

The iliotibial band and anterolateral capsule have a combined attachment to the Segond fracture

Marcio Albers¹ · Humza Shaikh¹ · Elmar Herbst^{1,3} · Kentaro Onishi^{1,2} · Kanto Nagai^{1,4} · Volker Musahl¹ · Freddie H. Fu¹

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Abstract The purpose of this report was to describe the injury mechanism, surgical findings, and outcomes in a 21-year-old professional female football player who presented with a complete anterior cruciate ligament (ACL) rupture and Segond fracture. Interview and video analysis were performed to elicit the injury mechanism. Clinical examination and imaging revealed a complete ACL tear, Segond fracture, lateral meniscus tear, MCL sprain, and posterolateral corner sprain. Examination under anaesthesia revealed Grade 2 pivot shift and varus/valgus instability. Surgical examination revealed attachment of the posterior fibres of the iliotibial band and the lateral capsule to the Segond fragment. The fracture was reduced with suture fixation, and an anatomic ACL reconstruction was performed. Follow-up demonstrated rotatory and anterior tibial translation stability, and imaging at 7 months post-operatively

revealed no movement and continued osseous integration of the Segond fragment.

Level of evidence V.

Keywords Segond · Iliotibial band · ACL · Capsule · Knee · Pivot shift · ALL

Introduction

The Segond fracture has been of interest as it relates to the ongoing debate about the soft tissue structures on the lateral aspect of the knee. Studies examining soft tissue attachments to the Segond fracture have come to disparate conclusions, describing attachments of the anterolateral ligament (ALL), biceps femoris, iliotibial band (ITB), fibular collateral ligament, and/or lateral capsule [1–3, 5, 9, 21, 22, 26, 28]. Numerous studies have also reported high-grade rotatory instability in ACL-injured patients with a Segond fracture [1, 8, 12]. While ACL reconstruction reliably restores anteroposterior (AP) stability, studies have shown it does not always restore rotatory stability [24]. Given the debate regarding how best to address this residual laxity, proposed interventions include osteosynthesis of the fracture, repair of lateral structures, and reconstruction of the ALL, in patients with concomitant Segond fractures [8, 13, 23]. However, as yet no consensus has been reached on how to best address injuries to the anterolateral aspect of the knee.

Thus, the purpose of this case report is to describe the pathogenesis, clinical examination, multi-modal radiologic assessment, surgical intervention, and outcome in a patient with an ACL injury and a Segond fracture, to better understand the anterolateral structures of the knee. This is the most comprehensive case report of a Segond fracture in the literature.

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✉ Freddie H. Fu
ffu@upmc.edu

¹ Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Kaufman Building Suite 1011, 3471 Fifth Avenue, Pittsburgh, PA 15213, USA

² Department of Physical Medicine and Rehabilitation, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

³ Department of Orthopaedic Sports Medicine, Klinikum rechts der Isar, Technical University Munich, Munich, Germany

⁴ Department of Orthopaedic Surgery, Kobe University Graduate School of Medicine, Kobe, Japan

Case report

A 21-year-old professional female football player with no prior injury or surgical history presented to clinic after sustaining a contact football injury. Her right knee was struck



Fig. 1 Video analysis of the incident revealing the injury mechanism shows that she was struck from the left while her foot was planted and internally rotated with the knee abducted and slightly flexed. After the knee gives way, it flexed to greater than 90°, further internally rotated, and abducted

