

The Biceps Femoris Muscle Complex at the Knee

Its Anatomy and Injury Patterns Associated with Acute Anterolateral-Anteromedial Rotatory Instability

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ABSTRACT

We dissected 30 cadaveric knees to provide a detailed anatomic description of the biceps femoris muscle complex at the knee. The main components of the long head of the muscle are a reflected arm, a direct arm, an anterior arm, and a lateral and an anterior aponeurosis. The main components of the short head of the biceps femoris muscle are a proximal attachment to the long head's tendon, a capsular arm, a confluens of the biceps and the capsuloosseous layer of the iliotibial tract, a direct arm, an anterior arm, and a lateral aponeurosis. We examined 82 consecutive, acutely injured knees with clinical signs of anterolateral-antemedial rotatory instability for the incidence and anatomic location of injuries to the biceps femoris muscle. Injuries to components of that muscle were identified in 59 (72%) of these knees; 29 knees (35.4%) had multiple components injured. There were 3 injuries to the long head of the biceps femoris muscle (all in the reflected arm) and 89 to the short head. A statistically significant correlation ($P = 0.01$) was found between increased anterior translation with the knee at 25° of flexion as demonstrated by the Lachman test and injury to the biceps-capsuloosseous iliotibial tract confluens. Additionally, adduction laxity at 30° of flexion correlated with a Segond fracture ($P = 0.04$). These data establish, in part, the relationship of the biceps femoris complex injury to anterior translation instability.

Interest in the association between biceps femoris muscle injuries and acute knee instability was prompted by stud-

ies by Hughston and colleagues^{8,9,14} of injuries to the lateral ligaments of the knee in athletes. However, a thorough review of the anatomic,^{6,7,10,11,19-21,24,27,32} surgical,^{2,12,13,17,29} and clinical literature^{4,8,9,14,18,33} provided no description of injury patterns to the biceps femoris muscle or a surgical approach for their evaluation. The purpose of our paper is threefold: 1) to present the anatomic relationships of the biceps femoris muscle complex at the knee with an emphasis on its clinically relevant components, 2) to report the incidence and anatomic location of injuries to these components in a patient population that had surgical treatment of acute knee injuries classified as combined anterolateral-antemedial rotatory instability,²⁸ and 3) to describe a surgical approach for examining the biceps femoris muscle for injuries.

MATERIALS AND METHODS

Anatomic Study

Thirty fresh-frozen cadaveric knees were dissected to provide a detailed anatomic description of the biceps femoris muscle at the knee. The dissections, done by the senior author (GCT), were photographed and examined for anatomic similarities. The components of the long and short heads of the biceps femoris muscle that were identified were recorded graphically on specially designed knee data sheets.

Clinical Study

Between September 1982 and October 1988, 82 consecutive, acutely injured knees in 82 patients who exhibited clinical signs of the combined anterolateral-antemedial instability²⁸ were examined for the incidence and anatomic location of injuries to the biceps femoris muscle. The study population consisted of 61 men and 21 women in whom 39 right knees and 43 left knees were injured. Their

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average age was 22.9 years (range, 14 to 53). The mechanism of knee injury was deceleration in 36, contact in 27, and twisting in 19 patients.

The diagnosis of combined anterolateral-anteromedial rotatory instability was made based on clinical criteria.^{10,11,28,30} The following clinical examination tests with the patient under anesthesia were performed by a single examiner (GCT): the anterior drawer test at 90° of knee flexion in both neutral and slight external tibial rotation, adduction (lateral joint line opening) and abduction (medial joint line opening) stability at 30° of knee flexion, anterior tibial translation near extension (Lachman test), and the pivot shift-jerk test.^{3,5,10,11,22,23,26,31} The motion produced by these tests was graded 0 to 3, according to the American Medical Association guidelines¹ and criteria in previously published works.^{8,10} The difference in motion limits detected by examination between the injured (index) and the normal knee was defined as abnormal (index minus normal). Significant abnormal motion was de-

finied as 1+ (5 mm) index-minus-normal difference. The knee injury was then classified as anterolateral-anteromedial rotatory instability^{10,11} (anterior tibial translation instability, ACL-deficient knee). The abnormal motion detected in each test was recorded for later correlation with anatomic injury.

