Return to Sport After Revision ACL Reconstruction
A Comparative Cohort Study of Outcomes After Single- Versus Multiple-Revision Surgeries

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Background: The return-to-sport rate at 2 years after multiple-revision anterior cruciate ligament (ACL) reconstructions has not been evaluated.

Hypothesis: It was hypothesized that patients who undergo multiple-revision ACL reconstructions would have a lower return-to-sport rate at 2 years after surgery than those who undergo a single-revision reconstruction. Furthermore, it was hypothesized that the multiple-revision group would have lower functional scores.

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

Methods: A single-center cohort study in patients who underwent revision ACL reconstruction was begun in 2012. This study included 2 groups: Patients who underwent a single revision, and those who underwent multiple revisions. The main evaluation criterion was the return to sport at the 2-year follow-up. The secondary criteria were the International Knee Documentation Committee (IKDC), Knee injury and Osteoarthritis Outcome Score (KOOS), Lysholm, and ACL–Return to Sport after Injury (ACL-RSI) functional knee scores at the 1- and 2-year follow-ups.

Results: A total of 322 patients (single-revision group: n = 302; multiple-revision group: n = 20) were included. A significant difference in the percentage of patients who stopped all sports activity was found between the 2 groups at 2 years (single-revision group: 19.4%; multiple-revision group: 50%). The return-to-sport rate at the same or lower level of performance was higher in the single-revision group as well (17% vs 14.3% for return at the same level; 45.6% vs 14.3% for return at a lower level; \( P = .03 \)). At the 2-year follow-up, the functional scores of the single-revision group were significantly higher than in the multiple-revision group: IKDC (77.7 ± 13.82 vs 64.79 ± 15.22; \( P < .001 \)), KOOS (72.66 ± 17.63 vs 52.5 ± 15.64; \( P < .001 \)), Lysholm (84.05 ± 11.88 vs 72.5 ± 13.49; \( P < .001 \)), and ACL-RSI (52.34 ± 21.83 vs 46.43 ± 14.8; \( P = .0036 \)).

Conclusion: Only a small percentage of patients returned to the same level of sport after single- revision and multiple-revision ACL reconstruction, yet significantly more in the former. More patients who underwent multiple revisions gave up their sport. Functional scores were higher for single-revision than multiple-revision surgeries.

Keywords: single-revision ACL reconstruction; multiple-revision ACL reconstruction; ACL-RSI; return to sport

Revision anterior cruciate ligament (ACL) reconstruction after retears with clinical instability ranges from 6% to 11% and is a challenge to surgeons.\(^2,7,11,13\) Comparison of outcomes after multiple revisions (>3 ACL reconstructions in the same knee) versus single revisions (first-time revision) is limited in the literature and is based on a series of multiple revisions in 2 cohort studies.\(^1,19\) The Multicenter ACL Revision Study cohort including 151 patients who underwent multiple revisions reported a decrease in physical activity on the Marx questionnaire (6.7 vs 9.8; \( P < .05 \)), an increase in chondral injuries particularly over the medial femoral condyle (46% vs 58%; \( P < .01 \)), and a higher rate of nontraumatic graft tear than in patients who underwent a single revision (47% vs 25%; \( P < .01 \)).\(^1\) A recent cohort comparing 62 patients who underwent a single revision with 20 patients who underwent multiple revisions showed greater clinical and radiological instability in the multiple-revision group as well as an increase in chondral...
and meniscal injuries. However, the functional scores as well as the tibial slopes were comparable between the 2 groups.¹⁹

Return-to-sport performance and the psychological readiness to return to sport have not been evaluated in these patients, and the results of functional scores in the literature are rare and contradictory.¹,¹⁹ The main goal of the current study was to compare the return-to-sport rate 2 years after surgery in patients who underwent multiple-revision ACL reconstruction with that of patients who underwent single-revision reconstruction. The secondary goals were to compare the psychological readiness to return to sport according to the ACL–Return to Sport after Injury (ACL-RSI) questionnaire, as well as the functional scores between these 2 groups. We hypothesized that (1) return-to-sport times would significantly decrease after multiple-revision compared with single-revision ACL reconstruction and (2) that functional scores would be lower at the 2-year follow-up in the multiple-revision group.