while her foot was planted, ‘I twisted my knee and I felt a pop. After that, my knee gave way, got further twisted, and I heard another pop’. Video analysis of the incident corroborated her description of the injury mechanism, showing that her foot was initially planted and internally rotated while the knee was abducted and slightly flexed. After the knee started to give way, it flexed to greater than 90°, further internally rotated, and abducted (Fig. 1). On-field physical examination revealed immediate effusion, significant tenderness over the anterolateral tibial plateau, and instability with Lachman and valgus testing. She was placed in a knee immobilizer and given crutches. In-office examination 9 days later revealed a moderate effusion, range of motion from 14° to 80°, a 3+ Lachman, 2+ varus and valgus laxity, and a Grade 1 pivot-shift test per the IKDC criteria. KT-1000 arthrometer revealed a 4-mm side-to-side difference of anterior tibial translation. Anteroposterior, lateral, flexion weight-bearing, and sunrise view plain radiographs revealed a Segond fracture 5 mm distal to the lateral joint line without other osseous abnormalities. Magnetic resonance imaging (MRI) and high-resolution ultrasound (US) confirmed the diagnosis of a complete, acute anterior cruciate ligament (ACL) tear with a Segond fracture, lateral meniscus tear, MCL sprain, and posterolateral corner sprain. MRI and US, respectively, revealed increased signal intensity and heterogeneity (suggestive of haemorrhage) across the distal femoral metaphysis, just above the lateral femoral epicondyle where the Kaplan fibres of the iliotibial band insert (Fig. 2).

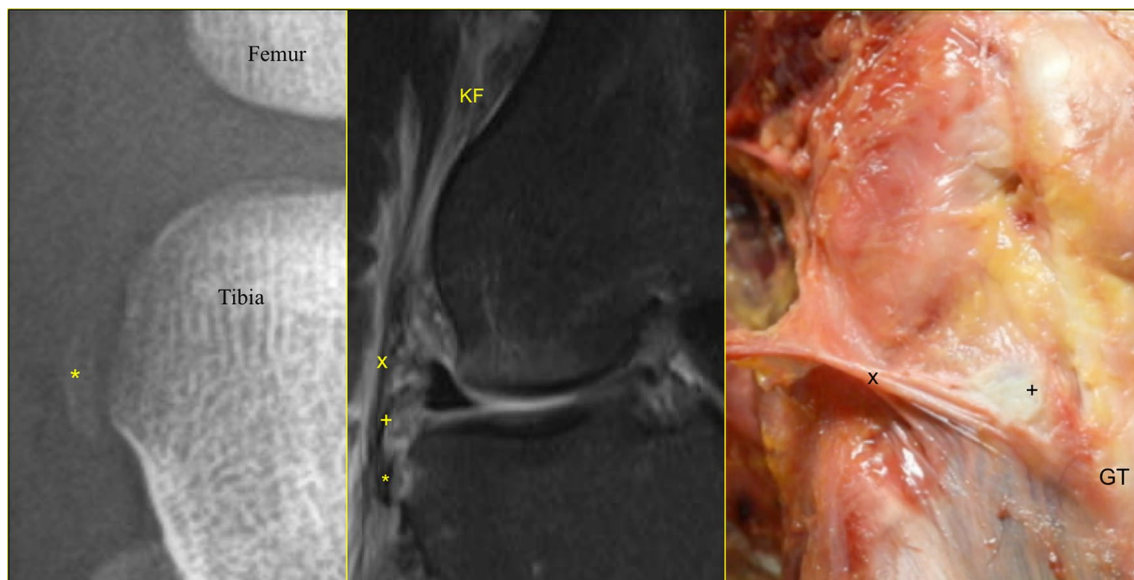


Fig. 2 **a** On the anteroposterior X-ray, the Segond fracture is visible. The proximal margin of the fracture bed is 5 mm distal to the joint line. **b** In the MRI, the attachments of the iliotibial band and the capsule to the avulsed bony fragment are appreciated, as well as haemorrhage in the area where the Kaplan fibres insert. **c** When comparing

these images with our anatomic dissection, we clearly see the posterior fibres of the ITB attach immediately posterior to Gerdy's tubercle along with the capsulo-osseous layer, whereas the anterolateral capsule inserts more proximal. + = anterolateral capsule, X = posterior ITB, * = Segond fracture, GT = Gerdy's tubercle

The patient opted for knee arthroscopy with anatomic ACL reconstruction using allograft and other repairs as indicated including exploration of the anterolateral aspect of the knee. Alternatives and potential complications such as knee stiffness, persistent instability, and failure were discussed, and the patient signed informed consent.