All of these knees were operated on because of the patient's profound sense of disability, as well as the objective determination of abnormal motion demonstrated by reproducing the patient's injury mechanism during pre-anesthesia examination testing. The observed displacement was associated with the patient's sense of disability. At surgery, the injured anatomic structures were evaluated, and all grade 3 (complete) injuries, as determined by visual inspection and probing, were recorded. Injuries to the anatomic components of the biceps femoris muscle were identified and recorded in detail.

Statistical Methods

Linear regression analysis was used to determine the correlations for each injured component of the biceps femoris muscle complex and the variations in the grades of pathologic motion (i.e., displacement) demonstrated during the patient's clinical examination.

Surgical Approach

A reproducible surgical approach was developed during the anatomic study and refined during the clinical study. It was used to examine the biceps femoris muscle for injuries.

Surgery was performed with the patient in a supine position with the knee flexed to approximately 60° to 70°. In this position, the components of the biceps femoris muscle complex could be more easily identified. A lateral curved skin incision was made that began parallel to the lateral intermuscular septum and extended parallel to the femur in the coronal plane. It continued distally, crossing the lateral epicondyle, and ended distally at a point centered between the anterior tibial tubercle and Gerdy's tubercle.

The skin and subcutaneous tissues were reflected from the fascia as a posteriorly based flap. Because the two are densely adherent, the skin flap was carefully reflected from the fascia of the short head of the biceps femoris muscle. After the skin flap was reflected, it was possible to visualize the entire lateral aspect of the biceps femoris muscle.

Three fascial incisions were used to evaluate the deeper lateral structures (Fig. 1). The primary incision for evaluating the biceps femoris muscle was made between the posterior edge of the lateral intermuscular septum and the short head of the biceps femoris muscle (Incision a).³⁰ The incision began approximately 6 to 7 cm proximal to the lateral epicondyle and posterior to the septum. It was extended distally, parallel to the biceps and posterior to the iliotibial tract.

The second incision was made posterior to the biceps tendon and parallel to the peroneal nerve (Incision b). An

