Original Research

Knee Hyperextension Greater Than 5° Is a Risk Factor for Failure in ACL Reconstruction Using Hamstring Graft

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Background: The degree of knee hyperextension in isolation has not been studied in detail as a risk factor that could lead to increased looseness or graft failure after anterior cruciate ligament (ACL) reconstruction.

Purpose: To analyze whether more than 5° of passive knee hyperextension is associated with worse functional outcomes and greater risk of graft failure after primary ACL reconstruction with hamstring tendon autograft.

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

Methods: A cohort of patients who had primary ACL reconstruction with hamstring tendon autografts was divided into 2 groups based on passive contralateral knee hyperextension greater than 5° (hyperextension group) and less than 5° (control group) of hyperextension. Groups were matched by age, sex, and associated meniscal tears. The following data were collected and compared between the groups: patient data (age and sex), time from injury to surgery, passive knee hyperextension, KT-1000 arthrometer laxity, pivot shift, associated meniscal injury and treatment (meniscectomy or repair), contralateral knee ligament injury, intra-articular graft size, follow-up time, occurrence of graft failure, and postoperative Lysholm knee scale and International Knee Documentation Committee subjective form scores.

Results: Data from 358 patients initially included in the study were analyzed; 22 were excluded because the time from injury to surgery was greater than 24 months, and 22 were lost to follow-up. From the cohort of 314 patients, 102 had more than 5° of knee hyperextension. A control group of the same size (n = 102) was selected by matching among the other 212 patients. Significant differences in the incidence of graft failure (14.7% vs 2.9%; $P = .005$) and Lysholm knee scale score (86.4 ± 9.8 vs 89.6 ± 6.1; $P = .018$) were found between the 2 groups.

Conclusion: Patients with more than 5° of contralateral knee hyperextension submitted to single-bundle ACL reconstruction with hamstring tendons have a higher failure rate than patients with less than 5° of knee hyperextension.

Keywords: anterior cruciate ligament; knee hyperextension; graft failure; hamstring

The anterior cruciate ligament (ACL) is the most frequently injured ligament of the knee, and ACL injuries commonly keep athletes from sports practice.[28] About 200,000 ACL reconstruction surgeries are performed each year in the United States.[5,28] Even though nonoperative treatment or ACL repair can be performed in specific situations,[6,30] the most accepted treatment for an ACL injury in active populations is reconstruction. Overall, ACL reconstruction presents good results in functional scales and a low failure rate.[15] However, some specific populations are known to have a higher risk for a failed reconstruction, including young patients involved in sports activities, patients with hyperlaxity, and patients with major preoperative knee anterior and anterolateral instabilities.[11,16]

The outcome of ACL reconstruction surgery depends on many factors. Surgical technique and proper graft positioning, restoration of anterior and rotatory knee stability, and restoration of full range of motion and muscle strength are some of the factors that affect the final function of the knee in the postoperative period.[2] Even though some factors such as technique and graft options are modified by the surgeon, patients might have intrinsic factors of bony morphology and hyperlaxity that the surgeon cannot modify.[13,27]

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There is a concern that higher degrees of hyperextension may lead to increased looseness or graft failure after ACL reconstruction. Markolf et al[19,20] showed there are high forces generated in the ACL graft during hyperextension, and this might account for ACL graft stretching and failure. One cohort study carried out by Benner et al[2] concluded that there is no increase in rupture or insufficiency of the ACL graft in patients with a high degree of hyperextension. However, the study evaluated only patients who received patellar tendon autografts; no other type of graft was used. Another cohort study, from the Multicenter ACL Revision Study (MARS) Group, evaluated patients who underwent ACL reconstruction revision and concluded that a passive hyperextension of the knee greater than 5° was an important predictor of graft failure.[21] To the authors' knowledge, this conclusion is not yet applicable to primary ACL reconstructions. Only a few authors performed the same evaluation in primary ACL reconstruction cases with double-bundle and single-bundle hamstring autografts. Even though generalized joint laxity is known to be an important risk factor for ACL reconstruction failure, the degree of knee hyperextension in isolation has not been studied in detail. Larson et al[16] showed a failure rate of 24.4% and Helito et al[11] a failure rate of 21.7% when evaluating patients with higher Beighton scores; however, none of these authors isolated knee hyperextension in the analysis.

