Twenty-year follow-up study comparing operative versus non-operative treatment of anterior cruciate ligament ruptures in high-level athletes

Abstract

Background: An anterior cruciate ligament (ACL) rupture has major consequences on the midterm follow-up, with increasing chance of developing an old knee in a young patient. The long-term (over 20 years or more) effects and treatment of operative and non-operative treatment of anterior cruciate ligament ruptures are still unclear.

Purpose: To compare the long-term treatment outcomes of operative versus non-operative treatment of ACL ruptures in high-level athletes.

Study design: Retrospective pair-matched cohort study

Methods: Fifty patients with an ACL rupture were eligible for participation and they were treated either non-operatively (n=25) in 1992, consisting of structured rehabilitation and lifestyle adjustments or operatively (n=25) between 1994-1996 with an arthroscopic transtibial bone-patellar-tendon-bone technique.

Both groups were pair-matched and assessed at 10 and 20-year follow-up, regarding radiological knee osteoarthritis, functional outcomes (Lysholm, IKDC, Tegner, KOOS), meniscal status and knee stability (KT-1000, pivot shift, Lachman, one-leg-hop-test).

Results: All 50 patients (100%) were included in our current study for follow-up. After 20-years we found knee osteoarthritis in 80% of the operative group compared to 68% of the non-operative group ($p = 0.508$). There was no difference between both groups regarding functional outcomes and meniscectomies performed.

The median performance on the IKDC subjective was 81.6 (IQR 59.8 – 89.1) for the operative group and 78.2 (IQR 61.5 – 92.0) for the non-operative group ($p = 0.679$). Regarding the IKDC objective score, 21 patients (84%) in the operative group had a normal score (IKDC A&B) compared to 5 patients (20%) in the non-operative group ($p <0.001$). The pivot shift was negative in 17 patients (68%) versus 3 patients (13%)

for respectively the operative and non-operative group (p = <0.001) and the Lachman test was negative in 12 patients (48%) versus 1 patient (4%) (p = 0.002) in the non-operative group.

Conclusion: In this retrospective pair-matched follow-up study we found that after 20-years follow-up there is no difference in knee osteoarthritis between operative or non-operative treatment. Although knee stability was better in the operative group, it did not result in better subjective and objective functional outcomes.

Key terms: Anterior cruciate ligament, rupture, operative, non-operative, treatment, osteoarthritis.

What is known about the subject: Anterior cruciate ligament ruptures are associated with an increased risk of knee osteoarthritis and have a major impact on the knee function of the affected patient. It is widely accepted to treat anterior cruciate ligament ruptures either operatively or non-operatively, both with predictable outcomes after short and mid-term follow-up. Long-term outcomes comparing operative and non-operative treatment strategies are scarce in particular for high-level athletes.

What this study adds to existing knowledge: This study compares operative versus non-operative treatment outcomes of anterior cruciate ligament ruptures after 20-years follow-up. It is a unique pair-matched study performed in a specific cohort of high-level athletes.

Introduction

An anterior cruciate ligament (ACL) rupture is a common injury among athletes. It is associated with functional impairment, meniscal damage, chondral joint lesions, tibiofemoral instability and eventually knee osteoarthritis (OA).[22] Globally there are two kinds of therapy available, operative and non-operative therapy. The aim of both treatment strategies is to restore functional stability of the knee and to avoid the development of OA. However, most patients with a ruptured ACL develop OA irrespective of therapy.[1, 22] The prevalence of knee OA after an isolated ACL rupture is about 0% to 13% with a follow-up of 10 years. This number increases to 21-48% when the rupture is combined with meniscal damage.[33]

Which therapy is advocated as the best treatment in the long-term for ACL ruptures is still being debated.[29] A widely accepted strategy is suggesting a reconstruction for young and active patients with a high demand of their ACL, and non-operative therapy for less active patients.