METHODS

This single-center cohort study was a retrospective analysis of prospectively collected data from patients who underwent single- and multiple-revision ACL reconstruction by 1 of 6 senior surgeons between January 2012 and March 2019. All patients practiced sports, were between 18 and 60 years of age, and had been treated for an ACL reconstruction retear. Inclusion criteria were (1) single- or multiple-revision ACL reconstruction and (2) single-bundle reconstruction. Exclusion criteria were (1) patients younger than 18 years of age, (2) multiligament injuries, and (3) a postoperative follow-up of less than 2 years. Patients were divided into 2 groups: single revision (patients operated on for a first-time revision) and multiple revisions (patients operated on for a second revision or more). The protocol for this study received approval from the local ethics committee and informed consent from all operated patients.

Surgical Technique

The different arthroscopic ligament reconstruction techniques used for single and multiple revisions were hamstring tendons harvested from the pes anserinus. If the hamstrings were harvested during a prior surgical intervention, a bone-tendon-bone autograft technique using the patellar tendon (Kenneth-Jones technique), a quadriceps tendon autograft, or a combined intra- and extra-articular ACL reconstruction with the fascia lata augmented with either a gracilis tendon autograft or an allograft (McIntosh fascia lata) was used.¹⁹ A lateral extra-articular tenodesis (LET) was frequently associated with articular reconstruction. The indications for a LET were multiple-revision surgeries, high-impact or high level of sports performance, a positive pivot-shift test, and a differential comparison with a healthy contralateral knee greater than 10 mm on Telos laximeter radiographs. Most of the single-revision surgeries also had a LET. The techniques were most frequently a modified Lemaire technique, an anterolateral ligament reconstruction with the gracilis tendon, and the fascia lata used in the MacIntosh technique. Standardization of the surgical protocol was established between all surgeons to avoid bias related to surgical technique: A transportal femoral tunnel, an antegrade tibial tunnel, and the abovementioned ACL grafts were used in both groups by all surgeons. Prior tunnel position and widening were routinely assessed via preoperative computed tomography scan; however, no tunnel grafting was necessary.

Postoperative Rehabilitation Protocol

Postoperative physical therapy was performed according to the same protocol in both groups. Passive range of motion from full extension to 90° of flexion was achieved during the first 4 weeks after surgery. An isometric quadricipital contraction was also achieved during the early postoperative stages. Concentric hamstrings and quadricipital contractions were allowed at 6 weeks postoperatively. Closed-chain exercises were started after gaining a full passive range of motion and adequate muscle strength, typically at 2 months postoperatively. Open-chain reactions were started at the fourth month. Return to sport was authorized starting the sixth month, and return to a competitive level of sports was authorized at 9 months.

Patient Data

Patient data included their age, sex, body mass index (BMI), type and number of ligament reconstructions, meniscal and chondral injuries identified during surgery, and any complications.

Outcome Criteria

The main outcome criterion was the return to sport 2 years after the last reconstruction. Secondary outcome criteria were the following functional outcome scores at 1 and 2

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Ethical approval for this study was obtained from Clinique du Sport, Groupe Ramsay Santé.
years of follow-up; International Knee Documentation Committee (IKDC),9 Knee injury and Osteoarthritis Outcome Score (KOOS),15 Lysholm,16 and ACL-RSI score for psychological readiness to return to sport.17

Clinical Scores

Self-administered functional outcome scores were prospectively and systematically administered during the study after all ligament reconstructions. Self-administered IKDC, KOOS, and Lysholm scores were obtained at 6 months, 1 year, and 2 years after surgery. The ACL-RSI score was determined at the 1-year and 2-year follow-ups. Finally, all patients were asked to identify their physical performance by reporting whether they returned to their sport at the same level as before their injury or at a lower level and if there had been a change in or if they had stopped their sports activities.

