

# Incidence and Prognostic Significance of the Segond Fracture in Patients Undergoing Anterior Cruciate Ligament Reconstruction

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**Background:** The Segond fracture is an avulsion of the anterolateral tibia that can be found in patients with an anterior cruciate ligament (ACL) tear. It is currently unclear if the Segond fracture needs treatment or if it heals spontaneously and if it is associated with an increased risk of failure after ACL reconstruction.

**Purpose:** To identify the incidence and spontaneous healing rate of Segond fractures in a consecutive cohort of patients undergoing ACL reconstruction and to examine the predictive value of the Segond fracture on the risk of undergoing revision surgery.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** A retrospective review of a cohort undergoing isolated ACL reconstruction between 2002 and 2016 was performed. Radiographs from the time of injury and preoperative radiographs were evaluated for Segond fractures and healed Segond fractures. Descriptive data were extracted from an internal quality database. Statistical analyses were performed to investigate risk of revision surgery and to compare across subgroups of patients.

**Results:** A total of 1364 patients were included in the study. The incidence of Segond fractures was 7.4%. In addition, 10.4% of patients displayed signs of healed Segond fractures. In total, 15.2% of patients had either 1 or both findings. The overall healing response of the fracture was 35.6%. Those with Segond fractures were older ( $P = .014$ ) and had a shorter interval from injury to surgery ( $P = .003$ ) as compared with the rest of the cohort. The incidence of Segond fractures was significantly higher in those injured during downhill skiing as compared with other injury mechanisms ( $P = .04$ ). The Segond fracture did not represent an increased risk of undergoing revision when compared with the control group (not significant).

**Conclusion:** The incidence of conventional Segond fractures in patients with ACL injury was found to be in accordance with former studies. Accounting for the high incidence of healed Segond fractures, a much higher incidence (15%) was seen. Although the spontaneous healing rate from initial radiographs to preoperative imaging was only 36%, the presence of Segond fractures did not represent a higher risk of undergoing revision surgery.

**Keywords:** Segond fracture; ACL reconstruction; healed Segond fracture; ACL

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The eponymous Segond fracture was first described by the French anatomist Paul Segond in the 19th century.<sup>8,12</sup> It is an avulsion of the anterolateral tibia, posterior of the Gerdy tubercle and inferior to the lateral tibial plateau, and it has historically been held as a sign of significant knee trauma indicating intra-articular injury.<sup>2,6,13</sup> There is a common notion that the Segond fracture is indicative of an anterior cruciate ligament (ACL) tear, but an ACL tear might very well exist without this bony avulsion.<sup>23,29,31</sup> Also, although cadaveric studies have suggested that internal rotation and varus strain might be part of the injury mechanism, the exact forces needed to create the avulsion are largely unknown.<sup>2,6,17,30</sup>

Whereas conventional radiographs have been considered the gold standard for describing Segond fractures, other radiological modalities have provided new and additional information on the size and location of the lesion.<sup>13,19</sup> In a study by Flores et al,<sup>13</sup> bony avulsions

were quantified on magnetic resonance imaging (MRI). A total of 146 patients were found to have a bony thin, ovoid, vertically oriented fragment of a mean  $12 \times 7 \times 3$  mm located anterolaterally or laterally along the proximal tibial epiphysis, posterior of the Gerdy tubercle and inferior to the articular surface of the lateral tibial plateau. Furthermore, MRI scans can be used to show the lesion is related to soft tissue structures inserting at the anterolateral part of tibia and to concomitant ligamentous lesions of the knee.<sup>6,13</sup> Other authors have studied the bony avulsion with ultrasound and suggested that dynamic ultrasound might be used to better visualize associated ligament injury.<sup>19</sup>

With the recent debate on anatomic features and biomechanical properties of the anterolateral complex, including the anterolateral ligament, new light has been shed on the potential importance of injuries to the anterolateral aspect of the knee.<sup>12,13,18</sup> Some authors have questioned if the Segond fracture represents a bony avulsion of the tibial anterolateral ligament insertion.<sup>6,13,16</sup> Others have stated that it represents an avulsion of the lateral capsular fibers of the iliotibial tract or anterior oblique band of the lateral collateral ligament.<sup>1,25</sup> These structures have, nevertheless, been found to have a significant effect on axial tibial rotation, thereby contributing to the pivot-shift phenomenon.<sup>11,12</sup> Repairing the fracture or performing an anterolateral reinforcement procedure could perhaps be justified to fully stabilize the knee during ACL reconstruction.<sup>18,24</sup>

