Is Treatment of Segond Fracture Necessary With Combined Anterior Cruciate Ligament Reconstruction?

Heath P. Melugin,* MD, Nick R. Johnson,* BS, Isabella T. Wu,* BA, Bruce A. Levy,* MD, Michael J. Stuart,* MD, and Aaron J. Krych,† MD

Investigation performed at the Departments of Orthopedic Surgery and Sports Medicine, Mayo Clinic, Rochester, Minnesota, USA

Background: There is a paucity of clinical information to guide the treatment of a combined anterior cruciate ligament (ACL) tear and Segond fracture.

Purpose: To compare clinical outcomes, graft failure rates, and activity levels between patients undergoing ACL reconstruction (ACLR) with and without an untreated Segond fracture at a minimum 2-year follow-up.

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

Methods: This study included a group of patients with a combined ACL tear/untreated Segond fracture that was matched based on age, sex, body mass index, and graft type to a control group of patients with an ACL tear and no Segond fracture. All patients were treated with ACLR alone between the years of 2000 and 2015. The diagnosis of a Segond fracture, or bony avulsion of the anterolateral complex, was made by radiographic analysis. Data regarding the initial injury, surgical intervention, and physical examination findings were recorded. Clinical and functional outcomes were obtained using physical examination results, International Knee Documentation Committee (IKDC) subjective scores, and Tegner activity levels.

Results: Twenty patients (16 male, 4 female) with a combined ACL tear/untreated Segond fracture with a mean age of 26.3 years (range, 13-44 years) were matched to a control group of 40 patients (32 male, 8 female) with an ACL tear and no Segond fracture with a mean age of 26.4 years (range, 13-47 years). The study group was followed for a mean of 59.1 months (range, 24-180 months) and the control group for a mean of 55.5 months (range, 24-120 months). The mean IKDC score was 86.5 (range, 54-100) for the study group compared with 93.0 (range, 54-100) for the control group (P = .03). The graft rupture rate was 10% for both groups (P = .97). The mean time to rupture was 33.0 months (range, 21-45 months) in the study group and 63.5 months (range, 39-88 months) in the control group (P = .24). Patients in the study group had significantly more anteroposterior instability by preoperative Lachman testing than those in the control group (control group: 0 normal, 3 grade 1, 33 grade 2, 0 grade 3; study group: 0 normal, 1 grade 1, 10 grade 2, 9 grade 3; P = .0001). There was no significant difference between the 2 groups in regard to postoperative Lachman testing (control group: 35 normal, 3 grade 1, 2 grade 2, 0 grade 3; study group: 17 normal, 3 grade 1, 0 grade 2, 0 grade 3; P = .31). Patients in the study group had significantly more instability by preoperative pivot-shift testing than those in the control group (control group: 0 normal, 7 grade 1, 33 grade 2, 0 grade 3; study group: 1 normal, 1 grade 1, 11 grade 2, 7 grade 3; P = .0003). No significant difference was found between the 2 groups for postoperative pivot-shift testing (control group: 36 normal, 2 grade 1, 2 grade 2, 0 grade 3; study group: 18 normal, 1 grade 1, 1 grade 2, 0 grade 3; P = .61) or final Tegner activity level (median, 6).

Conclusion: At midterm follow-up, patients undergoing ACLR with and without a Segond fracture had similar pivot-shift test results, graft failure rates, and activity levels. The IKDC score was statistically worse in the patients with a combined ACL tear/untreated Segond fracture, but the difference was less than the minimal clinically important difference for the IKDC score. These findings suggest that patients with a combined ACL tear/untreated Segond fracture can have comparable outcomes to patients with an ACL tear and no Segond fracture when treated with ACLR alone.

