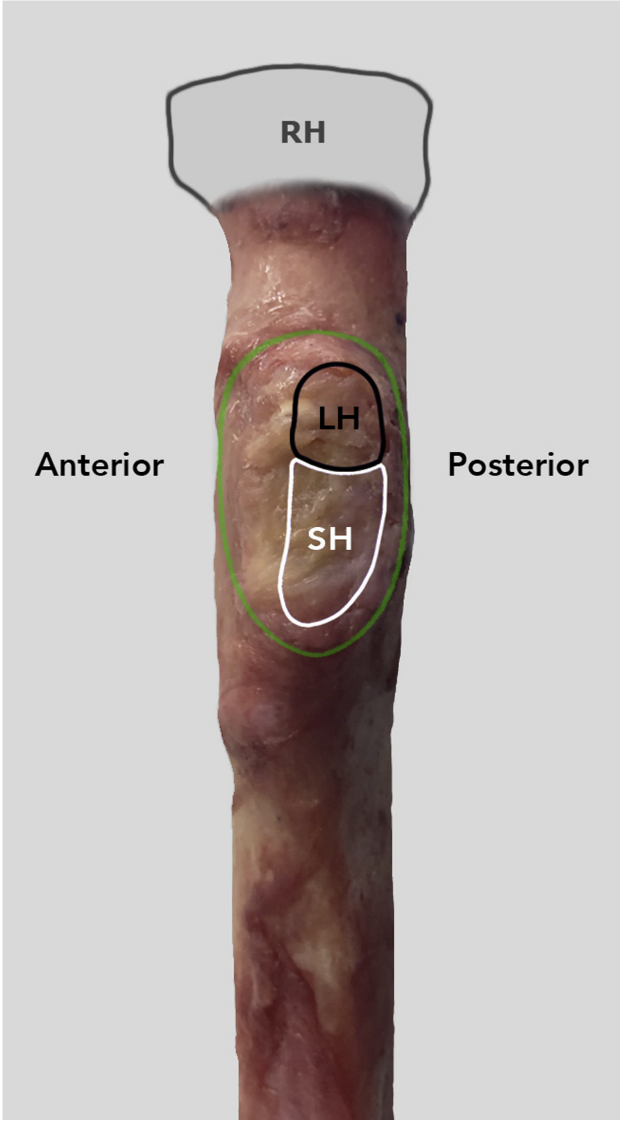

Figure 9 Anatomic dissection of the proximal radius demonstrating the insertion of the long head (LH) tendon in a radial-based crescent and the more distal short head (SH) tendon's oval insertion on the radial tuberosity. *RH*, radial head.

Supplementary Material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2020.04.021.

References

1. Athwal GS, Steinmann SP, Rispoli DM. The distal biceps tendon: footprint and relevant clinical anatomy. J Hand Surg Am 2007;32: 1225-9. https://doi.org/10.1016/j.jhsa.2007.05.027
2. Bain GI, Johnson LJ, Turner PC. Treatment of partial distal biceps tendon tears. Sports Med Arthrosc Rev 2008;16:154-61. https://doi.org/10.1097/JSA.0b013e318183eb60
3. Bauer TM, Wong JC, Lazarus MD. Is nonoperative management of partial distal biceps tears really successful? J Shoulder