Before the advent of modern intra-articular ACL reconstruction, Segond fractures were seen as being indicative of the need for open repair.<sup>7</sup> In light of the renewed focus on the use of anterolateral procedures, some authors have questioned whether an evident Segond fracture should affect the choice of surgical treatment in patients with ACL injury.<sup>12,18,24</sup> Whereas some studies have indicated that the bony avulsion has a potential for healing, seen as a characteristic residual bone excrescence,<sup>5</sup> others have promoted the need for additional anterolateral reinforcement in these patients.<sup>12,18</sup> Irrespective of the choice of treatment, there is a paucity of literature investigating the effect of the presence of a Segond fracture on outcomes after ACL surgery. The current study, therefore, intended to investigate several aspects of this phenomenon in a large cohort of patients undergoing ACL surgery. Aims of the study were to (1) identify the incidence of Segond fractures in a consecutive cohort of patients undergoing ACL reconstruction, (2) investigate the rate of healing of such lesions, and (3) examine the predictive value of the Segond fracture on risk of undergoing revision surgery.

## METHODS

### Patient Selection

Patients surgically treated for an ACL tear using an isolated intra-articular reconstruction at our clinic between 2002 and 2016, who had been prospectively enrolled in our quality database, were eligible for the study. A minimum of 2-year follow-up was required for inclusion. Patients with concomitant surgery to other ligaments (posterior cruciate ligament, lateral collateral ligament,

posterolateral corner, or medial collateral ligament) and patients with missing preoperative radiographs, performed as a routine in conjunction to the preoperative visit at the outpatient clinic, were excluded. Data on patient age, side of injury, sex, activity at the time of injury, time from injury to surgery, and choice of graft were extracted from the database. Later revision surgery after ACL failure to the same knee was also acquired from the database. A control routine toward the national Norwegian Knee Ligament Registry kept the internal database updated on potential revision surgery performed at other clinics. The regional ethical committee reviewed and approved the study before data extraction (REK Vest ID 2017: 1680).

### Surgical Technique

During the 2002-2016 period, different surgical techniques had been performed. In the first part of the study period, a modified transtibial technique was applied, while the anatomic technique was used in the latter part of the study period. All surgical procedures were performed with a single-bundle technique, with grafts harvested from the ipsilateral knee. A variety of tibial and femoral fixational devices was utilized in the period as a matter of availability. Of the patients, 78% were treated with hamstring autograft, while 18% had a patellar tendon autograft and 4% had a quadriceps tendon autograft.

### Radiographic Measurements

Radiographs acquired at the time of injury and in conjunction with the preoperative visit at the outpatient clinic were evaluated in the picture archiving and communication system (IMPAX; Afiga). Acute images were taken within 1 month after the injury, and images from the preoperative visit were taken no more than 2 months before surgery. Frontal anteroposterior radiographs were evaluated for the Segond fracture (Appendix Figure A1, available in the online version of article) according to established criteria (a visible bone flake at the superolateral rim of tibia).<sup>8,20</sup> Also, signs of healed Segond fractures were evaluated in accordance with a publication by Bock et al,<sup>5</sup> where the healed Segond fracture is defined as a characteristic bone excrescence of the superolateral tibia arising 3 to 6 mm inferior to the lateral tibial plateau (Appendix Figure A2, available online). Appropriate rotational alignment of the radiographs was determined when only the medial one-quarter part of the fibula was covered by the tibia on the radiograph.<sup>21</sup> Any gross malrotation would lead to exclusion of the radiograph from evaluation. Available images were evaluated by 2 independent investigators (I.S., A.P.P.) at 2 time points 3 months apart to establish inter- and intrarater reliability (intraclass correlation coefficient [ICC]) of the radiographic measures.

### Data Analyses

An a priori *P* value <.05 was used to denote statistical significance. Analyses were performed in SPSS Statistics for Windows (v 25.0; IBM Corp). Descriptive data were

TABLE 1  
Descriptive Data<sup>a</sup>

	Non-Segond Group (n = 1263)	Segond Group (n = 101)	P Value
Sex, female:male	46:54	41:59	NS
Affected knee, right:left	52:48	57:43	NS
Age at surgery, y	28 (10)	30 (12)	<b>.014</b>
Injury to surgery, mo	24 (46)	16 (22)	<b>.003</b>
Graft, patella:hamstring: quadriiceps	18:78:4	23:73:4	NS
Revisions	6.7	3.0	NS