Ten days following the original injury, examination under anaesthesia revealed a pivot shift, with 3.7 mm of lateral compartment anterior translation (compared to the contralateral side: 0.5 mm) as measured by two-dimensional image analysis using a tablet computer [14]. Prior to the surgical procedure, an ultrasound-guided methylene blue injection was performed in the area of the Segond fracture (Fig. 3). A 5-cm lateral hockey-stick incision was carried down to the superficial iliotibial band (ITB). Surgical exploration of the anterolateral knee did not reveal any injury to the ITB. After a longitudinal incision of the superficial ITB, the Segond fragment was identified

and marked with methylene blue (Fig. 4a). Careful dissection of the Segond fracture revealed the discernible attachment of the posterior ITB and the lateral capsule to the fragment, as previously seen on MRI (Fig. 4b–e). No interstitial capsular injury could be detected. The Segond fracture was reduced and repaired with two 0 Vicryl figure-of-eight sutures to maintain reduction in the Segond fragment.

Anatomic ACL reconstruction was performed using tibialis anterior allograft with fibrin clot [27]. After measuring the patient's intercondylar notch and native tibial insertion site area, the graft was sized to a 10-mm single bundle, restoring 72% of the original tibial insertion site area. The 10-mm femoral tunnel was drilled through the accessory medial portal using a flexible reamer, and the graft was fixed using an extra-cortical button. The tibial fixation was with a PEEK interference screw. Immediate post-operative examination revealed a 1A Lachman and a negative pivot



Fig. 3 Ultrasound-guided methylene blue injection to the area where the Segond fracture occurred. Both the long- and short-axis view show the attachment of the posterior fibres of the iliotibial band (ITB)

and the anterolateral capsule to the Segond fracture. + = anterolateral capsule, X = posterior ITB, * = Segond fracture, LE = lateral epicondyle, GT = Gerdy's tubercle