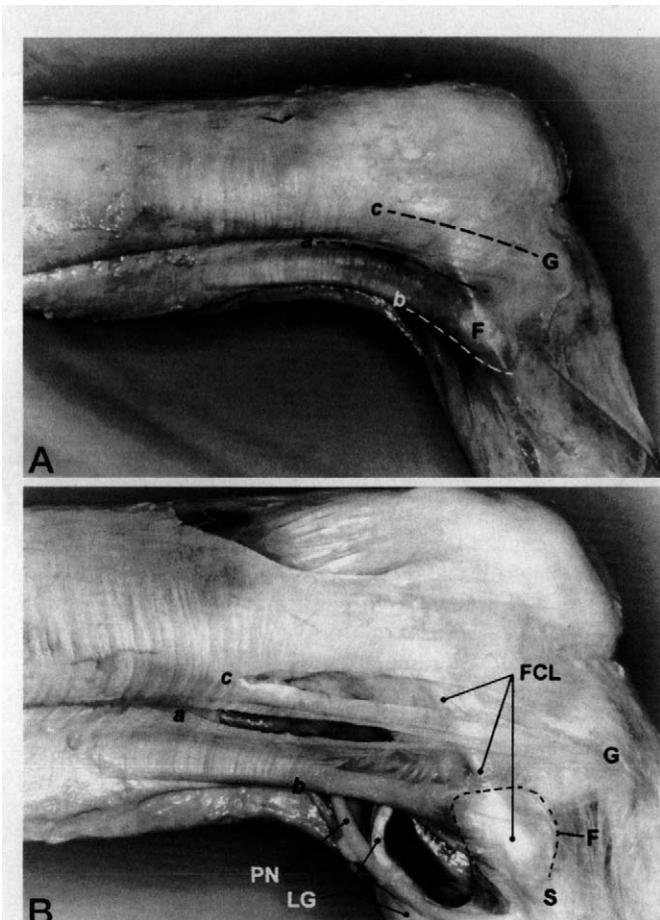


Figure 1. A, three fascial incisions were used to evaluate deeper structures: primary (a), secondary (b), and iliotibial-tract-splitting incisions (c). F, fibular head; G, Gerdy's tubercle. B, lateral structures evaluated through incisions a, b, and c were fibular collateral ligament (FCL), Gerdy's tubercle (G), fibular head (F), soleus (S) muscle, lateral gastrocnemius (LG) muscle, and peroneal nerve (PN). Dotted line indicates outline of fibular head.

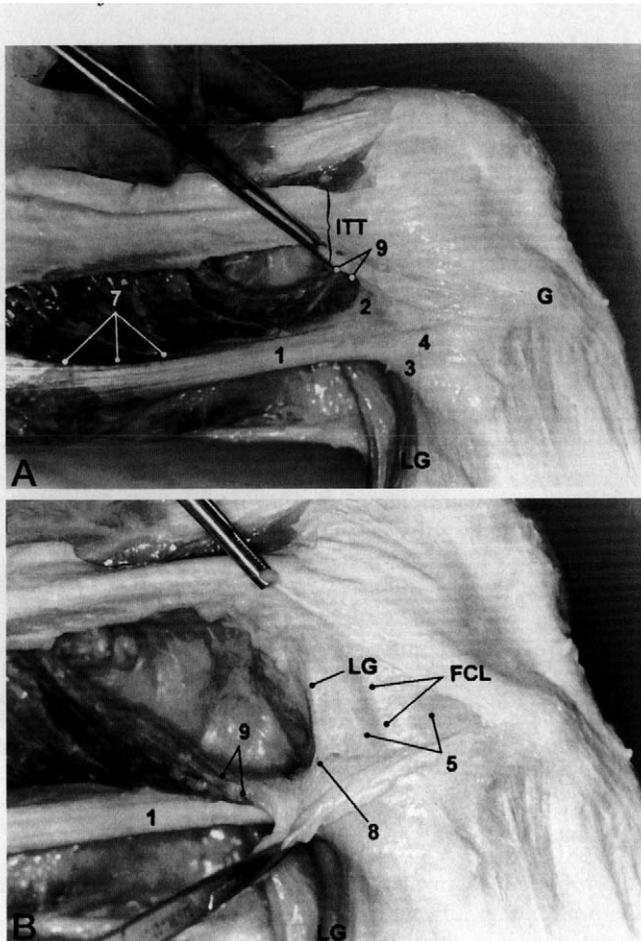


Figure 2. A, lateral aspect of the right knee with superficial fascia removed. Components of the long head of the biceps femoris muscle included the proximal tendon (1), reflected arm (2), direct arm (3), and anterior arm (4). Components of the short head of the biceps femoris muscle included the muscular attachment of short biceps to long head's tendon (7), and biceps-capsuloosseous iliotal tract confluents (9). LG, lateral gastrocnemius muscle; ITT, iliotal tract; G, Gerdy's tubercle. B, With the capsuloosseous layer reflected, components of the long head of the biceps femoris muscle included the proximal tendon (1) and lateral aponeurosis (5). Short head components visible were the capsular arm (8) and biceps-capsuloosseous iliotal tract confluents (9). LG, lateral gastrocnemius muscle; FCL, fibular collateral ligament.

external neurolysis was performed to prevent iatrogenic injury to the nerve. Retraction of the nerve provided access to the interval between the lateral head of the gastrocnemius and the soleus muscles. This interval provided access to the posterior aspect of the fibular head. Through this incision, the direct arm of the long biceps and the capsular arm of the short biceps muscle could be visualized, and the direct head of the short biceps muscle, the lateral arcuate ligament, and the fabellofibular ligament could be palpated.