<sup>a</sup>Values are presented as percentage or mean (SD). Bold indicates  $P < .05$ . NS, not significant.

described by use of mean and standard deviation. Normality of data was tested and confirmed by use of the Shapiro-Wilk test. Student *t* test was applied for comparison across subgroups based on the presence of the Segond fracture or healed Segond and to investigate for differences in age at surgery and time from injury to surgery between the whole cohort and those with a Segond fracture. Chi-square statistics were applied to compare incidences across sex, injured side, injury mechanism, graft type, age at surgery, and rate of revision after ACL failure between the whole cohort and the Segond group. Inter- and intrarater reliability (ICC) of the radiographic measures was calculated with SPSS Statistics for Windows (v 25.0; IBM Corp) based on an absolute agreement 2-way random model.

RESULTS

After application of the exclusion criteria, 1364 patients were eligible for the study. Of these, 54% were male, and the right knee was affected in 52% of cases. Mean (SD) time from injury to surgery was 23.7 (45.8) months, and the mean age at surgery was 28.3 (10.4) years. Soccer, downhill skiing, and team handball were the most common causes of injury (44.6%, 14.9%, and 11.8%, respectively). No other single cause made up >5% of injuries (traffic injuries). The mean time from surgery to the current evaluation was 8 years (range, 2-16 years). Descriptive data are reported in Table 1.

Radiographic Measures

Intra- and interrater reliability of the radiographic measures were excellent (ICC, 0.93 and 0.99, respectively). Among 1364 patients, 101 (7.4%) had a Segond fracture. In addition, 10.4% (n = 142) of patients displayed signs of a healed Segond fracture. In total, 15.2% (n = 207) of patients had either one or both findings.

Effect of the Segond Fracture

When patients with Segond fractures were compared with the rest of the cohort, there were no differences in sex or

TABLE 2  
Descriptive Data Across Patients With Segond Fracture and/or Healed Segond Fracture and the Cohort<sup>a</sup>

	Remaining Cohort (n = 1157)	Segond and/or Healed Segond (n = 207)	P Value
Sex, female:male	46:54	42:58	NS
Affected knee, right:left	51:49	57:43	NS
Age at surgery, y	28 (10)	30 (11)	NS
Injury to surgery, mo	21 (41)	39 (65)	<b>&lt;.001</b>
Graft, patella:hamstring: quadriiceps	19:78:3	18:78:4	NS
Revisions	7.3	3.9	NS

<sup>a</sup>Values are presented as percentage or mean (SD). Bold indicates  $P < .05$ . NS, not significant.

injured side (Table 1). The Segond fracture group was older at the time of surgery (mean [SD], 30 [12] vs 28 [10] years;  $P = .014$ ) and displayed a shorter interval from injury to surgery (16 [22] vs 24 [46] months;  $P = .003$ ). A total of 95 (7%) patients had undergone revision surgery at the time of follow-up. There was no difference in revision rates between patients with an identified Segond fracture and those who did not show signs of such an injury. Furthermore, the distribution of activities at the time of injury in those with Segond fractures was similar to that of the whole cohort, with soccer (40.6%), downhill skiing (24.8%), and team handball (7.9%) as the most common causes of injury. The incidence of Segond fractures, however, was significantly higher in those injured in downhill skiing as compared with the rest of the cohort ( $P = .04$ ). In the overall cohort, 40.5% of patients had meniscal procedures performed, and 2.2% had cartilage procedures performed. In the patients with Segond fractures, 50.5% had meniscal surgery ( $P = .033$ ), while 2% underwent cartilage procedures (not significant). When the group with a Segond fracture and/or a healed Segond fracture was compared with the remaining patient cohort, we found no difference in sex, affected knee, age at surgery, graft type used in surgery, or revision rate (Table 2). We did, however, find that the group with Segond fractures and/or healed Segond fractures had a significantly longer time from injury to surgery as compared with the remaining cohort ( $P < .001$ ).

Of the 101 identified Segond fractures, 36 (35.6%) displayed a healing response from the acute radiograph to the radiograph acquired at the preoperative visit. There was, however, a tendency toward a shorter time from injury to surgery in those who did not show a healing response (mean [SD], 4.9 [4.6] months) versus those who did display a healing response from the initial radiograph to the preoperative radiograph (19.8 [24] months;  $P = .052$ ).