A randomized-controlled trial by Frobell et al[11, 12] presented 2 and 5 year follow-up results of (delayed) operative versus non-operative treatment. They showed that 51% of the initially non-operatively treated patients underwent a delayed reconstruction within 5 years. They found no statistically significant differences between the operative group, done early or delayed, and the non-operative group, regarding the presence of radiological OA, patient reported outcomes and the amount of meniscus surgery. Therefore, they encourage physicians and patients to consider rehabilitation as a primary treatment for ACL ruptures. In the long-term, comparative studies with a follow-up of 10 years agree with the results presented by

Frobell et al.[10, 18, 26, 27, 39] Although Fink et al.[10] found higher involvement in sports after ACL reconstruction and Meunier et al.[27] found less secondary meniscectomies performed in the reconstructed group without significant difference in knee OA, there is no overwhelming evidence to state what treatment is superior for ACL ruptures.[8, 38]

Comparative studies with a follow-up of 20 years or more are scarce. Only one article presented outcomes after 17-20 years showing a significantly higher rate of radiological OA in the non-operative group.[28]

Based on the current state of knowledge there is still no consensus on what is most optimal for the treatment of ACL ruptures. There is a lack of knowledge concerning long-term follow-up outcomes and a lack in studies performed among high demanding patients, whom are considered to have a greater risk of failure with non-operative treatment, and therefore, could have a higher incidence of OA.

This current study was performed, as a sequel to our 10-year follow-up study, to gain more understanding about the long-term effects of operative versus non-operative treatment of ACL ruptures.[26]

Our study aim was to present the long-term outcomes of high-level athletes with an ACL rupture treated either operatively or non-operatively with regards to the presence of OA, patient's activity level, functional outcomes, the amount of meniscectomies performed and knee stability. We also investigated the presence of generalized OA, to determine whether this is of influence on the development of knee OA. We hypothesized that generalized OA could also express itself as OA in the knee and in that way have an effect on the development of OA within the injured knee.

We compared two pair-matched groups of high-level athletes treated for their ACL rupture either operatively with a bone-patellar-tendon-bone (BPTB) technique or non-operatively by following a physiotherapist led exercise program for a minimum duration of 3 months.

Methods

Participants

This pair-matched study presents the 20-year follow-up outcomes of patients with an ACL rupture treated operatively or non-operatively. All patients whom participated in our 10-year follow-up study were eligible for inclusion. All were high-level athletes with a median pre-injury Tegner score of 9 (interquartile range 7 to 9) and a ruptured ACL.

Both patient groups first followed an exercise program led by a physiotherapist for 3 months. When symptomatic knee instability, consisting of persistent giving way complaints as a result of an ACL injury, was not reduced by then, they were offered an ACL reconstruction or a pivoting and cutting free lifestyle.

Patients from the operative group underwent an ACL reconstruction between 1994 and 1996, and were reviewed at our outpatient clinic in 2006. The non-operative group had their ACL rupture diagnosed in 1992 either arthroscopically or by MRI and were reviewed in 2002.

The patients who chose non-operative treatment were retrospectively pair-matched with the operatively treated patients, with respect to age, gender and Tegner activity score before the initial injury.

At the time of 10-year follow-up, in total 50 patients could be pair-matched.

All subjects had sufficient knowledge of the Dutch language to understand the purpose of this study and to fill in the questionnaires (Tegner, Lysholm, IKDC and KOOS). None of the patients had had any other intra- or extra-articular knee

ligament reconstruction in the past and in case of a doubtful or partial rupture, the patient was not included.

Between April and September 2014 all 50 patients eligible for this study were invited to our outpatient clinic for reassessment. Written informed consent was obtained from all included patients and the study was approved by the institutions' Medical Ethics Committee.