Elbow Surg 2018;27:720-5. https://doi.org/10.1016/j.jse.2017.12.010

4. Behun MA, Geeslin AG, O'Hagan EC, King JC. Partial tears of the distal biceps brachii tendon: a systematic review of surgical outcomes. J Hand Surg Am 2016;41:e175-89. https://doi.org/10.1016/j.jhsa.2016.04.019
5. Cho CH, Song KS, Choi IJ, Kim DK, Lee JH, Kim HT, et al. Insertional anatomy and clinical relevance of the distal biceps tendon. Knee Surg Sports Traumatol Arthrosc 2011;19:1930-5. https://doi.org/10.1007/s00167-011-1586-x
6. Dellaero DT, Mallon WJ. Surgical treatment of partial biceps tendon ruptures at the elbow. J Shoulder Elbow Surg 2006;15:215-7. https://doi.org/10.1016/j.jse.2005.08.020
7. Dirim B, Brouha SS, Pretterklieber ML, Wolff KS, Frank A, Pathria MN, et al. Terminal bifurcation of the biceps brachii muscle and tendon: anatomic considerations and clinical implications. AJR Am J Roentgenol 2008;191:W248-55. https://doi.org/10.2214/AJR.08.1048
8. Eames MH, Bain GI, Fogg QA, van Riet RP. Distal biceps tendon anatomy: a cadaveric study. J Bone Joint Surg Am 2007;89:1044-9. https://doi.org/10.2106/JBJS.D.02992
9. Festa A, Mulieri PJ, Newman JS, Spitz DJ, Leslie BM. Effectiveness of magnetic resonance imaging in detecting partial and complete distal biceps tendon rupture. J Hand Surg Am 2010;35:77-83. https://doi.org/10.1016/j.jhsa.2009.08.016
10. Frazier MS, Boardman MJ, Westland M, Imbriglia JE. Surgical treatment of partial distal biceps tendon ruptures. J Hand Surg Am 2010;35:1111-4. https://doi.org/10.1016/j.jhsa.2010.04.024
11. Jarrett CD, Weir DM, Stuffmann ES, Jain S, Miller MC, Schmidt CC. Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. J Shoulder Elbow Surg 2012;21:942-8. https://doi.org/10.1016/j.jse.2011.04.030
12. Kelly MP, Perkinson SG, Ablove RH, Tueting JL. Distal biceps tendon ruptures: an epidemiological analysis using a large population database. Am J Sports Med 2015;43:2012-7. https://doi.org/10.1177/0363546515587738
13. Koulouris G, Malone W, Omar IM, Gopez AG, Wright W, Kavanagh EC. Bifid insertion of the distal biceps brachii tendon with isolated rupture: magnetic resonance findings. J Shoulder Elbow Surg 2009;18:e22-5. https://doi.org/10.1016/j.jse.2009.03.018
14. Kulshreshtha R, Singh R, Sinha J, Hall S. Anatomy of the distal biceps brachii tendon and its clinical relevance. Clin Orthop Relat Res 2007;456:117-20. https://doi.org/10.1097/BLO.0b013e31802f78aa
15. Ramsey ML. Distal biceps tendon injuries: diagnosis and management. J Am Acad Orthop Surg 1999;7:199-207.
16. Ruch DS, Watters TS, Wartinbee DA, Richard MJ, Leversedge FJ, Mithani SK. Anatomic findings and complications after surgical treatment of chronic, partial distal biceps tendon tears: a case cohort comparison study. J Hand Surg Am 2014;39:1572-7. https://doi.org/10.1016/j.jhsa.2014.04.023
17. Safran MR, Graham SM. Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. Clin Orthop Relat Res 2002:275-83.
18. Sassmannshausen G, Mair SD, Blazar PE. Rupture of a bifurcated distal biceps tendon. A case report. J Bone Joint Surg Am 2004;86:2737-40. https://doi.org/10.2106/00004623-200412000-00023
19. Schmidt CC, Brown BT, Williams BG, Rubright JH, Schmidt DL, Pic AC, et al. The importance of preserving the radial tuberosity during distal biceps repair. J Bone Joint Surg Am 2015;97:2014-23. https://doi.org/10.2106/JBJS.N.01221
20. Schmidt CC, Savoie FH III, Steinmann SP, Hausman M, Voloshin I, Morrey BF, et al. Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting-2015. J Shoulder Elbow Surg 2016;25:1717-30. https://doi.org/10.1016/j.jse.2016.05.025
21. Seiler JG III, Parker LM, Chamberland PD, Sherbourne GM, Carpenter WA. The distal biceps tendon. Two potential mechanisms involved in its rupture: arterial supply and mechanical impingement. J Shoulder Elbow Surg 1995;4:149-56.
22. Vardakas DG, Musgrave DS, Varitimidis SE, Goebel F, Sotereanos DG. Partial rupture of the distal biceps tendon. J Shoulder Elbow Surg 2001;10:377-9.
23. Zeltser DW, Strauch RJ. Vascular anatomy relevant to distal biceps tendon repair. J Shoulder Elbow Surg 2016;25:283-8. https://doi.org/10.1016/j.jse.2015.08.042