A third incision was made that split the superficial fibers of the iliotal tract longitudinally to the midpoint

of Gerdy's tubercle (Incision c). Through this incision, the lateral capsular structures, the medial and anterior aspects of the capsular arm of the short biceps muscle, and the medial aspect of the biceps-capsuloosseous layer of the iliotal tract confluents were evaluated.

RESULTS

Anatomy of the Biceps Femoris Muscle Complex

Anteriorly, the fascia covering the biceps femoris muscle was continuous with the superficial layer of the iliotal tract (Fig. 1A). Distally and anterolaterally, it blended with the fascia of the lateral compartment of the leg. Distally and posterolaterally, this layer covered the peroneal nerve. Reflection of this fascial layer^{21,27} revealed the superficial components of the long and short heads of the biceps femoris muscle (Fig. 2).

Long Head of the Biceps Femoris Muscle

The long head of the biceps femoris muscle originated from the ischial tuberosity of the pelvis and continued distally, with its tendinous insertion forming proximal to the knee joint. At the knee, this tendon divided into two tendinous components—a direct arm and an anterior arm—and three fascial components—a reflected arm and a lateral and an anterior aponeurosis. The reflected arm (Component 2 in Fig. 2A) originated from the tendon just proximal to the fibular head. It ascended anteriorly across the distal portion of the short head of the biceps femoris muscle to insert on the posterior edge of the iliotal tract. Proximal to the reflected arm, the short head's muscle fibers inserted into the long head of the biceps tendon (Component 7 in Fig. 2A).

The direct arm (Component 3 in Figs. 2A and 3) inserted on the posterolateral edge of the fibular head lateral to the fibular styloid. The insertion of the anterior arm was located along the lateral edge of the fibular head, crossing lateral to the fibular collateral ligament (Component 4 in Figs. 2A and 3). A small bursa (Component BB in Fig. 3, B and C) was located anterolateral to the distal fourth of the fibular collateral ligament in all cadaveric specimens. It separated the fibular collateral ligament from the medial aspect of the anterior arm of the long head as it turned medially to connect with the anterior arm of the short head of the biceps femoris muscle. The lateral side of the anterior arm then continued anteriorly and distally, terminating as an anterior aponeurosis covering the anterior compartment of the leg (Component 6 in Fig. 3 A and B).

The anterior edge of the anterior arm provided an attachment for a lateral aponeurotic expansion (Component 5 in Figs. 2B, 3A, and 3C), which covered the fibular collateral ligament. This expansion also had many fibrous attachments to the lateral and posterior aspects of the fibular collateral ligament.

Short Head of the Biceps Femoris Muscle

The short head of the biceps femoris muscle originated just medial to the linea aspera of the distal femur and