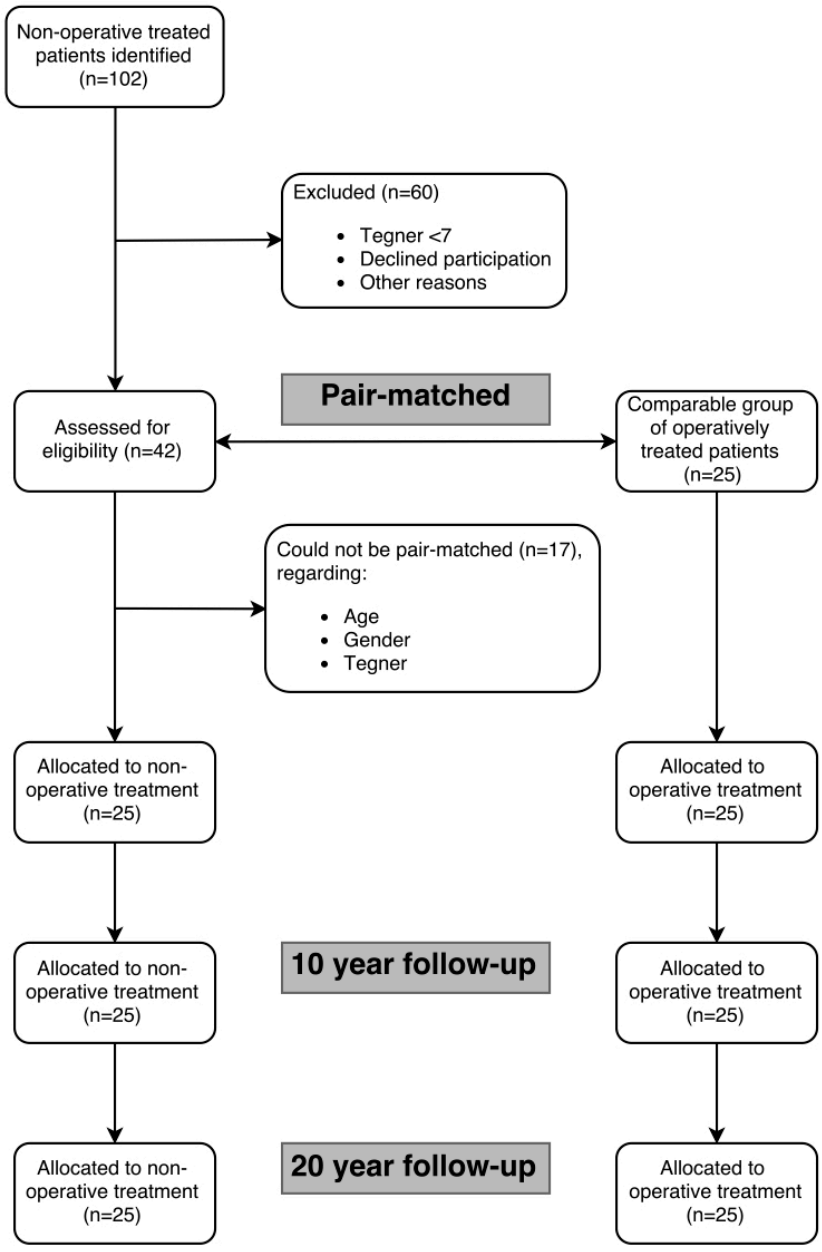

Figure 1 Patient selection procedure

Treatment

Two surgeons performed the ACL reconstruction, using a single incision, transtibial middle one-third bone-patellar-tendon-bone technique (BPTD). Tunnel placement was aided by Acufex tibial and femoral aimers. Tibial tunnel placement was 7 mm anterior of the posterior cruciate ligament. Femoral tunnel placement was at an eleven o'clock position for the right knee and at one o'clock for the left knee. Metal interference screws were used for the tibial and femoral bone block fixation. After surgery patients were allowed protective weight bearing for the first 4 weeks, after which rehabilitation was intensified. Sports return was allowed no sooner than 6 months post-operative. On average the reconstruction was performed 6 months (range 2 to 258 months) after the initial injury. One patient underwent a ACL reconstruction within 3 months after the initial trauma.

Patients who were treated non-operatively were advised to follow a physiotherapist led exercise program for a minimum duration of 3 months.

Measurements

Physical examination and radiological assessment was performed by the same orthopedic surgeon (DM) as in the previous study. The observer was not blinded for treatment.

Radiological knee osteoarthritis

Radiological examination of both knees was performed using weight-bearing anterior-posterior and Rosenberg-view images.[37] The Kellgren & Lawrence (K&L) classification was used for staging OA.[17] A K&L score equal or greater than two on

the anterior-posterior images was considered as radiological OA. The images were scored by two experienced and qualified readers (DM & MR).

