Original Article

Segond Fractures Involve the Anterolateral Knee Capsule But Not the Iliotibial Band

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Purpose: To investigate the relationship between the Segond fracture and the anterolateral complex of the knee. **Methods:** Between January 2014 and March 2020, patients who presented with an anterior cruciate ligament (ACL) tear requiring acute surgical reconstruction (within 10 days from trauma) were evaluated for inclusion in this study. Patients were included if they had an acute ACL tear with an associated Segond fracture (or "Segond lesion") as detected by radiograph or magnetic resonance imaging. The lateral compartment was exposed in all cases using a 5-cm lateral hockey-stick incision, which was carried down to the iliotibial band. The fascia lata was first inspected and then longitudinally divided along its fibers to expose lateral compartment. The posterolateral corner to Gerdy's tubercle anteriorly was exposed and examined. Once the Segond fracture was identified, it was recorded and photographed. **Results:** Seventeen patients were enrolled in the study. Dissection of the Segond fracture demonstrated attachment to the anterolateral capsule only. No other discernible attachment to the Segond fracture was noted. Surgical exploration of the anterolateral knee did not reveal injury to the iliotibial band. **Conclusions:** Careful dissection of Segond fractures during repair revealed that there is a discernible attachment with the anterolateral capsule to the bone injury in all patients with acute ACL tears undergoing surgical reconstruction and no connections to the iliotibial band. **Clinical Relevance:** The precise pathogenesis of Segond fractures has been the subject of debate, partially due to the complexity of the anatomy of the anterolateral aspect of the knee. Proper understanding of the anatomy of type IV ALL injures with Segond fractures is important to improve treatment of these injuries.

In 1879, Paul Segond[1] performed a series of cadaveric studies and described a relatively constant avulsion-type fracture that occurred on the anterolateral aspect of the tibial plateau with forced internal rotation of the knee. Segond further described in his report that "a pearly, resistant, fibrous band" was located in the anatomic position of this avulsion bone injury, which became tight with internal rotation of the knee. "Segond's fracture" is considered a pathognomonic sign of an anterior cruciate ligament (ACL) tear. One hundred years later, this anatomic structure has been described in various anatomical studies and given different names: the middle one-third of lateral capsule ligament,[2] the anterolateral femorotibial ligament,[3] the anterolateral ligament,[4,5] and the anterolateral complex.[6] The biomechanical role in rotational instability and the pivot shift phenomenon of this complex has been widely reported.

Although this Segond fracture has been broadly described and reported in the literature, an ongoing debate continues regarding the soft-tissue structures on the lateral aspect of the knee and its clinical effect to rotational instability. The purpose of this study was to investigate the relationship between the Segond fracture and the anterolateral complex of the knee. It was hypothesized that the tibial anterolateral capsule in

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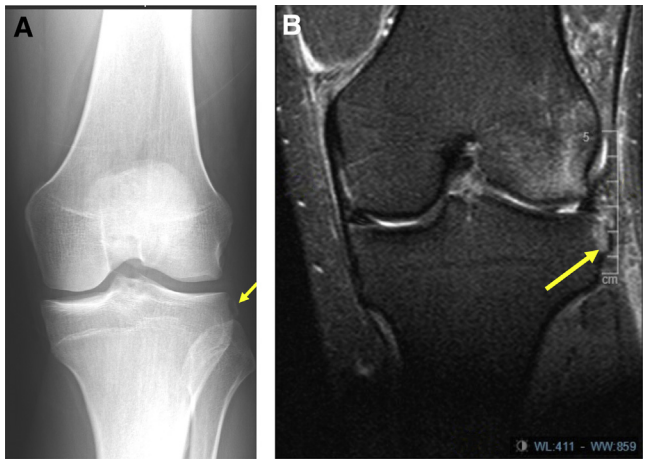

Fig 1. (A) Radiograph of Segond fracture in patient with ACL tear (left knee). (B) Magnetic resonance imaging of Segond fracture in patient with acute ACL tear (left knee). (ACL, anterior cruciate ligament.)

knees would match the location from where Segond fractures avulse on knee radiographs.