DISCUSSION

The main finding of the current study was a 7.4% incidence of Segond fractures in patients undergoing ACL reconstruction. These results are in accordance with previously

TABLE 3  
Incidence of the Segond Fracture in Patients  
With an ACL Tear in Previously Published Studies<sup>a</sup>

First Author	ACL Injuries, n	Segond Fractures, n (%)
Gaunder <sup>14</sup>	552	31 (6)
Hess <sup>17</sup>	151	14 (9)
Yoon <sup>31</sup>	383	34 (9)
Klos <sup>19</sup>	87	25 (29)
Bock <sup>5</sup>	129	4 (3)
Current study	1364	101 (7)

<sup>a</sup>ACL, anterior cruciate ligament.

published studies<sup>5,14,19,31</sup> based on radiographs for evaluation of such injuries (Table 3). However, when the radiological findings indicating healed Segond fractures were also accounted for, the incidence might have been as high as 15%. Furthermore, the presence of Segond fracture was not found to increase the risk of undergoing revision surgery after ACL reconstruction as compared with no signs of Segond fracture. The current study is the largest of its kind, including 101 patients with evident Segond fractures.

Although several studies have reported on the incidence and morphology of the Segond fracture, few have investigated the effect of this lesion on clinical outcomes after ACL reconstruction. Yoon et al<sup>31</sup> identified a subgroup of 34 patients undergoing ACL reconstruction who displayed Segond fractures on postoperative computed tomography scans intended to evaluate ACL tunnel placement. These were compared with a control group of 383 patients at a 2-year follow-up. No differences were seen in patient-reported outcome measures, knee stability, or return to postoperative level of activity. A study by Gaunder et al<sup>14</sup> investigated the incidence among 552 primary ACL reconstructions, in which 31 displayed a Segond fracture. None of these had a "graft failure" during the follow-up period, and the authors concluded that the Segond fracture was not a risk factor for failure after ACL reconstruction. In this latter study, few details were given on the follow-up interval and examinations. The current study, involving 101 Segond fractures from a consecutive cohort of 1364 patients, demonstrated a 7% overall risk of undergoing revision surgery at a mean 8 years of follow-up. Our study, as previously published studies, found no difference in risk of undergoing revision surgery based on the presence of the Segond fracture. The current work did not include clinical parameters, such as knee laxity, patient-reported outcome measures, or return to sports. It is well-known that revision surgery as an endpoint might account for only some of those experiencing failed ACL reconstruction.<sup>9</sup> Including such clinical parameters could, therefore, affect results, but this was outside the scope of the current work.

Bock et al<sup>5</sup> described the healed Segond fracture as a characteristic bone excrescence at the location where the Segond fracture occurs, suggesting former significant knee trauma. Accounting for this bony sequela and the acute fractures, the total incidence of such anterolateral lesions could be as high as 15% in the current work. Because some of the patients without a visible initial

fracture were later seen to have a bony spur at that location, one could speculate whether small lesions, not visible on radiographs, can occur. With the recent renewed interest in anterolateral structures, a range of studies have investigated the anterolateral complex, known to insert in the area where the Segond fracture occurs.<sup>28</sup> By applying other radiological modalities, such as MRI scans and ultrasound, high incidences of anterolateral complex (ALC) injuries have been seen in patients with acute ACL injuries. Klos et al<sup>19</sup> described a 29% incidence of injury to the ALC using ultrasound, while Mansour et al<sup>22</sup> described such injuries in 58% of patients with ACL injury in a retrospective evaluation of MRI scans. The relationship between the bony Segond fracture and the soft tissue injuries seen in those latter studies still has to be settled. Also, any relationship between microscopic avulsions that are attributed to soft tissue injuries, not detectable on radiographs, and later visible bony spurs (sequela) needs further investigation.

Although the Segond fracture has been speculated to have inert healing potential, few studies have investigated the natural course of this phenomenon. The present data indicated that in 36% of cases, the initial bony avulsion was transformed to a bony sequela at the anterolateral tibia upon the final radiographs. This contrasts the finding of Gaunder et al,<sup>14</sup> where 90% of patients were seen to have a healing response. In that study, the healing response was assessed from initial radiographs and MRI scans to postoperative radiographs only. Postoperative radiographs were, however, available in only 61% of patients. One could question whether repeat assessment from initial MRI scans to postoperative radiographs is a valid approach (given that the former likely has higher sensitivity in detecting anterolateral lesions). Based on the current repeat examination using radiographs only, the bony healing process is likely somewhat lower than in that previous study. This further leads to the discussion of whether there is a need to address these lesions with surgery. Some authors have indicated how direct repair of the bony avulsion in conjunction with ACL reconstruction can yield good rotational control and a stable knee.<sup>12</sup> Others would state that performing an anterolateral reinforcement procedure (eg, tenodesis) would be a sound approach, especially if patients are seen in a chronic phase after injury.<sup>12,24,31</sup> The current approach, with an isolated intra-articular ACL reconstruction, did not seem to result in a higher risk of undergoing revision ACL surgery among the patients with a Segond fracture. The lack of clinical correlate of the evident avulsions limits the generalizability of results. The group of patients with evident Segond fractures could have a higher risk of subtle residual laxity, making them more prone to sustaining secondary meniscal injuries or developing long-term knee osteoarthritis.