Generalized osteoarthritis

To investigate the rate of generalized OA, anterior-posterior images were taken of both hands to determine the rate of hand OA. These images were assessed separately for degenerative changes in 3 groups of hand joints (5 distal interphalangeal (DIP) joints, 4 proximal interphalangeal (PIP) joints and the first carpometacarpal (CMC1) joint or the trapezioscaphoid (TS) joint).
Radiological OA was present when one or more joints of a group, is affected by OA, with OA defined as a K&L score equal or greater than 2. Hand OA was defined as the presence of radiological OA in at least 2 out of 3 groups of hand joints (DIP, PIP and CMC1/TS).[4]
We defined generalized OA as the presence of OA in the affected knee as well as in the unaffected knee, in combination with hand OA in at least one hand.[30]

Functional outcome

Subjective functional outcomes were assessed using the Lysholm score[23], the International Knee Documentation Committee (IKDC) subjective form[14, 16] and the Knee injury and Osteoarthritis Outcome Score (KOOS).[7, 36, 43] All grading systems range from 0-100, in which 100 equals a perfectly functional knee. To assess the patient's activity level the Tegner activity scale was used. This scale has a range from 0-10, in which 10 is the highest activity score, for instance a professional soccer

player.[40] Functional stability was measured with the one-leg-hop-test (OLHT), reflecting a quotient between the injured and non-injured knee.[32]

Meniscectomy

Medial, lateral or combined meniscectomies during the 20-year follow-up period were reported based on patient's information and surgery reports.

Knee stability

Clinical outcome was assessed with the International Knee Documentation Committee (IKDC) objective form, range A to D.[15] IKDC scores A-B were considered as having a normal knee and C-D as abnormal.

Knee laxity was tested using the KT-1000 arthrometer, the pivot shift and Lachman test.[2, 6, 25] The KT-1000 arthrometer manually measured the tibiofemoral anterior-posterior translation in both knees. Side-to-side laxity at maximal load was measured and a maximum difference of >3 mm was used to define an instable ACL. The pivot shift and Lachman test were graded 0 to 3+. A score ≥1+ for both tests was defined as an instable ACL.[21]

Statistical analysis

Patients were analyzed within the same treatment group (operative or non-operative) as to the 10-year follow-up analysis. Data was tested for normal distribution using the Shapiro-Wilk test. We presented the mean and standard deviation for normally distributed variables and the median and interquartile range (IQR) for not normally distributed variables. To compare the rate of OA between

both groups we used the McNemar's test. Differences in clinical outcomes between and within groups were analyzed with the paired t-test and the Wilcoxon signed rank test. A p-value of <0.05 was regarded as significant. The statistical evaluation was performed using SPSS 21.0 for Windows.

We used multiple imputation for missing data by creating 5 new data sets and using the pooled variable for further analysis.

To investigate the inter-observer reliability of the scoring of knee and hand radiographs we performed a Kappa analysis. An inter-observer similarity of 0.60 was set as an acceptable agreement rate.[20]

Results

Patient characteristics

All 50 patients (100%) of our previous study, of whom 25 had been assigned to the operative group and 25 to the non-operative group, were included in this 20-year follow-up study. From the non-operative group 2 patients did not participate in all functional testing due to kinesiophobia or pain at 20-year follow-up consultation. Between 10 and 20-year follow-up one patient from the non-operative group underwent a delayed ACL reconstruction. Four patients from the operative group had a graft rupture of which two underwent revision ACL surgery. One patient from the operative group underwent a total knee arthroplasty (TKA), which was radiographically scored as end stage knee OA. The patient characteristics are reported in table 1.

Table 1 Patient characteristics

	Operative		Non-operative		p-value	
	10 year	**20 year**	**10 year**	**20 year**	**10 year**	**20 year**
Gender (men/women)	19/6	19/6	19/6	19/6	1.000	1.000
Age (years)	37.6 (6.1)	45.8 (6.4)	37.8 (6.8)	49.3 (6.8)	0.808	0.042
BMI (kg/m^2)	25.8 (2.8)	26.3 (3.4)	25.0 (2.5)	25.8 (2.5)	0.443	0.598
Follow-up (years)	10.3 (9.7 – 11.4)	21.2 (20.0 – 22.8)	12.0 (11.0 – 13.0)	24.1 (22.6 – 27.0)	0.007	0.006

Age and BMI are presented as mean and standard deviation, follow-up is presented as median and interquartile range

Radiological knee osteoarthritis

We found no statistical significant difference regarding knee OA between both groups (p value of 0.508). Twenty patients (80%) from the operative group had knee OA, compared to 17 patients (68%) from the non-operative group (table 2).
In the operative group we found contralateral knee OA in 4 patients (16%) compared to 2 patients (8%) in the non-operative group.