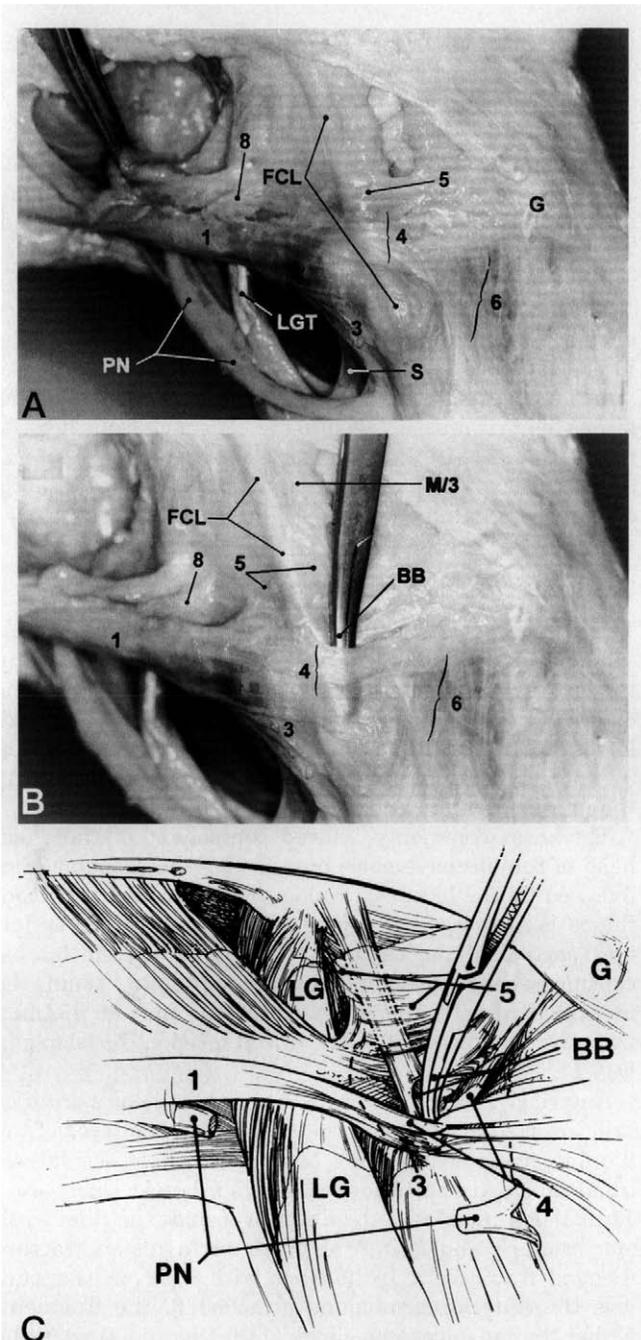


Figure 3. A, lateral aspect of the right knee with posterior iliotibial tract, biceps-capsuloosseous iliotibial tract confluens, and reflected arm of the long head of the biceps femoris muscle removed. Components of the long head of the biceps femoris muscle that were visible included the proximal tendon (1), direct arm (3), anterior arm (4), lateral aponeurosis (5), and anterior aponeurosis (6). FCL, fibular collateral ligament; G, Gerdy's tubercle; S, soleus muscle; LGT, lateral gastrocnemius tendon; PN, peroneal nerve. Component of the short head of the biceps femoris muscle was the capsular arm (8). B, visible components of the long head of the biceps femoris muscle were the direct arm (3), anterior arm (4), lateral aponeurosis (5), and anterior aponeurosis (6). FCL, fibular collateral ligament; M/3, mid-third lateral capsu-

descended distally and laterally at approximately a 45° angle to the sagittal plane of the femur and a 30° angle to the coronal plane of the femur when the knee was flexed to 90°. The first component of the short head of the biceps femoris muscle visualized was a proximal muscular attachment to the anterior and medial side of the tendon of the long head (Component 7 in Fig. 2A). Other significant insertions included an attachment of the capsular arm to the posterolateral joint capsule (Component 8 in Fig. 2B), the attachment of the capsuloosseous layer to the iliotibial tract (biceps-capsuloosseous iliotibial tract confluens) (Component 9 in Fig. 2), a lateral aponeurosis (Component 12 in Fig. 4A), and two tendinous attachments—the direct arm (Component 10 in Fig. 4) and the anterior arm (Component 11 in Fig. 4).

With the knee extended, the short head of the biceps femoris muscle crossed the posterolateral aspect of the knee capsule as it descended toward the fibula. Just before reaching the medial side of the fibular head, it had a pronounced capsular attachment (Component 8 in Figs. 2B, 3A, 3B, and 4) in the interval between the tendon of the lateral head of the gastrocnemius muscle and the fibular collateral ligament. In the transverse plane, this attachment was at the level of the posterior horn of the lateral meniscus and was at the anterior edge of the fabellofibular ligament. This posterior capsular attachment was more easily evaluated in the flexed knee. Anterior and lateral to this capsular attachment, the muscular part of the short head terminated into the capsuloosseous layer of the iliotibial tract to form a confluens of these two anatomic structures (the biceps-capsuloosseous iliotibial tract confluens) (Component 9 in Fig. 2).