Methods

Between January 2014 and March 2020, patients who presented with an ACL tear requiring surgical reconstruction were evaluated for inclusion in this study. Patients were included if they had an acute ACL tear with an associated Segond fracture (or "Segond lesion") as detected by radiograph (Fig 1A) or magnetic resonance imaging (Fig 1B). The diagnosis of a Segond fracture was confirmed by the presence of a proximal anterolateral tibial avulsion fracture. For the purposes of this study, ACL tears were considered "acute" if the patient underwent ACL reconstruction within 10 days of initial injury. All patients were counseled and consented for ACL reconstruction with lateral knee exposure and repair of the Segond lesion.

Surgical Technique (With Video Illustration)

Patients received preoperative antibiotics per institutional standard and underwent regional anesthesia. The procedure was performed with the patient in a supine position. Examination under anesthesia was performed for preoperative ligamentous evaluation on both knees before incision. The procedure was performed using a tourniquet.

The lateral compartment was exposed in all cases using a 5-cm lateral hockey-stick incision (Video 1), which was carried down to the iliotibial band (ITB). The fascia lata was first inspected and then longitudinally divided along its fibers to expose lateral compartment. The posterolateral corner to Gerdy's tubercle anteriorly was exposed and examined. Once the Segond fracture was identified, it was recorded and photographed. The Segond fracture was directly repaired in all cases using a technique based on the size of the bone fragment—direct suture (Fig 2A), anchors (Fig 2B), or screw fixation (Fig 2C).

In all cases, an arthroscopically assisted anatomic single-bundle ACL reconstruction was performed as previous described.[7] To summarize, a 2-incision technique was used to reconstruct the ACL with a doubled semitendinosus and gracilis tendon autograft.

Postoperative Rehabilitation

The surgical knee was placed in a full-extension brace for 4 weeks postoperatively. Patients were allowed immediate weight-bearing as tolerated in the brace with crutches. Progressive range of motion exercises were initiated on the first postoperative day as well as daily isometric and isotonic exercises. At 4 weeks postoperatively, full weight-bearing without crutches or the brace was permitted. At 6 weeks postoperatively, open kinetic chain exercises were initiated within the strengthening program. At 4 months postoperatively, a gradual return to athletic and sport-specific training was encouraged, including running and cutting. Return to full sport participation was allowed based on trainer evaluation and determination of readiness for return to sport, beginning as soon as 5 months postoperatively.

Results

A total of 210 patients (143 male and 67 female) with acute ACL tears were evaluated for inclusion in the study. Seventeen patients (8.1%) were found to have an associated Segond fracture on preoperative radiograph and were included in the study. During examination under anesthesia, 15 patients (88.2%) demonstrated a severe (3+) lateral pivot shift, and the pivot shift was graded as 2+ in 2 cases (11.8%).

On surgical exploration of the anterolateral knee, the ITB appeared mildly stretched or hemorrhagic and did not reveal evidence of severe injury (Fig 3). The Segond fragment was identified deep to the ITB. In all cases, the Segond fracture was found to have a discrete and isolated connection with the anterolateral capsule without

Fig 2. Fixation methods for Segond fracture open reduction and internal fixation including (left knee). (A) Suture fixation, (B) suture anchor fixation, and (C) screw fixation.

evidence of other connections to the anterolateral knee or fibers of the ITB (Fig 4).

Repair of the Segond fracture was performed in all patients with this lesion. Periosteal stitches were used for repair of this fragment in 11 patients, suture anchors were used in 5 patients, and in 1 patient due to a larger fragment, a cancellous screw transfixed the fracture.

No complications such as infection, malunion of the bone fragment, postoperative stiffness, or rerupture of the ACL were reported. Patients returned to sport at an average of 6 months postoperatively. At the latest follow-up, all patients had returned to their preoperative activity level.

Discussion

The main finding in this case series that, under direct visualization, the tibial anterolateral capsule in knees with acute ACL tear and associated Segond fracture matched the constant location from where Segond fractures avulsed, which supported the hypothesis of this study. Furthermore, this study demonstrated that the occurrence of a Segond fracture is strongly associated with a concomitant ACL injury and with a severe lateral pivot shift (2+ or 3+), but although the test was performed by the same experienced surgeon, the results in term of actual biomechanical effect of the Segond fracture on anterolateral instability, should be considered with caution.