Keywords: knee; ligaments; anterior cruciate ligament; ACL reconstruction; anterolateral complex; anterolateral ligament; Segond fracture
The proximal tibial avulsion fracture, resulting from forced internal rotation of the knee, was first described by Dr Paul Segond in 1879. It was not until later that this avulsion fracture was observed on radiographs and was correlated with ACL tears and knee instability. Claes et al showed that the area of the bony avulsion "Segond fracture" was the site of the anterolateral ligament (ALL) insertion. Recently, it was demonstrated by magnetic resonance imaging (MRI) analysis that the Segond fracture represents an avulsion of the anterolateral complex. An injury to the anterolateral structures of the knee, which include the iliotibial band and ALL, has been correlated with the pivot-shift test. The specifics of ALL function and biomechanical properties have been well outlined by Sonnery-Cottet et al. They demonstrated that the ALL alone was a major contributor to rotational control of the knee at varying degrees of knee flexion. Therefore, if the ALL is injured and does not heal, this could compromise knee stability and function. However, the healing ability of the ALL is largely unknown.

It has been reported that up to 25% of patients undergoing ACL reconstruction (ACLR) have persistent rotational instability. Some believe that part of this persistent instability is caused by a tear of the lateral capsuloligamentous structures including the ALL. Multiple biomechanical studies have assessed the role of the ALL in rotational stability of the knee. Noyes et al, using cadaveric specimens, compared isolated ACLR with a sectioned iliotibial band and ALL to combined ACLR and lateral tenodesis. They found small decreases in internal rotation limits and ACL graft forces in the combined group. Although changes were observed, the authors deemed them clinically indeterminate. In addition, the healing potential of the ALL was also undetermined. Therefore, it is unknown whether patients with a combined ACL tear/untreated Segond fracture have clinically different outcomes compared with those with an ACL tear and no Segond fracture. To our knowledge, there is a paucity of research comparing patients with a combined ACL tear/untreated Segond fracture to patients with an ACL tear and no Segond fracture. To date, it is not known whether a Segond fracture is pathognomonic for an ACL tear, but this was not the case in the present study. This finding has also been reported in both pediatric and adult patients.

The diagnosis of a Segond fracture (Figure 2) was confirmed by the presence of a proximal tibial avulsion fracture on radiographs with an associated ACL tear on MRI. All data regarding the initial injury, surgical intervention, and physical examination findings were recorded. Preoperative age, BMI, sex, Tegner activity level, Lachman test results, and pivot-shift test results were recorded. The ACLR procedures were performed by 4 surgeons at a single institution, and during the study period, approximately 1210 ACLRs were performed. The graft type used was recorded along with meniscal and articular cartilage damage as documented in the operative report. If a subsequent procedure on the injured or contralateral knee was needed, the procedure date and time to rupture were analyzed.

The primary postoperative clinical outcome measure was the International Knee Documentation Committee (IKDC) subjective score. The postoperative graft status was primarily determined based on Lachman and pivot-shift testing, as performed by the attending orthopaedic surgeon. Examination results were reported based on the IKDC.
criteria. For Lachman testing, compared with the contralateral knee, grading was as follows: 0, normal (–1 to 2 mm); 1+, nearly normal (3 to 5 mm); 2+, abnormal (6 to 10 mm); and 3+, severely abnormal (>10 mm). For pivot-shift testing, grading was as follows: 0, normal (none); 1+, nearly normal (glide); 2+, abnormal (clunk); and 3+, severely abnormal (gross). The graft rupture rate, time to rupture, and knee range of motion on physical examination were also investigated. The postoperative activity level was reported based on the Tegner activity score. Postoperatively, we analyzed radiographs on all patients in the study group to determine the rate of Segond fracture healing.

**Matched Cohort**

Patients in the Segond fracture group were matched (2:1) by sex, age (within 5 years), graft type, and BMI (within 8 kg/m²) to patients with no associated Segond fracture who underwent isolated ACLR. Investigators assigned to match the groups were blinded to outcomes. The control group consisted of 160 patients who had been reported on in a previous study at the same institution. We chose to match in a 2:1 fashion as it has been shown in prior studies to increase the power and precision of results in addition to help control for confounding variables when the sample size is small. Clinical and functional outcomes were obtained using IKDC subjective scores and Tegner activity levels.

**Statistical Analysis**

Chi-square analysis was used for categorical variables, and the Wilcoxon rank-sum test was used for continuous variables. The study and control groups were analyzed statistically using a 2-sample $t$ test. Continuous variables were reported as the mean ± SD, and ordinal variables were reported as the median (range). All data were reported and collected with accuracy to one decimal place. Patients were randomly matched to a previous cohort using SAS software version 9.4 (SAS Institute). All other statistical tests were 2-sided. $P$ values <.05 were considered statistically significant. Statistical analyses were performed using SAS JMP version 7.0.

