Prevalence of Tibiofemoral Osteoarthritis 15 Years After Nonoperative Treatment of Anterior Cruciate Ligament Injury

A Prospective Cohort Study

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Background: The occurrence of osteoarthritis (OA), associated meniscal injuries, meniscectomy, and patient-related measures for patients treated nonoperatively after anterior cruciate ligament (ACL) injuries have not been well described in the literature in terms of natural history.

Hypothesis: Patients with ACL injury can achieve a low occurrence of tibiofemoral OA and good knee function when treated without ACL reconstruction.

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: One hundred consecutive patients with an acute, complete ACL injury were observed for 15 years. All patients were primarily treated with activity modification and without ACL reconstruction. To achieve improved functional stability, supervised physical therapy was initiated early after injury. The patients were examined using anteroposterior weightbearing radiography. The Knee injury and Osteoarthritis Outcome Score (KOOS) was used to quantify knee-related symptoms and knee function.

Results: Seventy-nine patients consented to radiographic examination and 93 completed the KOOS questionnaire. Thirteen patients (16%), all of whom were among the 35 patients whose knees were meniscectomized, developed radiographic tibiofemoral OA. In contrast, none of the remaining nonmeniscectomized and radiographed knees developed OA (n = 44) ($P < .0001$). Sixty-three patients (68%) had an asymptomatic knee. Twenty-two patients (23%) had undergone ACL reconstruction with a mean time of 4 years after injury.

Conclusion: The study had a favorable long-term outcome regarding incidence of radiographic knee OA, knee function and symptoms, and need for ACL reconstruction. Although risk factors for posttraumatic OA are multifactorial, the primary risk factor that stood out in this study was if a meniscectomy had been performed. Early activity modification and neuromuscular knee rehabilitation might also have been related to the low prevalence of radiographic knee OA. In patients with ACL injury willing to moderate activity level to avoid reinjury, initial treatment without ACL reconstruction should be considered.

Keywords: anterior cruciate ligament (ACL); osteoarthritis (OA); nonoperative treatment; long-term follow-up

Anterior cruciate ligament (ACL) injury due to sports activities with pivoting movements of the knee, such as soccer, basketball, floorball, team handball, and downhill skiing, is a growing problem with serious consequences for the patient and society. The yearly ACL injury incidence is estimated to be as high as 0.8 per 1000 inhabitants aged 10 to 64 years.[17] Anterior cruciate ligament deficiency is a well-recognized risk factor for developing knee osteoarthritis (OA).[19,47] Radiography has shown OA in >50% of ACL-deficient knees 5 to 15 years after injury.[7,8,14,23,26,28,29,41,44,46]

Anterior cruciate ligament injuries and deficiencies are commonly associated with meniscal and joint cartilage tears.[8,16,22,32] At injury, approximately 50% of ACL injuries are accompanied by meniscal tears,[8,13,16,22,32] whereas in

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TABLE 1
Characteristics of the Study Sample[a]

Characteristic	Index Injury (N = 100)	Follow-up (N = 93)
Age, mean (SD) years [range]	26 (8) [15-43]	42 (7) [30-60]
Women, n (%)	42 (42)	39 (42)
Body weight, mean (SD) kg	72 (14)	82 (17)
Body height, mean (SD) cm	176 (9)	176 (9)
Body mass index, mean (SD) kg/m^2	23 (3)	26 (4)
Occupational load, median	Light labor	Light labor
Tegner score, median (range)	7 (3-9)	4 (0-7)
Lysholm score, mean (SD)		85 (17)

[a]SD, standard deviation.

the chronic phase in an ACL-deficient knee, arthroscopy has shown meniscal tears in 80% of patients with symptoms.[13,22] Meniscectomy, whether partial or total, is also a well-recognized risk factor for knee OA.[9,11]

More than 100 000 ACL reconstructions are performed every year in the United States and some 4000 in Sweden (approximately 50% of ACL-injured patients in both countries) to decrease the risk of chronic instability and secondary meniscal tears.[3,14] However, no consensus has been established about specific criteria for ACL reconstruction or nonoperative treatment. The natural course of an unreconstructed ACL-injured knee has not been carefully studied, and ACL reconstructive surgery, in general, has not been shown to decrease the OA risk.[7,8,12,14,21,26,29,46] The average in-hospital charges for an ACL reconstruction in the United States in 2000 were $7000,[6] with an estimated total annual cost of $3 billion. However, the cost for subsequent posttraumatic knee OA is significantly greater.[20]

Our main hypothesis was that good knee function with a low frequency of knee OA could be achieved for most patients with ACL injury if they were treated with early neuromuscular rehabilitation and activity modification. The purpose of the study was to determine OA prevalence, associated meniscal injuries, and meniscectomies, as well as patient-relevant knee function and symptoms, in nonoperatively treated patients with ACL injury 15 years after the injury.