The Segond fracture is generally defined as an avulsion-type fracture, defined as the detachment of a bony fragment by the pull of a ligament from its insertion point. The Segond fracture occurs in less than 10% of cases of acute anterolateral instability. Ninety percent of these patients were mid-substance tears. Although Segond himself reported on the existence of a "fibrous band" attached to his eponymous fracture,[1] contemporary literature has remained unclear as to what structure causes this discrete avulsion fracture.[5,8] Authors have described this anatomic structure in anatomical studies using various names, including the" iliotibial band,"[9] the "[menisco-tibial portion of the] middle one-third of the lateral capsular ligament"[10] the "anterior [oblique] band of the lateral collateral ligament,"[11] and the "anterior arm of the short head of the biceps femoris."[12]

Ambiguous reports and a lack of photographic depictions of the anatomic structures at the anterolateral proximal tibia may have led to a misunderstanding about the anatomy and function of Segond's "fibrous band." In a case report, Herbst et al.[8] described the surgical examination of a Segond fracture and found that the posterior fibers of the ITB and the lateral capsule were linked to the bone fragment.[13] More recent studies have described the anatomical structures of the anterolateral aspect of the knee, such as the anterolateral ligament[5] and anterolateral complex.[14] Claes et al.[5] confirmed the hypothesis that the anterolateral ligament inserts in the region on the proximal tibia from where Segond fractures

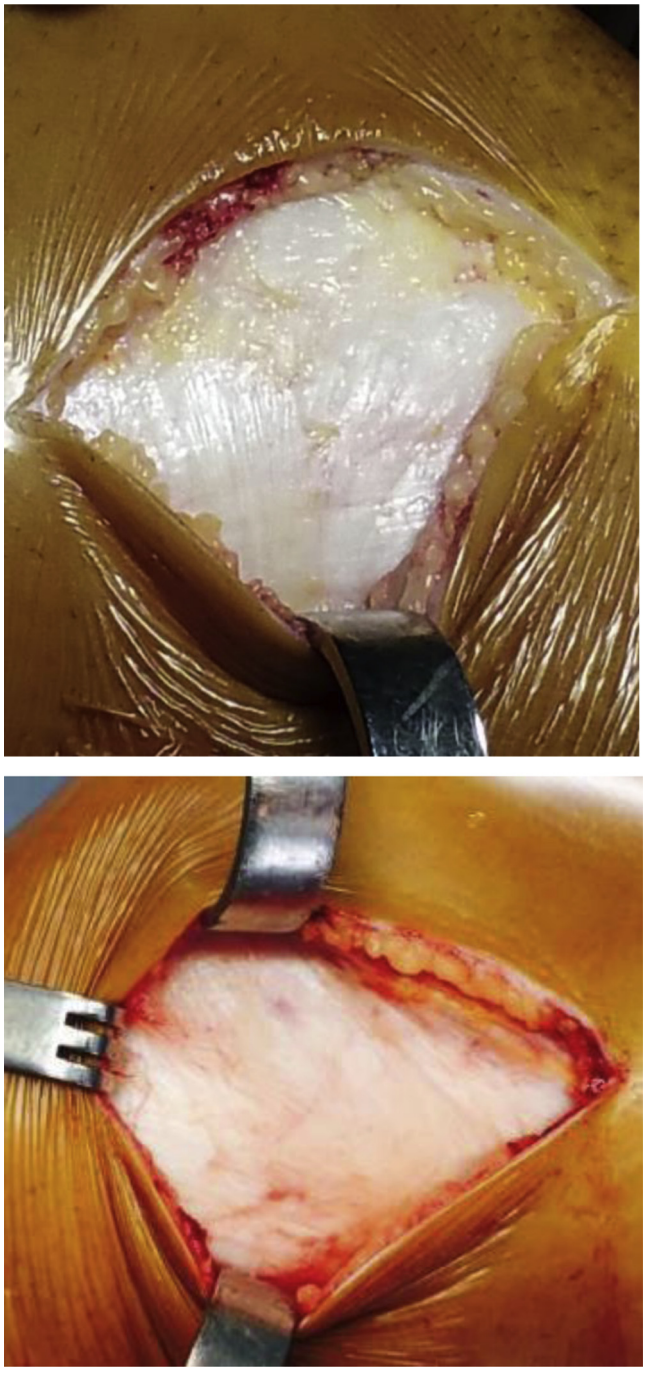

Fig 3. Direct visualization of the iliotibial band on the lateral aspect of the left knee in a patient with an anterior cruciate ligament tear did not demonstrate evidence of significant injury.