Statistical Analysis

Statistical analyses were performed using Python software (Python Software Foundation 3.9.0). Analysis of normal data distribution was performed by the Shapiro-Wilk test. Quantitative variables were presented as means and standard deviations or medians and percentages. Qualitative variables were compared using the chi-square test and the Fisher exact test. The return-to-sport comparison between both groups was made using the Fisher exact test. The Student t test was used to compare pre- and postoperative functional scores. \(P < .05\) was considered to be statistically significant and \(P < .001\) highly significant.

RESULTS

Patient Characteristics

A total of 322 patients fulfilled the inclusion criteria. There were 302 patients who underwent a single revision and 20 patients who underwent multiple revisions (Figure 1). The single- and multiple-revision groups were comparable and not significantly different for age (33.34 ± 9.24 vs 34.01 ± 9.71; \(P = .08\)), female/male sex ratio (84/218 vs 5/15; \(P = .8\)), and BMI (24.47 ± 4.06 vs 24.51 ± 2.84; \(P = .3\)). The prevalence of overweight patients was the same in both groups. Patient data are presented in Table 1.

Meniscal and Chondral Injuries

Meniscal injuries were identified in 166 patients (55%) who underwent a single revision. There were 102 medial (34%) and 64 lateral (21%) meniscal lesions. Meniscal injury was reported in 7 patients (35%) who underwent multiple revisions. There were 4 medial (20%) and 3 lateral meniscal (15%) lesions. There was no significant difference in the occurrence of meniscal lesions between the groups (\(P > .05\); chi-square test). The number of repairable meniscal tears was not recorded.

Chondral injuries were identified in 21% of the single-revision group and in 30% of the patients who
underwent multiple revisions. The difference was not significant (P = .1).

LET and the Use of Artificial Ligament

LET was frequently associated with these different techniques.14, 278 of 302 patients in the single-revision group underwent an associated LET. It was performed in all multiple-revision cases. Allografts were used in 4 single-revision cases (1%) and in 4 multiple-revision cases (20%). The Ligament Augmentation and Reconstruction System artificial ligament system (Corin) was used in 2 patients who underwent multiple revisions. A summary of graft choice and associated lesions is presented in Table 2.

TABLE 2
Surgical Technique and Associated Meniscal and Chondral Injuries

|                          | Single-Revision Group (n = 302) | Multiple-Revision Group (n = 20) |
|--------------------------|---------------------------------|---------------------------------|
| Medial meniscal injury   | 102 (34)                        | 4 (20)                          |
| Lateral meniscal injury  | 64 (21)                         | 3 (15)                          |
| Chondral injury          | 64 (21)                         | 6 (30)                          |
| Bone-tendon-bone autograft | 171 (57)                  | 3 (15)                          |
| Hamstring autograft      | 59 (19)                         | 0 (0)                           |
| Mahtintosh fascia lata   | 68 (23)                         | 8 (40)                          |
| Quadriceps tendon        | 0 (0)                           | 3 (15)                          |
| Autograft                | 4 (1)                           | 4 (20)                          |
| LARS artificial ligament | 0 (0)                           | 2 (10)                          |
| LET                      | 278 (92)                        | 20 (100)                        |

"Data are reported as n (%). LARS, Ligament Augmentation and Reconstruction System; LET, lateral extra-articular tenodesis.

Return to Sport

Of the 302 patients, 217 (72%) who underwent a single revision reported on their return to sport at 2 years after surgery, and 14 of the 20 patients who underwent multiple revisions (70%) reported on their return to sport. Table 3 presents the return-to-sport data and level of performance. There was a significant difference between the 2 groups regarding the return to the same or lower level of sport (P = .03).

TABLE 3
Return to Sport After Single- and Multiple-Revision ACL Reconstruction

|                          | Single-Revision Group (n = 217) | Multiple-Revision Group (n = 14) |
|--------------------------|---------------------------------|---------------------------------|
| Same level               | 37 (17)                         | 2 (14.3)                        |
| Lower level              | 99 (45.6)                       | 2 (14.3)                        |
| Changed sport            | 39 (18)                         | 3 (21.4)                        |
| Stopped                  | 42 (19.4)                       | 7 (50)                          |

"Data are reported as n (%). There was a significant between-group difference for the return to the same or lower level of sports (P = .03; Fisher exact test). ACL, anterior cruciate ligament.