The most lateral and posterior tendinous part of the short head inserted directly onto the fibular head (direct arm), just lateral to the fibular styloid and just medial to the fibular collateral ligament (Component 10 in Fig. 4). Anteriorly and medially, the remaining tendinous part of the short head continued as an anterior arm insertion. The anterior arm of the short head passed medial to the fibular collateral ligament. It then continued anteriorly on the fibula to partially blend with the anterior tibiofibular ligament, and inserted on the lateral tibial tuberosity approximately 1 cm posterior to Gerdy's tubercle (Component 11 in Fig. 4). Throughout its course, the anterior edge of the anterior arm was inseparable from the lateral aponeurosis of the short head, its last component (Component 12 in Fig. 4A).

The lateral aponeurosis of the short head of the biceps femoris muscle was significant in forming a triangular appearance to the lateral complex. The lateral aponeuroses of both the long and short heads inserted primarily onto the posterior and medial aspects of the fibular collateral ligament, respectively.

lar ligament; BB, bicipital bursa; 8, capsular arm. C, anatomic drawing of long head of biceps femoris muscle. Forceps are within bicipital bursa (BB). (See descriptions of abbreviations in A.)

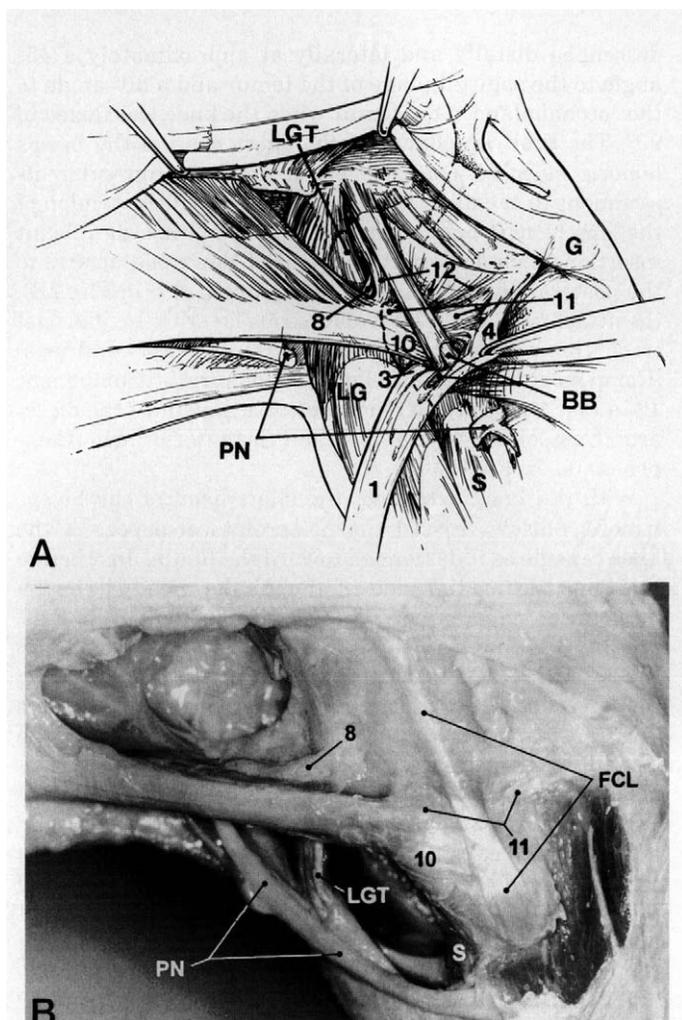


Figure 4. Lateral aspect of the right knee. A, anatomic drawing of short head of biceps femoris muscle. Long head components—proximal tendon (1), direct arm (3), and anterior arm (4)—are retracted. Components of the short head of the biceps femoris muscle visible here were the capsular arm (8), direct arm (10), anterior arm (11), and lateral aponeurosis (12). LGT, lateral gastrocnemius tendon; G, Gerdy's tubercle; BB, bicipital bursa; S, soleus muscle; LG, lateral gastrocnemius muscle; PN, peroneal nerve. B, deep and capsuloosseous layers of the iliotibial tract with long head of the biceps femoris muscle removed. Short head of the biceps femoris muscle's capsular arm (8), direct arm (10), and anterior arm (11). FCL, fibular collateral ligament; S, soleus muscle; LGT, lateral gastrocnemius tendon; PN, peroneal nerve.