Therefore, the purpose of this study was to analyze whether a high degree (more than 5°) of passive hyperextension of the knee was associated with worse functional outcomes and greater risk of graft failure after primary ACL reconstructions with hamstring tendon autografts in adult patients. Our hypothesis was that patients with more than 5° of passive knee hyperextension would have a higher rate of graft tear/failure and lower subjective scores after surgery than patients with less knee extension.

METHODS

The study was approved by the ethics committee of our institution, and informed consent was obtained. This was a retrospective cohort study designed to assess the functional outcome of patients undergoing primary ACL reconstruction with hamstring tendon autografts. Patients who underwent surgery from June 2013 to June 2018 were included. Inclusion criteria were patients aged between 18 and 60 years, with acute or chronic ACL injury, who underwent anatomic, single-bundle, intra-articular ACL reconstruction with autologous hamstring autografts with a minimum follow-up of 2 years. Patients with associated injuries that required additional surgical procedures, such as peripheral ligament reconstructions (including anterolateral ligament reconstruction or iliotibial band tenodesis), posterior cruciate ligament reconstruction, osteotomy, and cartilage procedures and patients with previous contralateral knee injury were not included for this evaluation. Patients who had surgery more than 24 months after the ACL tear and patients lost to follow-up were excluded.

ACL reconstruction was performed using the outside-in technique for preparing the femoral tunnel. The tunnel was positioned close to the anteromedial bundle of the ACL in the lateral femoral condyle. The tibial tunnel was created at the center of the ACL footprint. The hamstring graft was passed from the tibia to the femur, and fixation was performed with absorbable interference screws. The femur was fixed first and the tibia second, with around 30° of knee flexion.

Data were collected from medical records and databases of operated patients completed prospectively during normal patient follow-up. The following data were collected: patient data (age and sex), time from injury to surgery, passive knee hyperextension, KT-1000 arthrometer laxity, pivot shift, associated meniscal injury and treatment (meniscectomy or repair), contralateral knee ligament injury, intra-articular graft size, follow-up time, occurrence of graft failure, and postoperative Lysholm knee scale[3] and International Knee Documentation Committee (IKDC) subjective form scores.[10] Passive knee hyperextension was measured preoperatively (at the time of the surgical procedure and under anesthesia) using a goniometer in the contralateral knee to minimize the effects of the ACL injury on the affected knee, assuming both knees had the same degree of mobility before the ACL injury (Figure 1). Patients with a previous contralateral knee injury were not included. Graft failure was based on clinical ACL failure criteria (physical examination showing laxity with no clear endpoint for Lachman and anterior drawer tests [at least +2/+3] or pivot-shift positivity [at least +2/+3] associated with instability complaints) and when imaging showed a new graft rupture.

All patients who did not undergo meniscal repair followed the same rehabilitation protocol. No immobilization device of any type was used, and movement was not restricted. Patients were encouraged to walk as tolerated on the operated limb, and the range of motion was free and stimulated since the first day after surgery. In patients who underwent meniscal repair, the rehabilitation included weightbearing as tolerated with a knee brace and range of motion restricted from 0° to 90° for 4 weeks. After that, the protocol was similar to that for the other patients. The

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Ethical approval for this study was obtained (CAAE control No. 32727320.2.0000.0068/SGP 11257).

Figure 1. Knee showing passive hyperextension, observed with the patient under anesthesia.

range of motion goal was to return the knee to the same contralateral range of motion, including the hyperextension degree. Full return to sports activities was not allowed until at least 8 months and only if the patient was evaluated with good muscular control.

A hyperextension group was formed comprised of patients with passive knee hyperextension. A control group with the same number of patients was selected by matching among the other patients of the cohort. The matching was performed using age (each patient in the case group was paired with a patient up to 5 years older or 5 years younger), sex, and associated meniscal tear. Physical examination parameters were not used to match patients as they could be influenced by the knee laxity of each patient. We also did not use Beighton classification for this study and focused only on the knee hyperextension parameters.

Continuous variables were reported as means and standard deviations for normal distributions and medians and interquartile ranges for non-normal distributions, according to the Shapiro-Wilk test and histogram analysis. Group comparisons were made using the Student *t* test or Mann-Whitney *U* test, according to the normality of the variable. Categorical variables were reported as absolute number and percentage within the group, and the Fisher's test was used in the respective contingency tables.