Functional Scores and Psychological Readiness

Single-Revision Group. Compared with preoperative scores, the IKDC, KOOS, and Lysholm scores significantly improved at both the 1-year and 2-year follow-ups in the single-revision group (P < .001 for all). The IKDC score increased from 57.5 ± 16.47 preoperatively to 76.31 ± 14.39 after 1 year and 77.7 ± 13.82 after 2 years; the KOOS increased from 49.28 ± 23.15 preoperatively to 70.3 ± 19.24 after 1 year and 72.66 ± 17.68 after 2 years; and the Lysholm score increased from 65.62 ± 13.81 preoperatively to 83.61 ± 12.12 after 1 year and 84.05 ± 11.88 after 2 years. Significant improvements in these scores were also seen between the 1-year and 2-year follow-ups (P = .03 for IKDC, .006 for KOOS, and .04 for Lysholm). The ACL-RSI score increased from 40.66 ± 22.4 preoperatively to 51.46 ± 20.1 at the 1-year follow-up (P < .001); however, this score did not change significantly between postoperative year 1 and year 2 (P = .43). The results of the functional outcome scores in patients who underwent a single revision are presented in Figure 2.

Multiple-Revision Group. Progression of the functional outcome scores in patients who underwent multiple revisions was less predictable. The IKDC score increased from 56.39 ± 14.2 preoperatively to 67.97 ± 15.86 after 1 year (P = .003). However, the difference between 1 and 2 years of follow-up was not significant. The preoperative KOOS increased from 40.88 ± 22.5 to 56.67 ± 18.33 (P = .001) at 1 year of follow-up. There was a nonsignificant decrease to 52.5 ± 15.64 (P = .07) between 1 and 2 years of follow-up, but it was still higher than the preoperative scores (P = .04). The Lysholm and ACL-RSI scores were not significantly different after 2 years of follow-up compared with the scores obtained before the last revision (Lysholm: 73.15 ± 13.75 vs 72.5 ± 13.49; P = .81; ACL-RSI: 38.65 ± 19.63 vs 46.43 ± 14.8; P = .11) (Figure 3).

All 4 functional outcome scores were higher in the single-revision group than in the multiple-revision group, and this difference was highly significant despite comparable preoperative IKDC and ACL-RSI scores between the 2 groups (P < .05 for all) (Table 4).

DISCUSSION

The main results of this comparative study between patients who underwent a single revision and those who
underwent multiple revisions indicated that the return-to-sport rate was lower in the latter group. We found that 50% of patients who underwent multiple revisions stopped all sports activity because of their knee. Our hypothesis of a decrease in return to sport after multiple-revision versus single-revision ACL reconstruction was thus proven. Identification of the risk factors of poor results as well as positive predictive factors has not been clearly established.

Our results are similar to other retrospective studies in multiple-revision ACL reconstructions. In 1 retrospective study including 17 patients who underwent multiple revisions, 1 of 4 patients returned to sport at the preinjury level of play.23 A study from the French ACL Study (FAST) cohort comparing the return-to-sport rate and functional scores in patients who underwent primary ACL reconstruction and those who underwent a single revision showed that the return-to-sport rate was the same between the 2 groups.

**Figure 2.** Progression of functional scores in patients who underwent a single revision. Significant difference between times: *P < .05; **P < .01; ***P < .001. ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score.

**Figure 3.** Progression of functional scores in patients who underwent multiple revisions. Significant difference between times: *P < .05; **P < .01. ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score.
Knee injury and Osteoarthritis Outcome Score. IKDC, International Knee Documentation Committee; KOOS, RSI, Anterior Cruciate Ligament Return to Sport after Injury; ACL-sions have shown improved functional scores, the level of play decreased significantly after revision ACL reconstruction, with 49% of the patients returning to their preinjury level of play (vs 64% after primary ACL reconstruction; \(P = .04\)). The current follow-up within the same cohort shows an even lower return-to-sport rate at the same-level percentages than what was previously published (17% for single revision). 