**RESULTS**

Sixty patients were included in the study, including 20 patients with a Segond fracture, left untreated, who underwent ACLR (study group) matched to 40 patients (2:1) with no associated Segond fracture who underwent ACLR (control group). The mean time to final follow-up in the study group was 59.1 months (range, 24-180 months) compared with 55.5 months (range, 24-120 months) in the control group ($P = .96$). There were no major differences between the 2 groups preoperatively (Table 1).
Clinical Outcomes

Postoperative outcome data are shown in Table 2. The study group had a statistically significant lower IKDC score at final follow-up compared with the control group (mean, 86.5 [range, 54-100] vs 93.0 [range, 54-100], respectively; \( P = .03 \)).

Lachman Test

Patients in the study group had significantly more anteroposterior instability by preoperative Lachman testing than those in the control group (\( P = .0001 \)). There was no significant difference between the 2 groups in regard to postoperative Lachman testing (\( P = .31 \)). These results are presented in Table 3.

Pivot-Shift Test

Patients in the study group had significantly more instability by preoperative pivot-shift testing than those in the control group (\( P = .0003 \)). No significant difference was found between the 2 groups in regard to postoperative pivot-shift testing (\( P = .61 \)). These results are presented in Table 4.

Range of Motion

Postoperatively, the study group had a mean extension of \( 0.05 \pm 0.85 \)° compared with \( -0.48 \pm 1.90 \)° in the control group (\( P = .43 \)). The mean flexion was \( 137.1 \pm 5.1 \)° in the study group compared with \( 134.1 \pm 5.3 \)° in the control group (\( P = .034 \)).

Graft Ruptures and ACL Tears

Overall, 2 patients (10%) in the study group and 4 patients (10%) in the control group sustained a postoperative graft rupture (\( P = .97 \)). The mean time to rupture was 33.0 months (range, 21-45 months) in the study group compared with 63.5 months (range, 39-88 months) in the control group (\( P = .24 \)).

---

### TABLE 1

**Patient Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Study Group (n = 20)</th>
<th>Control Group (n = 40)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, male:female, n</td>
<td>16:4</td>
<td>32:8</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Autograft:allograft</td>
<td>16:4</td>
<td>32:8</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Body mass index, mean (range), kg/m²</td>
<td>26.3 [18.5-36.4]</td>
<td>26.0 [17.3-32.4]</td>
<td>.84</td>
</tr>
<tr>
<td>Preinjury Tegner score, median (range)</td>
<td>7 (4-9)</td>
<td>7 (4-9)</td>
<td>.60</td>
</tr>
<tr>
<td>Meniscal damage at surgery, %</td>
<td>55.0</td>
<td>40.0</td>
<td>.71</td>
</tr>
<tr>
<td>Cartilage damage at surgery (grade ≥3), %</td>
<td>15.0</td>
<td>10.0</td>
<td>.57</td>
</tr>
</tbody>
</table>

### TABLE 2

**Postoperative Outcomes**

<table>
<thead>
<tr>
<th></th>
<th>Study Group (n = 20)</th>
<th>Control Group (n = 40)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective IKDC score, mean (range)</td>
<td>86.5 (54-100)</td>
<td>93.0 (54-100)</td>
<td>.03</td>
</tr>
<tr>
<td>Graft rupture, n (%)</td>
<td>2 (10)</td>
<td>4 (10)</td>
<td>.97</td>
</tr>
<tr>
<td>Time to rupture, mean (range), mo</td>
<td>33.0 (21-45)</td>
<td>63.5 (39-88)</td>
<td>.24</td>
</tr>
<tr>
<td>Range of motion, mean ± SD, deg tend</td>
<td>137.1 ± 5.1</td>
<td>134.1 ± 5.3</td>
<td>.034</td>
</tr>
<tr>
<td>Contralateral ACL tear, n (%)</td>
<td>2 (10)</td>
<td>4 (10)</td>
<td>.16</td>
</tr>
<tr>
<td>Tegner score, median (range)</td>
<td>6 (3-8)</td>
<td>6 (2-9)</td>
<td>.78</td>
</tr>
</tbody>
</table>