Surgical Correlation to Biceps Femoris Muscle Anatomy

The surgical approach used in the anatomic study provided access to all components of the long and short heads of the biceps femoris muscle at the time of surgical repair. The primary incision (Incision a in Fig. 1) allowed for examination of the short head's attachment to the tendon of the long head, the biceps-capsuloosseous iliotibial tract confluents, and the anterior arm and lateral aponeurosis of

the long head of the biceps femoris muscle. Probing this expansion allowed for evaluation of the anterior and direct arms of the short head of the biceps femoris muscle.

The second incision (Incision b in Fig. 1) posterior to the tendon of the long head of the biceps muscle provided access to the direct arm of the long head and the posterior and medial aspects of the capsular arm of the short head. The capsular arm's relation to the fabellofibular ligament could also be evaluated.

The iliotibial tract-splitting incision (Incision c in Fig. 1) allowed evaluation of the medial and anterior aspect of the biceps-capsuloosseous iliotibial tract confluents and the anterior aspect of the capsular arm of the short head of the biceps femoris muscle (deep to the capsuloosseous layer of the iliotibial tract). Both the anterior arm and the lateral aponeurosis of the short head of the biceps femoris muscle could be evaluated as well.

Biceps Femoris Muscle Injury Patterns

The abnormal motion produced by the examination test sequence is recorded in Table 1. Injury to a component of the biceps femoris muscle was identified in 59 (72%) of the 82 knees with acute anterior translation instability. In 29 knees (35.4%), multiple injuries were identified. A total of 92 injuries to the biceps femoris muscle were found—3 to the long head and 89 to the short head (Table 2).

The most commonly injured component of the short head of the biceps femoris muscle was the capsular arm, followed by the biceps-capsuloosseous iliotibial tract confluents. Avulsion of the capsular arm from the posterolateral portion of the capsule or an injury to the biceps-capsuloosseous iliotibial tract confluents could be identified when the long head's tendon and the iliotibial tract were retracted after the initial incision (Incision a in Fig. 1).

Anteriorly, the termination of the short head's anterior arm inserted overlapping the capsuloosseous layer of the iliotibial tract where they both attached to the lateral tibial tuberosity posterior to Gerdy's tubercle. There were 11 avulsion injuries of the anterior arm at the tibia without fracture and 8 injuries with an avulsion fracture (Segond fracture²⁵). In no knee with a Segond fracture was the anterior arm alone attached to the fragment. Either the capsuloosseous layer of the iliotibial tract or the mid-third lateral capsular ligament, or both, were at-

TABLE 1
Variations in Clinical Examination Findings in 82 Knees with Anterolateral-Anteromedial Rotatory Instability

Test	Displacement				Not recorded
	0	1+	2+	3+	
Adduction 30°	18	25	37	2	
Abduction 30°	5	21	35	21	
Anterior translation					
90°/tibia neutral	7	29	38	7	1
90°/tibia external rotation	6	27	36	13	
Lachman	12	48	22	0	
Pivot shift-jerk	4	25	35	18	

TABLE 2
Injuries to Components of Biceps Femoris Muscle Complex in
82 Knees with Acute Anterolateral-Anteromedial Rotatory
Instability

Anatomic structures injured	N ^a	Percent of knees injured
Long head of biceps femoris reflected arm	3	3.7
Short head of biceps femoris		
Capsular arm	44	53.7
Capsuloosseous ITT ^b confluens	24	29.3
Anterior arm (tibia) without fracture ^c	11	13.4
Anterior arm (tibia) with fracture ^c	8	9.8
Direct arm	2	2.4

^a There were 92 multiple injuries in 29 of the 59 injured knees.

^b Iliotibial tract.

^c Segond fracture.

tached to the fracture fragment as well. The direct arm of the short head of the biceps femoris muscle was injured in two knees.