The secondary results of the FAST study concern the IKDC, KOOS, and Lysholm functional scores and in particular the ACL-RSI score, as not all of these scores improved in the multiple-revision group. The IKDC, KOOS, and ACL-RSI functional scores were all significantly lower after revision surgery (78 vs 83, 68 vs 73, 50 vs 65; \(P < .05\), respectively). The return to sport after multiple revisions does not follow the same pattern in the same cohort. The IKDC score and KOOS improve; however, the Lysholm and ACL-RSI scores do not show any functional improvement 2 years after the last revision compared with the preoperative scores. Possible reasons for the lack of improvement in outcome scores in patients who underwent multiple revisions might be accounted for by multiple factors: lower preoperative ACL-RSI scores and a psychological fear of reinjury, multiple graft harvests and donor-site morbidity, and worse chondral injuries. Because multiple revisions are rare and specific clinical situations, functional scores should be interpreted with caution in these cases.

Although previously reported results after multiple revisions have shown improved functional scores, the level of activity was found to decrease in these patients. ACL-RSI analysis in this patient population seems very interesting because other functional outcomes reported in the literature are comparable between patients who underwent a single revision and those who underwent multiple revisions. However, the ACL-RSI along with the aforementioned functional scores were different between the groups in this study.

### TABLE 4
Comparison of Functional Scores at the 1- and 2-Year Follow-ups

|                          | Single-Revision Group (n = 322) | Multiple-Revision Group (n = 20) | \(P\) |
|--------------------------|---------------------------------|---------------------------------|-------|
| 1-year follow-up         |                                 |                                 |       |
| IKDC subjective          | 76.31 ± 14.39                   | 67.97 ± 15.86                   | .001  |
| KOOS                     | 70.3 ± 19.24                    | 56.67 ± 18.33                   | .001  |
| Lysholm                  | 83.61 ± 12.12                   | 75.75 ± 13.41                   | .001  |
| ACL-RSI                  | 51.46 ± 20.1                    | 36.71 ± 19.99                   | .001  |
| 2-year follow-up         |                                 |                                 |       |
| IKDC subjective          | 77.7 ± 13.82                    | 64.79 ± 15.22                   | <.001 |
| KOOS                     | 72.66 ± 17.63                   | 52.5 ± 15.64                    | <.001 |
| Lysholm                  | 84.05 ± 11.88                   | 72.5 ± 13.49                    | <.001 |
| ACL-RSI                  | 52.34 ± 21.83                   | 46.43 ± 14.8                    | .004  |

*Data are presented as mean ± SD. Boldface \(P\) values indicate statistically a significant difference between groups (\(P < .05\)). ACL-RSI, Anterior Cruciate Ligament Return to Sport after Injury; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score.

### Strengths and Limitations

The strong points of our study are the 2-year follow-up and the use of the ACL-RSI score. A recent systematic review shows that the ACL-RSI score is the best tool to measure psychometric and functional results, including 6 parameters with a high level of evidence. This highly pertinent measurement tool has not yet been evaluated in patients who underwent multiple revisions. This study has several limitations. The group of patients who underwent multiple revisions was small compared with the single-revision group, also making analysis of the effect of different graft choices difficult. Both groups were heterogeneous, with multiple reconstruction techniques applied, making it difficult to analyze data according to a single reconstruction technique. No laxity measurements (Telos, KT-1000, or GNIB) were taken into account. No radiographic analysis for a potential cause of failure or functional testing (Cybex, hop tests) was used.

### CONCLUSION

Study findings indicated that only a small percentage of patients returned to the same level of sport after single-revision and multiple-revision ACL reconstruction, yet significantly more in the former. More patients who underwent multiple revisions gave up their sport than those who underwent a single revision. Functional outcome scores were higher for single-revision than multiple-revision surgeries. Finally, in patients who underwent multiple revisions, there was no significant improvement in ACL-RSI or Lysholm scores at 2 years of follow-up compared with preoperative score values. The study findings constitute a valuable addition to the literature regarding high-demand athletes who have specific questions about their level of performance after multiple-revision ACL surgeries.

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