No sample size estimation was performed, as all patients in our database who met the inclusion criteria were analyzed. A post hoc power calculation revealed an achieved power of 85% for graft failure, which was considered adequate for the study. Statistical significance was considered when the $P < .05$. We used SPSS Version 24 (IBM) and G*Power 3.1.9.3 (Erdfelder et al, Universität Düsseldorf, 2009) for the statistical analyses.

RESULTS

A total of 358 patients were initially included in the study; 22 were excluded because the time from injury to surgery was greater than 24 months, and 22 were excluded because they had less than 24 months of follow-up (lost to follow-up). From our cohort of 314 patients, 102 had more than 5° of knee hyperextension. A control group of the same size (n = 102) was selected by matching among the other 212 patients (Figure 2).

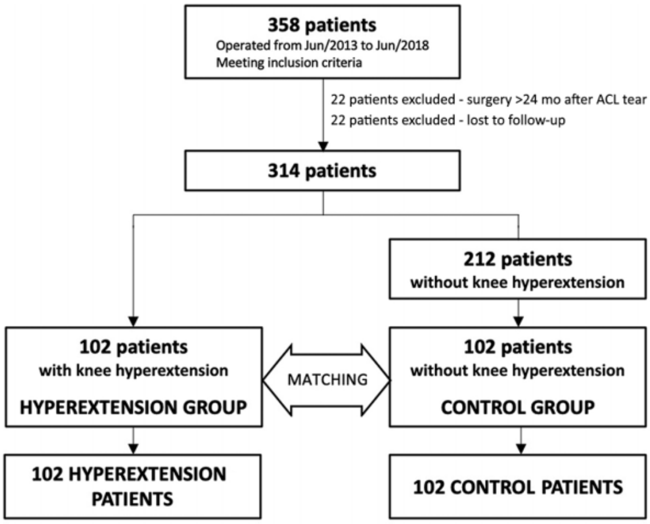

Figure 2. Flowchart of study participants. ACL, anterior cruciate ligament.

TABLE 1
Patient Characteristics and Preoperative Clinical Data[a]

	Control Group (n = 102)	Hyperextension Group (n = 102)	*P* Value
Age, y	31.5 ± 9.1	31.6 ± 9	.753
Female patients	35 (34.3)	35 (34.3)	
Time from injury to surgery, mo	7.9 ± 6.5	7.9 ± 5.9	.838
KT-1000 arthrometer laxity, preoperative, mm	7.5 ± 1.1	7.5 ± 1.2	.727
Pivot shift, preoperative, 0-3			.261
1	28 (27.5)	18 (17.6)	
2	48 (47.1)	55 (53.9)	
3	26 (25.5)	29 (28.4)	
Knee passive hyperextension, deg	1.6 ± 1.8	9.6 ± 3.1	**<.001**
Associated meniscal injury	28 (27.5)	28 (27.5)	≥.999
Contralateral knee ligament injury	2 (2)	2 (2)	≥.999
Follow-up time, mo	34.7 ± 12.8	38 ± 13.2	.028

[a]Data are presented as mean ± SD or n (%). Bolded *P* value indicates a statistically significant difference between groups ($P < .05$).

Data from 204 patients (102 patients in the hyperextension group and 102 patients in the control group) were evaluated. Patient characteristics and preoperative clinical data are shown in Table 1. Both groups were similar regarding all variables with the exception of passive knee hyperextension, which presented a mean of 1.6° ± 1.8° for the control group and 9.6° ± 3.1° for the hyperextension

TABLE 2
Outcomes[a]

	Control Group	Hyperextension Group	*P* Value
Intra-articular graft size, mm	7.8 ± 0.7	8.2 ± 0.8	**<.001**
Graft failure	3 (2.9)	15 (14.7)	**.005**
KT-1000 arthrometer laxity, postoperative, mm	2.0 ± 1.2	2.1 ± 1.4	.833
Pivot shift, postoperative, 0-3			.876
0	62 (60.8)	61 (59.8)	
1	37 (36.3)	36 (35.3)	
2	3 (2.9)	5 (4.9)	
Residual pivot shift	40 (39.2)	41 (40.2)	≥.999
IKDC subjective score	87.9 ± 7.9	84.7 ± 11.6	.141
Lysholm score	89.6 ± 6.1	86.4 ± 9.8	**.018**

[a]Data are presented as mean ± SD or n (%). Bolded *P* values indicate a statistically significant difference between groups ($P < .05$). IKDC, International Knee Documentation Committee.

group ($P < .001$). Follow-up time was also higher in the hyperextension group by a mean difference of 3.3 months ($P = .028$).