Assessment of the anterior-posterior knee radiographs showed a Kappa value of 0.58 for the dichotomous outcomes. Therefore, only the scores of the same experienced orthopaedic surgeon as in our 10-year study were used for analysis.

Table 2 Radiological assessment

	Operative, number (%)		Non-operative, number (%)	
Kellgren & Lawrence	10 year	20 year	10 year	20 year
0	4 (16)	1 (4)	8 (32)	3 (12)
1	9 (36)	4 (16)	10 (40)	5 (20)
2	9 (36)	16 (64)	4 (16)	12 (48)
3	3 (12)	3 (12)	3 (12)	4 (16)
4	0 (0)	0 (0)	0 (0)	1 (4)
TKA	0 (0)	1 (4)	0 (0)	0 (0)

TKA = Total Knee Arthroplasty

Generalized osteoarthritis

An equal amount of 2 patients (8%) in both groups presented with generalized OA at 20-year follow-up. Of all patients without hand OA, 2 patients (8%) from the operative group had radiological OA in both knees.

Functional outcome

At follow-up the median Lysholm score was 86.0 (IQR 75.5 – 91.0) and 89.0 (IQR 75.5 – 95.5) for respectively the operative and non-operative group. The median performance on the IKDC subjective was 81.6 (IQR 59.8 – 89.1) for the operative group and 78.2 (IQR 61.5 – 92.0) for the non-operative group.

Directly post-operative, the operative group had a median Tegner score of 8 (3-10), which was not significant compared to the median Tegner of 7 (4-10) in the non-operative group post-injury. At follow-up the operative group scored a median Tegner of 5 (IQR 0 – 9) versus 4 (IQR 1 – 8) scored by the non-operative group. We found no significant differences in functional outcomes as shown in table 3. The

mean change between 10 and 20-year follow-up in Lysholm score and IKDC subjective was not significant for both groups.

The KOOS questionnaire was performed only at 20-year follow-up and was not significantly different between both groups at follow-up.

Table 3 Functional outcome

	Operative		Non-operative		p-value	
	10 year	**20 year**	**10 year**	**20 year**	**10 year**	**20 year**
Lysholm	88.0 (80.5 – 91.0)	86.0 (75.5 – 91.0)	85.0 (77.0 – 90.0)	89.0 (75.5 – 95.5)	0.442	0.851
IKDC subjective	77.1 (65.1 – 87.3)	81.6 (59.8 – 89.1)	77.1 (67.5 – 84.9)	78.2 (61.5 – 92.0)	0.683	0.679

	Baseline	**10 year**	**20 year**	**Baseline**	**10 year**	**20 year**	**10 year**	**20 year**
Tegner	9 (7 – 9)	6 (4 – 7)	5 (3 – 6)	9 (7 – 9)	5 (4 – 7)	4 (4 – 6)	0.191	0.331

	Operative	**Non-operative**	
	20 year	**20 year**	
KOOS subscales			
- Pain	91.7 (70.8 – 100)	97.2 (80.6 – 100)	0.487
- Symptoms	85.7 (67.9 – 96.4)	92.9 (80.4 – 100)	0.156
- ADL	95.6 (78.7 – 100)	98.5 (88.2 – 100)	0.276
- Sports	85.0 (35 – 95.0)	85.0 (52.5 – 100)	0.330
- QoL	62.5 (50.0 – 81.3)	68.8 (46.9 – 78.1)	0.948

Results are presented as median and interquartile range between parentheses
ADL = Activities of daily living
QoL = Quality of life

Meniscal status

At follow-up in total 18 patients (72%) from the operative group had a meniscectomy performed within their injured knee. Eight patients (32%) had a meniscectomy performed before trauma and 6 patients (24%) had this procedure performed during the ACL reconstruction. Within the first 10 years after treatment another 3 patients (12%) had to undergo a meniscectomy and within the second 10-years follow-up 1 other patient (4%) underwent a meniscectomy.

In the operative group 15 patients (60%) had a medial, 6 patients (24%) a lateral and 3 patients (12%) a combined meniscectomy performed. Of all patients with a meniscectomy and an ACL reconstruction, 17 (94%) developed knee OA.

In the non-operative group, a total of 19 (76%) patients underwent a meniscectomy after 20 years. Before inclusion 9 patients (36%) already had a meniscectomy performed. Another 10 patients (40%) after the first 10 years of treatment and none within the second 10-years follow-up.