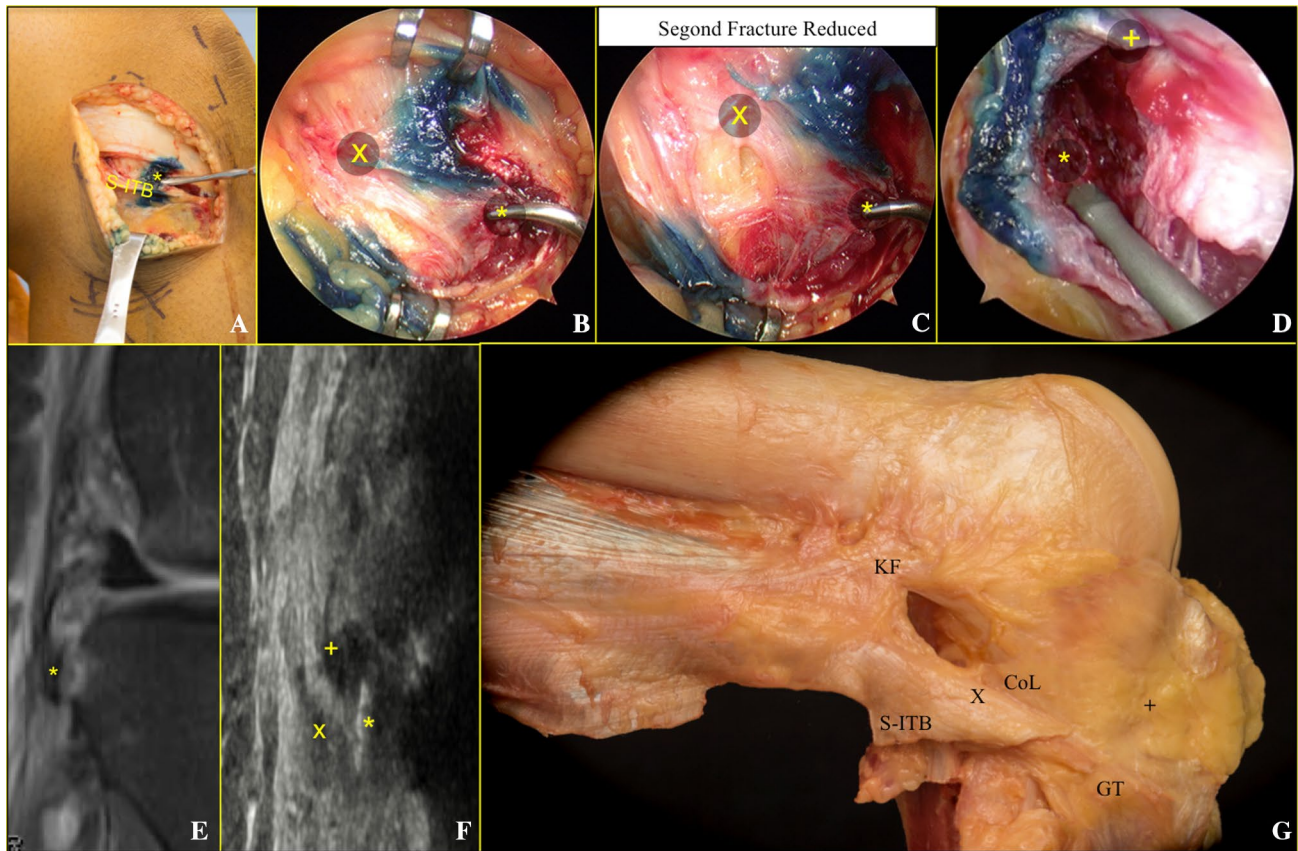


Fig. 4 **a** Incising the superficial ITB longitudinally revealed no obvious injury to the anterolateral capsule, whereas the Second fracture marked with methylene blue could be readily appreciated. **a–c** Endoscopic view showing the attachment of the posterior fibres of the ITB to the Second fracture. **d** Endoscopic view between the bony fragment and the fracture bed demonstrates the capsular attachment to the

Second fragment. **e** These findings are consistent with the MRI findings and **f** US findings. **g** These surgical findings are also consistent with the anatomic dissections. + = anterolateral capsule, X = posterior ITB, * = Second fracture, CoL = capsulo-osseous layer, GT = Gerdy's tubercle, KF = Kaplan fibres, S-ITB = superficial ITB

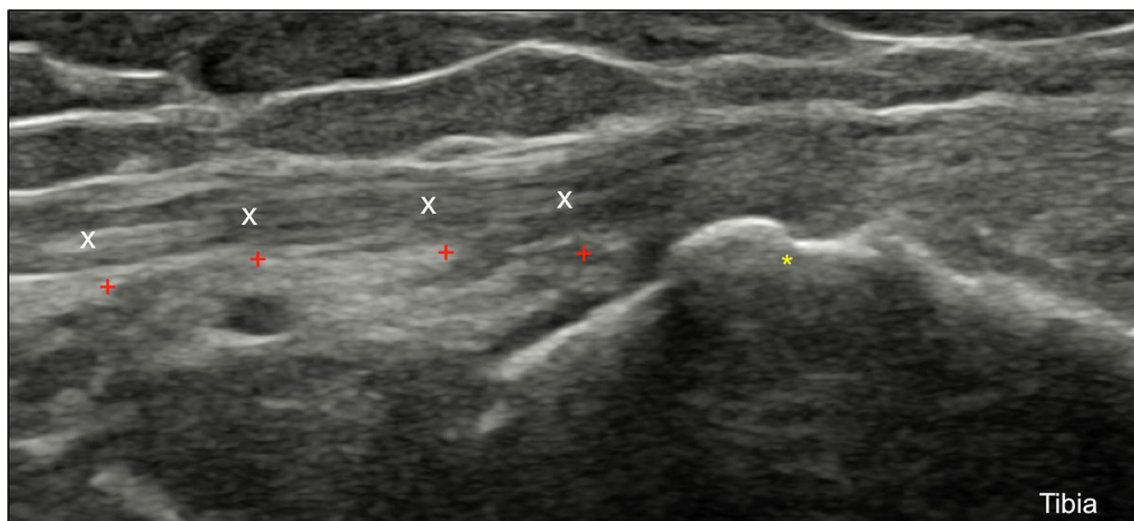


Fig. 5 US examination at 7 months post-op reveals osseous integration of the Second fragment into the tibial fracture bed. + = anterolateral capsule, X = posterior ITB, * = Second fracture

shift. The patient was discharged with a hinged knee brace, locked in extension for 1 week, weight bearing as tolerated.