A significant difference in the incidence of graft failure and Lysholm score between the 2 groups was found (Table 2). Subjective IKDC scores did not present any difference between the groups. Graft failure occurred at an incidence of 2.9% in the control group and 14.7% in the hyperextension group ($P = .005$). All patients evaluated with a graft failure were scheduled for revision surgery. The mean hyperextension for graft failure cases was 1.3° ± 1.5° for the control group and 9.3° ± 2.0° for the hyperextension group. There was no statistical difference in hyperextension between graft failures and nonfailures within each group ($P = .667$ for the control group and $P = .384$ for the hyperextension group). The Lysholm score was 89.6 ± 6.1 in the control group and 86.4 ± 9.8 in the hyperextension group ($P = .018$)

A significant difference was also found in the intra-articular graft size between the 2 groups, which was slightly larger in the hyperextension group (8.2 ± 0.8 mm vs 7.8 ± 0.7 mm; $P < .001$).

DISCUSSION

This study showed that patients with preoperative knee hyperextension greater than 5° have a higher failure rate after an ACL reconstruction performed with hamstring grafts than patients with less than 5° or no hyperextension. This finding is important as it suggests that this type of graft should be used with caution as a first choice for this specific population or should be associated with an extra-articular augmentation procedure if chosen for primary ACL reconstruction. The difference in graft failure was significant, with a study power of 85% that corroborates the results.

Patients with generalized ligamentous hyperlaxity based on the Beighton classification are known to have a higher failure rate after ACL reconstruction. Recent studies by Larson et al[16] and Helito et al[11] showed failure rates above 20%, while the average failure for the general population is around 6% according to a systematic review published by Wright et al.[33] Helito et al[11] found a failure rate of 21.7% in reconstructions with hamstring grafts, and Larson et al[16] found a failure rate of 25% for hamstring grafts and 21.1% for bone–patellar tendon–bone (BTB) grafts. Kim et al[14] also reported an IKDC index of C and D in patients with hyperlaxity for reconstruction with both hamstring grafts (36.4%) and BTB grafts (20%). In a systematic review, Sundemo et al[29] also showed that generalized hyperlaxity leads to worse functional results. Despite the results above, few studies have evaluated only cases of knee hyperextension, outside the context of generalized ligamentous laxity, and its significance as an isolated risk factor for ACL failure is still controversial. Saita et al[24] suggested that because of their greater preoperative anterolateral rotational instability, cases with hyperextension could also have a higher failure rate, but Nagai et al[22] found no increase in anterior translation or internal knee rotation in the postoperative period of ACL reconstruction in cases of hyperextension. In an editorial published in 2018, Owens[23] pointed that the current literature presented conflicting results regarding knee hyperextension.

Ettinger et al[7] performed a study on cadavers and showed that a single-bundle ACL reconstruction in patients with hyperextension did not interfere with the postoperative extension values, unlike the double-bundle reconstruction that decreased the knee extension. These data are important because they show that single-bundle reconstruction does not impair knee motion in these cases, possibly unlike the double-bundle reconstruction. However, the average hyperextension studied by these authors was 4° to 5° for all groups, with no cases of greater hyperextension as in our study, in which the lower limit for the hyperextension group was 5°. As the study by Ettinger et al was carried out on cadavers, it was not possible to assess the clinical effect of this possible constriction. On the other hand, Saito et al[26] clinically evaluated patients with hyperextension of more or less than 10° submitted to double-bundle reconstruction with hamstring grafts and found greater loss of extension and greater partial laceration of the graft in patients with more than 10° of preoperative hyperextension. However, these authors did not find significant differences in the functional scores between the groups, showing that reconstruction with the double-bundle graft in these patients did not generate worse functional outcomes.