In the non-operative group we saw 17 patients (68%) with a medial, 7 patients (28%) with a lateral and 4 (16%) patients with a combined meniscectomy performed.

Of the 19 patients with a meniscectomy 13 patients (68%) had knee OA at 20-year follow-up.

Within the total 20 years of follow-up, an additional 4 meniscectomies were performed in the operative group compared to an additional 10 meniscectomies in the non-operative group. This was not significantly different with a p-value of 0.057.

Knee stability

The operative group scored significantly better than the non-operative group regarding clinical outcome, assessed with the IKDC objective score. The IKDC score for the operative group was: A: 7 patients (28%), B: 14 patients (56%), C: 3 patients (12%) and D: 1 patient (4%). For the non-operative group this was A: 0 patients, B: 5 patients (20%), C: 15 patients (60%) and D: 4 patients (16%). At follow-up, a total of 21 patients (84%) from the operative group had a normal IKDC score, versus 5 patients (20%) from the non-operative group, (p value <0.001). After 10-years follow-up, only 16 patients (64%) from the operative group and 5 patients (20%) from the non-operative group presented a normal IKDC score. Over time, 5 patients from the operative group recovered from an abnormal to a normal IKDC score, whereas the non-operative group remained equal.

The operative group achieved significantly better stability of the injured knee measured with the KT-1000 arthrometer, pivot shift and Lachman test (table 4). The OLHT was not significantly different between both groups, with a median score of 85.9% (IQR 68.1 – 101.9) for the operative group and 95.1% (IQR 70.8 – 104.7) for the non-operative group.

Table 4 Knee stability

	Operative		**Non-operative**		**p-value**	
	10 year	**20 year**	**10 year**	**20 year**	**10 year**	**20 year**
KT-1000, number (%) - side-to side difference > 3mm	6 (24)	10 (40)	17 (68)	19 (82.6)	0.002	0.013
Pivot shift, number (%)					< 0.001	< 0.001
- 0	20 (80)	17 (68)	4 (16)	3 (13)		
- ≥1+	5 (20)	8 (32)	21 (84)	20 (87)		
Lachman, number (%)					-	0.002
- 0	11 (44)	12 (48)	0 (0)	1 (4)		
- ≥1+	14 (56)	13 (52)	25 (100)	23 (96)		
OLHT; % Injured/non-injured side	93.7 (80.0 – 100.7)	85.9 (68.1 – 101.9)	96.1 (84.2 – 100.9)	95.1 (70.8 – 104.7)	0.522	0.449

OLHT = One leg hop test, presented as median and interquartile range
In the non-operative group we tested:
- *10-year follow-up; 96% for the OLHT*
- *20-year follow-up; 92% for the KT-1000, Pivot shift, OLHT and 96% for the Lachman*

Discussion

The aim of this study was to gain more insight into the long-term effects of an ACL rupture in patients with a high activity level. To ensure this aim we compared two pair-matched groups of high-level athletes treated for their ACL rupture, either operatively with a bone-patellar-tendon-bone technique or non-operatively by following a physiotherapist by following a physiotherapist led strengthening program for a minimum duration of 3 months including lifestyle adjustments. At approximately 20 years after an ACL rupture we found no significant difference between operative and non-operative treated patients regarding the rate of OA, presence of meniscectomy and functional outcome. Only objectively measured knee stability was significantly better in the operatively treated patients.

Comparison with other studies

In our cohort, 80% of the operatively treated patients showed radiological knee OA. These results are comparable to a 12 and 20-year follow-up study, showing respectively 74% and 61% knee OA after ACL reconstruction.[34, 41] In the non-operative group we found 68% knee OA, which is considerably higher than the 16% Neuman et al found, 15 years after non-operative therapy.[31] Our results showed no great deviation from our previous 10-year follow-up study[26] which has also been demonstrated by several other studies comparing operative and non-operative therapy.[12, 18, 39] A meta-analysis published by Ajuied et al.[1] presented a significantly higher relative risk (RR) for the development of knee OA in the non-operative group (RR 4.98) compared to the operative group (RR 3.62). However, they found a

significantly higher relative risk in the operative group for the development of more severe OA.