### TABLE 3

**Lachman Test Results**

<table>
<thead>
<tr>
<th></th>
<th>Study Group (n = 20)</th>
<th>Control Group (n = 40)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative (( P = .0001 ))</td>
<td>Normal 0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Grade 1+</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Grade 2+</td>
<td>10</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Grade 3+</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Postoperative (( P = .31 ))</td>
<td>Normal 17</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Grade 1+</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Grade 2+</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Grade 3+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

\( ^a \)Data are shown as No.
TABLE 4
Pivot-Shift Test Results

<table>
<thead>
<tr>
<th></th>
<th>Study Group (n = 20)</th>
<th>Control Group (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative (P &lt; .0003)</td>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grade 1+</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grade 2+</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Grade 3+</td>
<td>7</td>
</tr>
<tr>
<td>Postoperative (P = .61)</td>
<td>Normal</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Grade 1+</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grade 2+</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grade 3+</td>
<td>0</td>
</tr>
</tbody>
</table>

*Data are shown as No.

Additionally, 2 patients (10%) in the study group and 4 patients (10%) in the control group had a contralateral ACL tear (P = .16). The mean time to injury in the study group was 19.5 months (range, 0.4-39 months) compared with 53.2 months (range, 25-82 months) in the control group.

Postoperative Activity Levels

There was no major difference in the postoperative activity level or Tegner score (median, 6; study group range, 3-8; control group range, 2-9). Fifty percent of patients in the study group and 47.5% in the control group were able to return to activity at or above their preinjury Tegner level after surgery (P = .86).

Segond Fracture Healing

All 20 patients in the study group had postoperative radiographs to determine the rate of fracture healing. Eighteen patients (90%) demonstrated healing of their Segond fracture at a median of 4 months (range, 3-30 months) after injury.

DISCUSSION

ACLR with concomitant ALL reconstruction has recently gained increased attention. This present study provides further information into the prognostic implications of combined ACL/anterolateral complex tears treated with ACLR alone by evaluating the unique population of patients with an ACL tear and associated Segond fracture. The purpose of this study was to compare clinical outcomes, graft failure rates, and activity levels between patients with a combined ACL tear/untreated Segond fracture to patients with an ACL tear and no Segond fracture at a minimum 2-year follow-up after ACLR.

The combined ACL tear/untreated Segond fracture group had a statistically significantly lower IKDC score at follow-up, with a mean of 86.5 compared with 93.0 for the control group (P = .03). There has not been a comparable study assessing clinical outcome scores between patients with a combined ACL tear/untreated Segond fracture treated with ACLR alone. Sonnery-Cottet et al evaluated 83 patients treated with combined ACLR/ALL reconstruction and found the mean IKDC score to be 86.7 (P < .0001). However, it is unclear in that study whether the ALL was torn in all patients undergoing ALL reconstruction. Our control group’s IKDC score of 93.0 is comparable with those in previous studies with similar follow-up times. The minimal clinically important difference for the IKDC subjective score has been determined to be 11.5. Therefore, this statistically significant difference between the groups is not clinically relevant.

We found no difference in graft failure rates between the 2 groups. In the study group, there were 2 patients (10%) with a graft rupture compared with 4 patients (10%) in the control group. The graft failure rate for both groups in this study is higher than in previously reported studies. The higher failure rate may be because of our relatively low number of patients and the younger mean age of the patients. The mean age at the time of surgery was 26.3 and 26.4 years for the combined ACL tear/untreated Segond fracture and ACL tear with no Segond fracture groups, respectively. Previous studies have reported that the failure rate is dependent on how young and active the patients are. Sonnery-Cottet et al recently conducted a retrospective cohort study to evaluate the comparative outcomes of patients with ACL tears treated with bone–patellar tendon–bone (B-PT-B), quadrupled hamstring tendon (4HT), or hamstring tendon grafts combined with ALL reconstruction (HT+ALL). The cohort consisted of 502 patients (aged 16-30 years) who participated in pivoting sports. It was found that the HT+ALL group had a significantly lower rate of graft ruptures (4.1%) compared with the B-PT-B (16.8%) and 4HT (10.8%) groups. This study has limitations as all operative procedures were performed by a single surgeon, and there is a possibility of selection bias as 44% of the cohort were in the HT+ALL group.