Statistical Analysis

The Lachman test (anterior tibial translation test), with the patient's knee at 25° of flexion, demonstrated increased anterior translation in those knees with biceps femoris muscle injury compared with knees in which that muscle was not injured. A statistically significant correlation ($P = 0.01$) was established between this increase in displacement during clinical testing and injury to the biceps-capsuloosseous iliotibial tract confluens. We also found that increased adduction at 30° correlated with an avulsion fracture (Segond fracture) of the anterior arm of the short head of the biceps femoris muscle ($P = 0.04$).

DISCUSSION

Other publications have mentioned the various components of the biceps femoris muscle complex that we are describing here: the superficial fascial layer^{16,21}; the reflected arm of the long head of the biceps femoris muscle,^{16,27} direct arm,^{16,20,27} aponeurotic expansion,²⁷ and anterior arm^{16,21,27}; the short head's attachment to the long head,²⁷ the biceps-capsuloosseous iliotibial tract confluens,^{29,30} capsular attachment,²¹ direct arm,^{16,20,27} aponeurotic expansion,²⁷ and anterior arm^{21,27}; and the bicipital bursa.^{16,20,27} The three-layer relationships have also been described by Sneath²⁷ and Marshall et al.²¹ However, no single article described the anatomic relationships of the individual components of both the long and short heads of the biceps femoris muscle nor described a surgical access through which the surgeon can evaluate these components.

A clearer understanding of these complex anatomic relationships can be facilitated by studying the phylogenetic evolution of the site of bicipital insertion from the lateral capsule of the knee with an extension to the anterior tibia in the primate to the fibular and tibial insertion sites in man.³² We think the lateral aponeurotic expansions of the biceps muscle and their relationship with the fibular col-

lateral ligament described in this paper are derived from those found in primates.^{17,32} Published descriptions of dissections on a chimpanzee, a gibbon, and a rhesus monkey reveal that the biceps femoris muscle complex inserts onto the anterolateral tibia as a broad sheet covering the fibular collateral ligament with intimate connection to it in these species.¹⁷ In man, the tendon of the biceps has moved distally to the fibula, and we think the lateral aponeuroses are remnants of these earlier phylogenetic attachments.

Injuries to the biceps tendon have been documented in athletes with acute lateral ligamentous knee injuries,^{8,9,14} and injury to the biceps femoris muscle has also been associated with anterolateral-antemedial rotatory instability.²⁸ However, the specific anatomic details of these injuries have not been reported.^{8,9,14,28}

The surgical approach described in this paper enabled us to evaluate the various components of the biceps femoris muscle. The approach was chosen because of the need to determine the source of externally identified hemorrhage within the muscle itself and the source of hemorrhage found along the tendon of the lateral gastrocnemius muscle in patients with acutely injured knees and abnormal anterior translation. Other surgical reports proved insufficient for this purpose.^{8,9,14-16}

This study reports a relatively high incidence of biceps femoris muscle injuries, and 35.4% of the knees had multiple injuries. In addition, eight knees sustained injury to the anterior arm of the short head of the biceps femoris muscle with a Segond fracture. Although the necessity of repairing these injuries has not been documented, the findings in this study provide evidence of the relevance of these injuries when interpreting clinical stability tests of patients with acute anterolateral-antemedial rotatory instability.

We found statistically significant correlations between the following tests and injuries: increased anterior translation (as demonstrated by the Lachman test with the patient's knee at 25° of flexion) and injury to the biceps-capsuloosseous iliotibial tract confluens and abnormal adduction laxity at 30° of flexion and a Segond fracture.²⁵ These findings support our contention that the biceps femoris muscle complex is an important static, as well as dynamic, stabilizer to the lateral side of the knee.

The importance of the dynamic knee stabilizers, such as the biceps femoris muscle, to normal knee limits-of-motion function is emphasized by these data. Although the effect of the biceps femoris muscle on in vivo knee stability is difficult to assess biomechanically, it is also impossible to ignore in terms of static and dynamic stability and proprioception.

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