This study found a higher incidence of Segond fractures in patients injured during downhill skiing as compared with other mechanisms of injury. In addition to citing the potential high velocity involved, previously published analyses have indicated how several independent mechanisms of injury can lead to an ACL tear during downhill skiing.<sup>3,4,15</sup> Hyperflexion and hyperextension of the knee in addition to internal tibial torque seem to be the central

injury mechanisms.<sup>15</sup> In more than half of cases described by Bere et al<sup>4</sup> in 2011, the skier was injured during a sudden impact attributed to the loss of balance backward and/or inward while in the midst of a turn. The majority of injuries seem to occur while the skier is still upright, just before the fall or even without falling.<sup>3</sup> In cases where falling is involved, high speed may be important, especially if the knee is forced into an awkward position, such as hyperflexion with internal tibial rotation, or if the fall is too rapid for the skier to counteract the tibial rotation.<sup>15</sup> Downhill skiers may also experience hard landings from jumping. The following massive quadriceps contraction, trying to force the upright position, can displace the tibia anteriorly, causing the ACL to tear.<sup>4,15</sup> Other mechanisms include the “dynamic snowplow,” where loss of control of 1 ski leads to internal rotation and/or valgus load,<sup>4</sup> and the “phantom foot,” where the skier falls backward with hyperflexion of the knees and loses control over 1 ski, leading to internal rotation of the tibia relative to the femur.<sup>4,15</sup> The combined high energy and sudden rapid changes in force vectors acting on the knee might explain the higher incidence of Segond fractures seen in ACL injuries sustained during downhill skiing. As most of the skiers included in the current cohort were participating at a recreational level, further analyses were prevented by the lack of details from the time of injury.

Strengths of the current study include a large consecutive cohort, yielding the highest number of patients with Segond fractures to date. Furthermore, routine use of radiographs in preoperative planning has given standardized and high-quality images for use in the current investigation. There are important limitations to the current work. As some patients did not seek immediate medical care after their knee trauma, radiographs were not available to assess healing response in all patients. We do, however, believe that including the healed Segond fracture and fractures still visible at preoperative counseling accounts for the incidence in most of these cases. Radiographs are considered the gold standard when investigating Segond fractures,<sup>8</sup> but as discussed formerly, the use of other radiological modalities might help establish the relationship between this bony avulsion and the high incidences of ALC soft tissue injuries.<sup>19,22</sup> Given that very few studies have related clinical evaluation of anterolateral rotational instability to imaging signs of anterolateral injury, the clinical correlate of the Segond fracture still has to be settled. Another limitation of the current work is the slight change in surgical techniques throughout the study period. It is well known that the revision rate may be affected by choice of surgical technique<sup>27</sup> and methods of graft fixation.<sup>26</sup> The current work had a lack of data on postoperative knee laxity, knee range of motion, return to sports, and patient-reported functional outcome measures, and we were therefore not able to compare these measures among subgroups. According to Crawford et al,<sup>10</sup> including clinical data on instability might give a cumulative failure rate up to twice as high as when including only patients who have undergone revision surgery. Therefore, further studies should also aim to investigate differences in clinical laxity, in particular anterolateral rotational instability.

## CONCLUSION

The incidence of Segond fractures in patients with ACL injury was 7.4%. Although this is consistent with previously published studies, the true rate might be as high as 15% because a high incidence of healed Segond fractures was also seen. The spontaneous healing rate of 36% from initial radiographs to preoperative imaging is somewhat lower than previously reported. Furthermore, the presence of a bony avulsion could not be related to any increase in risk of undergoing revision surgery, but the lack of clinical data calls for further studies examining the relationship of Segond fractures with objective assessment of anterolateral rotatory instability.

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