When comparing our results to our 10-year follow-up study, we noticed an increased rate of knee OA in both groups. The operative group went from 48% to 80% and the non-operative group from 28% to 68%. Concerning the contralateral knees, this group showed progression of knee OA from 4% to 12%, regardless of treatment strategy, which is normal for the Dutch population.[44] These numbers show us that no matter what therapy is used, a knee that suffers an ACL injury is more at risk of developing knee OA on the long-term compared to a normal healthy knee.

Scoring of radiological images remains difficult and can vary between observers. This is shown by the kappa value of 0.58 we found when two qualified readers scored the images. Therefore, we used the results of the one reader (DM) whom also scored the 10-year follow-up images.

The effect of generalized OA on the proportion of knee OA was assessed by analyzing both hands on the presence of radiological OA. There is no widely accepted definition for generalized OA and the definition we used for our study is based on consensus within our institution. Several studies showed a relationship between the presence of hand OA and a higher rate of knee OA.[5, 9, 13] We found generalized OA in only 8% of the patients in each group and in our study this had no effect on the rate of knee OA. Our data suggest that hand OA did not influence the onset of knee OA in patients with an ACL rupture.

Twenty years after an ACL rupture the operatively treated patients showed a 72% rate of meniscectomies performed which was not significantly different compared to the 76% among the patients that underwent a non-operative treatment. A randomized controlled trial reported 48% and 67% meniscectomies performed after 15-year follow-up for respectively the operative and non-operative group.[27] This is a considerably lower rate compared to our cohort, particularly compared to the operative group. A possible explanation could be that our cohort had a higher average age at baseline and a higher activity level during follow-up.

Some other studies have reported a protective function of ACL reconstruction on the development of further meniscal lesions.[3, 33] Our results did not support such effect. We found no significant difference between both groups in meniscectomies performed in the past 20 years.

The relationship between knee OA and meniscal tears have been widely described by several studies. Meniscal tears or meniscectomies are associated with an increased risk on the development of knee OA.[22, 24, 42] This is supported by our study results, namely we found 81% knee OA in patients with a meniscectomy performed, and 54% in those without.

Twenty years after treatment we found no significant difference between the operative and non-operative group regarding functional outcomes (Lysholm, IKDC subjective, OLHT, Tegner and KOOS). This is comparable to what other studies found.[12, 19, 27, 35, 39] As expected, the non-operative group had significantly less stable knees, expressed by a positive pivot shift in over 90% of the patients. However, that

did not result in worse functional outcomes, nor did the increased instability result in more comorbidity like knee OA and meniscal damage.

On the IKDC objective score, it was surprisingly to see that over time, 5 patients recovered from an abnormal (C-D) to a normal (A-B) IKDC score. A possible explanation could be that to the progressing OA, the osteophyte formation and capsular thickening, reduced the laxity expressed during physical examination. Even though the physical examination was performed by the same experienced examiner, there might be an intra-observer variance, or the patients experienced more muscular resistance decreasing the objective laxity measurements.

Limitations

A limitation of this study is that our follow-up period is based on the first presentation in our outpatient clinic which means there is a large range of time between trauma and initial treatment. Thus making both groups more heterogeneous concerning this aspect. However, making it more comparable with current clinical practice.

Due to the 20-year follow-up technique progress and innovation occurs, which means that the transtibial technique used 20 years ago is more outdated and replaced with a more anatomical femoral placement. But the use of arthroscopic technique and the BPTB autograft is still a widely accepted procedure. Only time will tell whether our innovation is an actual improvement to reduce the rate of knee OA.

Because we compared both groups without a randomization procedure and due to the retrospective design of this study, there is a risk for allocation bias.

Allocation to treatment was based on a combination of the desire of the patient and the preferences of the surgeon. To adjust for this bias and in order to obtain two comparable groups, we pair-matched the operatively and non-operatively treated patients.

Main strength of this study is that it is one of the few to present results with a follow-up of more than 20-years and 100% response after our previous 10-year follow-up, within a specific population of high-level athletes.

Conclusion

This 20-year follow-up study of high level athletes showed no significant differences between operative and non-operative treatment of ACL ruptures, regarding presence of knee OA, functional outcomes and occurrence of meniscectomies. The non-operative group showed decreased knee stability compared to the operative group but this did not result in reduced functional outcomes or comorbidity. Even within high-level athletes there is no clear evidence to state that reconstruction of the ACL is superior to non-operative treatment. Therefore, also for the long-term, non-operative treatment is a suitable therapy for ACL ruptures.