consistently avulse. These findings suggest that the Segond fracture is a bony avulsion of the anterolateral ligament. In our series, the Segond fracture was linked only to anterolateral capsule without ligamentous connection to the ITB. Johnson[15] reported that the occurrence of a Segond fracture attached to an intact "lateral capsular ligament" implies a "strength beyond that previously attributed to this ligament." In addition, he proposed the presence of a relationship between the injury to this "lateral capsular ligament" and the manifestation of a rotational instability, called the "lateral pivot shift."

Previous studies[16-18] have concluded that the primary complaint of a patient with ACL deficiency after an injury or failed reconstruction is rotational instability. These patients primarily complain of rotational instability with pivoting or cutting activities. Therefore, a primary goal after ACL reconstruction is rotational stability.

Krych et al.[19] showed that at midterm follow-up, patients undergoing ACL reconstruction with and without a Segond fracture had similar pivot shift test outcomes, graft failure rates, and activity levels. However, the IKDC score was statistically worse in the patients with a combined ACL tear with an untreated Segond fracture. Furthermore, a recent biomechanical study[20] affirmed that the addition of a Segond fracture in an ACL-deficient knee has a significant effect on axial tibial rotation in both static and dynamic execution of the pivot-shift test, as evaluated with the aid of navigation. A more comprehensive treatment of the rotational instability of the ACL-deficient knee could be considered when a severe injury of anterolateral structure as a Segond fracture is detected. The anterolateral ligament complex is very important in controlling rotational stability of the knee and the pivot-shift phenomenon, supporting early speculation that unrecognized injury to an extra-articular structure such as the Segond fracture may account for some cases of rotational instability after ACL reconstruction.

Limitations

As the nature of this paper is to be a descriptive surgical study, the first limitation is the absence of clinical follow-up, as previously described.[1] Anatomical descriptions are further biased due to interpretation of the imaging and dissection, which also can leave the results up to interpretation by the reader and experts within the field. Moreover, the preoperative evaluation was performed by a manual pivot shift, which is strongly related to the feeling and the experience of the examiner.

Conclusions

Careful dissection of Segond fractures during repair revealed that there is a discernible attachment with the anterolateral capsule to the bone injury in all patients with acute ACL tears undergoing surgical reconstruction and no connections to the ITB.

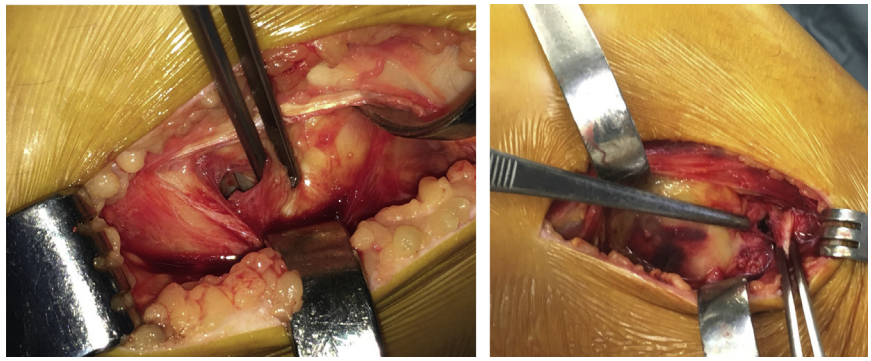

Fig 4. Intraoperative imaging of the anterolateral aspect of the left knee in a patient with an acute anterior cruciate ligament tear and associated Segond fracture. Intraoperative evaluation showed a discrete ligamentous connection between the anterolateral capsule of the knee and the Segond fracture.

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