In a multicenter study, Ueki et al[31] concluded that hyperextension greater than 10° was related to the presence of residual pivot shift 12 months after the ACL reconstruction; despite having a short follow-up and a diversity of techniques, most of them were performed with double-bundle graft. These authors found only hyperextension and preoperative pivot shift as risk factors for postoperative rotational residual instability and suggest that in these situations, an eventual extra-articular surgical procedure associated with the ACL should be performed to obtain better functional results. The MARS Group also showed that hyperextension greater than 5° was considered an independent risk factor for failure in cases of revision ACL reconstruction.[21] On the other hand, Benner et al[2] concluded that there were no functional differences and failure rates in patients with knee hyperextension in a comparative study using only BTB grafts. These authors evaluated a group of patients with more than 6° of hypertension and another group with less than 3°, leaving patients with 4° and 5° out of the analysis.

In our study, we used the cutoff value of 5° for hyperextension based on the MARS Group study, since there is no precise definition in the current literature as to which degree of hyperextension can be considered as a risk factor for ACL reconstruction failure. Although some studies use 10° based on the Beighton classification—even though this classification value has been questioned recently[18]—cutoff values of 5° or 6° can also be found in the literature. According to our findings, hyperextension did not worsen the clinical anterior instability measured by KT-1000 or anterolateral instability measured by pivot-shift test, but it was an important risk factor for failure. If we consider that the diameter of the graft was 0.4 mm thicker in the hyperextension group and that, despite some controversy, as pointed by Wernecke et al,[32] graft diameters can be a potential risk factor for graft failure, it is possible that the difference in favor of the control group is even greater.[4,17] The Lysholm functional scale also showed a difference of 3.2 in favor of the control group, which, despite being statistically significant, tends to not be clinically significant since the minimum significance value for this scale is 8.9 points.[9]

Considering our findings, which showed a 5 times higher failure rate in the hyperextension group, we believe that the hamstring graft should not be used in primary ACL reconstructions in patients with knee hyperextension greater than 5°. Owens[23] previously pointed out that “it is possible that graft choice may have an influence on the finding of increased laxity after ACL reconstruction in patients with hyperextension,” mainly based on the results of Kim et al[14] showing more pronounced laxity in patients undergoing hamstring graft reconstructions compared with BTB grafts. The current study presents more evidence to support this scenario. Although the hamstrings are the most used graft for ACL reconstructions worldwide, in these situations, we recommend the use of another option. Benner et al[2] showed satisfactory results using BTB grafts for a similar population, but there is still no established gold-standard graft for these situations. The addition of an anterolateral extra-articular augmentation may also be an alternative if the use of hamstring graft is chosen or mandatory for any reason.[1,25] Helito et al[11] showed that anterolateral ligament reconstruction in patients with ligamentous hyperlaxity reduced the failure rate from 21.7% to 3.3%. Both ALL reconstruction and iliotibial tract tenodesis could be used in this situation since both have good functional results and a low rate of complications according to recent studies.[8,12] Also, the rehabilitation program might have a role in this higher failure rate in the hyperextension population. It is possible that a program in which full extension is restricted with a knee brace in order to try to achieve less than 5° of hyperextension in the postoperative period could improve the results. However, so far, there are no data to fully support this.

The present study has some limitations. The sample was retrospectively analyzed; there was only a small difference in follow-up between the groups, although we believe that 3 months in the context of around 3 years is not clinically relevant; there was a difference in graft diameter between the groups, although the difference tended to favor the group with hyperextension, which had the worst results; use of the Tegner activity scale was absent in the analysis; and the 5° cutoff value used between groups was arbitrary, as there is no clear cutoff in the literature for this specific evaluation. Studies decreasing the cutoff value of knee hyperextension should now be carried out to assess whether any hyperextension can generate an increase in graft failures when using hamstring grafts or if there is a magic number that can be considered safe. Also, because we did not use the full Beighton score, it could be that the hyperextension numbers found were just a surrogate for Beighton scores greater than 6.

CONCLUSION

The study results indicated that patients with more than 5° of knee hyperextension treated with a single-bundle ACL reconstruction with hamstring grafts have a higher failure rate than patients with less than 5° of knee hyperextension.

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