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Table 1 Patient characteristics

	Operative		Non-operative		p-value	
	10 year	**20 year**	**10 year**	**20 year**	**10 year**	**20 year**
Gender (men/women)	19/6	19/6	19/6	19/6	1.000	1.000
Age (years)	37.6 (6.1)	45.8 (6.4)	37.8 (6.8)	49.3 (6.8)	0.808	0.042
BMI (kg/m^2)	25.8 (2.8)	26.3 (3.4)	25.0 (2.5)	25.8 (2.5)	0.443	0.598
Follow-up (years)	10.3 (9.7 – 11.4)	21.2 (20.0 – 22.8)	12.0 (11.0 – 13.0)	24.1 (22.6 – 27.0)	0.007	0.006

Age and BMI are presented as mean and standard deviation, follow-up is presented as median and interquartile range

Table 2 Radiological assessment

	Operative, number (%)		Non-operative, number (%)	
Kellgren & Lawrence	**10 year**	**20 year**	**10 year**	**20 year**
0	4 (16)	1 (4)	8 (32)	3 (12)
1	9 (36)	4 (16)	10 (40)	5 (20)
2	9 (36)	16 (64)	4 (16)	12 (48)
3	3 (12)	3 (12)	3 (12)	4 (16)
4	0 (0)	0 (0)	0 (0)	1 (4)
TKA	0 (0)	1 (4)	0 (0)	0 (0)

TKA = Total Knee Arthroplasty

Table 3 Functional outcome

	Operative		Non-operative		p-value	
	10 year	**20 year**	**10 year**	**20 year**	**10 year**	**20 year**
Lysholm	88.0 (80.5 – 91.0)	86.0 (75.5 – 91.0)	85.0 (77.0 – 90.0)	89.0 (75.5 – 95.5)	0.442	0.851
IKDC subjective	77.1 (65.1 – 87.3)	81.6 (59.8 – 89.1)	77.1 (67.5 – 84.9)	78.2 (61.5 – 92.0)	0.683	0.679

	Baseline	**10 year**	**20 year**	**Baseline**	**10 year**	**20 year**	**10 year**	**20 year**
Tegner	9 (7 – 9)	6 (4 – 7)	5 (3 – 6)	9 (7 – 9)	5 (4 – 7)	4 (4 – 6)	0.191	0.331

	Operative	**Non-operative**	
	20 year	**20 year**	
KOOS subscales			
Pain	91.7 (70.8 – 100)	97.2 (80.6 – 100)	0.487
Symptoms	85.7 (67.9 – 96.4)	92.9 (80.4 – 100)	0.156
ADL	95.6 (78.7 – 100)	98.5 (88.2 – 100)	0.276
Sports	85.0 (35 – 95.0)	85.0 (52.5 – 100)	0.330
QoL	62.5 (50.0 – 81.3)	68.8 (46.9 – 78.1)	0.948

Results are presented as median and interquartile range between parentheses
ADL = Activities of daily living
QoL = Quality of life

Table 4 Knee stability

	Operative		Non-operative		p-value	
	10 year	**20 year**	**10 year**	**20 year**	**10 year**	**20 year**
KT-1000, number (%)						
- side-to side difference > 3mm	6 (24)	10 (40)	17 (68)	19 (82.6)	0.002	0.013
Pivot shift, number (%)						
- 0	20 (80)	17 (68)	4 (16)	3 (13)	< 0.001	< 0.001
- ≥1+	5 (20)	8 (32)	21 (84)	20 (87)		
Lachman, number (%)						
- 0	11 (44)	12 (48)	0 (0)	1 (4)	-	0.002
- ≥1+	14 (56)	13 (52)	25 (100)	23 (96)		
OLHT; % Injured/non-injured side	93.7 (80.0 – 100.7)	85.9 (68.1 – 101.9)	96.1 (84.2 – 100.9)	95.1 (70.8 – 104.7)	0.522	0.449

OLHT = One leg hop test, presented as median and interquartile range
In the non-operative group we tested:
- *10-year follow-up; 96% for the OLHT*
- *20-year follow-up; 92% for the KT-1000, Pivot shift, OLHT and 96% for the Lachman*