At 1 month post-operatively, quadriceps strength had returned. Full extension was achieved by 2.5 months and full flexion by 4 months.

At 7-month follow-up, the patient reported no pain or instability. Physical examination revealed a 1A Lachman, negative pivot shift, +1 mm side-to-side difference of anterior tibial translation on KT-1000 measurement, and full range of motion compared to the contralateral knee. Ultrasound examination revealed continued osseous integration of the Segond fragment (Fig. 5). Based on her recovery, she was cleared to begin cutting and pivoting exercises with physical therapy at 7 months post-operatively.

Discussion

The main finding of this case report is the combined insertion of posterior fibres of the ITB and the anterolateral capsule on Segond fragment. Recent literature has proposed the anterolateral ligament (ALL) as the primary soft tissue attachment to the Segond fragment [2, 6, 17, 19]. These studies suggest that the ITB fibres insert separately from the ALL, at a location different and posterior from the Segond fracture. This case report finds that both the posterior fibres of the ITB and the anterolateral capsule attach to the Segond fragment in a combined insertion (Fig. 4f, g). Comparison of these images suggests that the Segond fracture occurs just posterior to Gerdy's tubercle, where the posterior fibres of the superficial and deeper capsulo-osseous layers of the ITB become confluent. Additionally, it was found that the anterolateral capsule attaches to the proximal aspect of the bony fragment. It could be appreciated that the bulk of the soft tissue attachment to the bony fragment was from the posterior fibres of the ITB. These findings are consistent with studies describing the contribution of the ITB and lateral capsule to the pathogenesis of the Segond fracture, in the absence of a discrete ligamentous structure [1, 5, 7, 12, 13, 15, 16, 25, 28].

This case describes one possible injury mechanism of the Segond fracture. The pivot-shift ACL injury mechanism is well known and is consistent with biomechanical studies showing the ACL bears greatest in situ force during combined internal rotation and valgus stress at 30° knee flexion [11]. However, Segond fracture injury mechanism literature is sparse. In his 1879 study, Segond concluded that with internal rotation and knee flexion to >35°, the 'pearly, resistant, articular fibrous band... suffers an extreme degree of tension', causing an avulsion fraction posterior to Gerdy's tubercle, a Segond fracture. A more recent study dissected their cadavers of all soft tissue structures, leaving just the anterolateral ligament. Vertical pull-to-failure

testing with the knees at 30° of flexion resulted in a Segond fracture in 6 of 15 specimens at a mean 175 N [17]. Unfortunately, vertical distraction of the knee replicates a non-physiologic injury mechanism.

Studies have demonstrated that the ITB and anterolateral capsule experience greatest tension with internal rotation and knee flexion >30° [18, 20]. The findings of these studies are in line with the injury mechanism reported by this patient.

Clinical outcomes in this case demonstrate restoration of rotatory knee stability with an anatomic, single-bundle (SB) ACLR. At short-term interval, this patient had no subjective pain or instability, 1A Lachman, and a negative pivot shift. Though studies conflict, effective restoration of the tibial footprint with anatomic graft placement has proven to restore dynamic rotatory knee stability in the absence of additional extra-articular procedures [4]. While this patient's Grade 2 pivot shift was effectively corrected with an anatomic SB ACLR, residual pivot shift following ACLR is multi-factorial [10].

Conclusions

The Segond fracture is a combined avulsion of the posterior portion of the iliotibial band and the anterolateral capsule as demonstrated by imaging, clinical, and intra-operative findings. Its injury mechanism is similar to the pivot-shift phenomenon, but likely at higher flexion angle. This flexed and internally rotated position of the knee joint corresponds with the position of maximal anterolateral tension, as previously reported in the literature [18, 20].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval The institutional review board at the University of Pittsburgh approved the protocol of this study (ID number: 12020619).

Informed consent All participants gave their written informed consent.

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