The mean time to rupture was 33.0 months (range, 21-45 months) in the study group and 63.5 months (range, 39-88 months) in the control group. Although not statistically significant, it would be a relevant finding if the group with an associated Segond fracture had a decreased time to failure. The control group’s mean time to rupture was similar to that found in previous retrospective and prospective studies.

The study group had statistically significant preoperative increases in both pivot-shift and Lachman test results compared with the control group. No significant differences were seen postoperatively. It is possible that the preoperative findings were related to the Segond fracture as the ALL has been shown to be a contributor to rotational stability, as tested by the pivot-shift test. Increased anteroposterior laxity has not been demonstrated with ALL disruption.

The pivot-shift test has been proven to be the most reliable examination technique in evaluating functional instability. In evaluating functional rotational instability, only 2 patients (10%) in the study group had a grade ≥1 pivot-shift test result at follow-up. Previous findings have shown that rotational instability commonly persists after ACLR. More subtle abnormalities in the pivot-shift test may have been found in this study had a quantitative method of pivot shift been
utilized. For example, a recent study used cadaveric models to compare knees undergoing ACLR with a sectioned iliotibial band and ALL to combined ACLR and lateral tenodesis. They did find small decreases in internal rotation limits and ACL graft forces in the combined group using a robotic simulator. Ultimately, though, they deemed the decreases to be clinically indeterminate and do not recommend ALL reconstruction in primary ACL injuries. As assessed on clinical examination, this present study found no difference in rotational stability between the 2 groups.

Postoperative activity levels were similar for the 2 groups. Both groups were found to have a median Tegner score of 6. In the past, the Lachman test was used as the primary predictor of activity level after ACLR; however, the pivot-shift test has since shown to be more reliable. The majority of patients had a negative pivot shift and corresponding high activity level. The 1 patient in the study group with a grade 2 pivot-shift test finding had an associated Tegner score of 4. The postoperative activity levels are consistent with previously reported findings. Sonnery-Cottet et al reported a mean postoperative Tegner score of 7.1 ± 1.8 in 83 patients treated with combined ACLR/ALL reconstruction at a minimum 2-year follow-up.

On postoperative radiographic analysis, 90% of the patients in the study group demonstrated healing of their Segond fracture. This high rate of healing correlates with the lack of clinically relevant differences found between the study and control groups. To our knowledge, there has been no comparable study analyzing the rate of Segond fracture healing.

The results of this study should be considered with its limitations. It was a matched-cohort retrospective study that has inherent drawbacks. Although the difference in IKDC scores between the groups was statistically significant, the study group consisted of a small sample size. This is because of the relative small percentage of Segond fractures seen on imaging associated with ACL tears. In this retrospective study, 6 (23.1%) patients were lost to follow-up. With regard to graft type, we were unable to match the groups more specifically than allograft versus autograft. An instrumented measurement device was not used to grade the Lachman and pivot-shift test results. This certainly created the possibility of variability in interexaminer grade reporting. Our study evaluated patients with Segond fractures and should not be interpreted to apply to patients with ACL tears and concomitant soft tissue injuries to the ALL. Despite these limitations, to our knowledge, this is the first study comparing patients with a combined ACL tear/untreated Segond fracture to patients with an ACL tear and no Segond fracture treated with ACLR alone.

CONCLUSION

At midterm follow-up, patients undergoing ACLR with and without a Segond fracture had similar pivot-shift test results, graft failure rates, and activity levels. IKDC scores were statistically worse in the patients with a combined ACL tear/untreated Segond fracture, but the difference was less than the minimal clinically important difference for the IKDC score. These findings suggest that patients with a combined ACL tear/untreated Segond fracture can have comparable outcomes with patients with an ACL tear and no Segond fracture when treated with ACLR alone.

REFERENCES