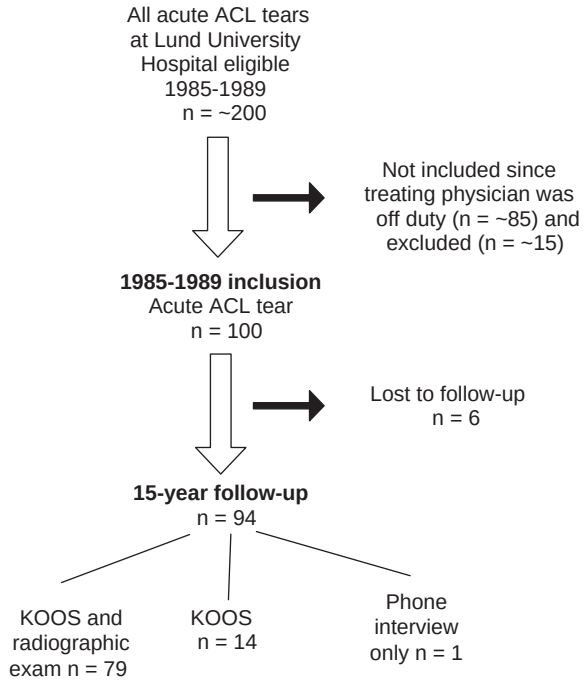

Figure 1. Flowchart detailing inclusion of patients and loss to follow-up. KOOS, Knee injury and Osteoarthritis Outcome Score; ACL, anterior cruciate ligament.

PATIENTS AND METHODS

Patients

One hundred patients with acute ACL injuries, out of 200 eligible, were recruited from the Department of Orthopedics, Lund University Hospital, between February 1985 and April 1989 for a randomized trial of supervised physiotherapy versus self-monitored training. Both short-term and long-term follow-up was planned for this cohort of subjects primarily treated without surgical reconstruction of the ACL (Table 1, Figure 1).

Patients 15 to 45 years of age, with an acute knee sprain combined with hemarthrosis and/or suspected instability at manual testing, were within 5 days consecutively referred from the emergency unit to the same orthopaedic surgeon (T.F.), who specializes in knee injuries. No referrals for recruitment occurred when this surgeon was off duty (these periods were not systematically the same every year). At the time of the study, there were no private or community-based alternative hospitals available, thus all referrals for acute knee injuries in the region were sent to the Orthopedic Emergency Department of Lund University Hospital.

The following criteria were used for exclusion (n = 15): participation in sports at a professional level and not willing to decrease the activity level (n = 5), an explicit wish to have a primary ACL reconstruction (n = 3), previous major injury to the lower extremities, a fracture on radiographs, or a psychosocial disorder (n = 7).

TABLE 2
Descriptions of Activity Causing Knee Injury and Knee Structures Injured at Baseline[a]

Characteristic	Men (n = 58)	Women (n = 42)	Total (N = 100)
Activity			
Soccer	29	6	35
Downhill skiing	9	21	30
Team handball	6	9	15
Other activities	14	6	20
Injured knee structures[b]			
ACL (no other associated injury)	9	5	14
+ MCL	12	10	22
+ Medial meniscal tear	4	4	8
+ Lateral meniscal tear	11	5	16
+ Medial and lateral meniscal tear	3	2	5
+ MCL + medial meniscal tear	4	3	7
+ MCL + lateral meniscal tear	6	5	11
+ MCL + medial and lateral meniscal tear	5	2	7
+ TF chondral tear	0	1	1
+ TF chondral tear + MCL	0	3	3
+ TF chondral tear + lateral meniscal tear	2	0	2
+ TF chondral tear + MCL + lateral meniscal tear	2	2	4

[a]Reinjuries not included in these numbers. ACL, anterior cruciate ligament; MCL, medial collateral ligament (grades 1-3 not specified); TF, tibiofemoral.
[b]Numbers for meniscal tears include both minor and major tears.

Diagnosis at Arthroscopy

The verification of the diagnosis by arthroscopy within 10 days after injury showed that 14 of the patients had an isolated tear of the ACL. The remaining patients had additional meniscal injury, medial collateral ligament injury (grade 1-3), and/or chondral injury (Table 2). A meniscal tear was defined as minor if considered to heal by itself (partial or shorter full-thickness but stable tears in the red-red zone) or major if there was a full-thickness tear in the substance or a peripheral tear that required excision. Meniscal repair was not a standard procedure in Lund at the time of inclusion in this study.

Among the 60 patients with a coexisting meniscal tear, 25 had a major injury and thus had a partial meniscectomy performed. Thirty-five minor meniscal tears were left in situ. No patients had any signs of OA on arthroscopy or baseline radiographs. None of the associated medial collateral ligament injuries were treated surgically.

Rehabilitation and Physiotherapy

Nonoperative treatment was advocated and patients in doubt were actively encouraged and persuaded. Follow-up took place regularly (at 6 weeks, 3 months, 1 year, and 3 years) to ensure that the rehabilitation occurred without knee swelling or new "giving way" episodes.

Immediately after arthroscopy, patients were randomized to either neuromuscular training, supervised by a physical therapist specialized in training of knee-injured patients, or self-monitored training. The aim of both training methods was to regain joint mobility and improve neuromuscular function to obtain compensatory functional stability.[48] In neuromuscular function, we imply the complex interaction between sensory and motor pathways. Defective neuromuscular function leading to decreased strength and functional performance, alterations in movement and muscle activation patterns, proprioceptive deficiencies, and impaired postural control is commonly seen after an ACL injury,[1] and all these aspects were taken into account during the rehabilitation.

To obtain compensatory functional stability, the training was based on the closed kinetic chain principle, focusing on postural function of weightbearing muscles. At the 6-week follow-up, 49% of the patients in the self-monitored training group were referred to the neuromuscular supervised training group because of restricted joint mobility or considerable muscle atrophy.[48] As a result, the majority of the patients underwent neuromuscular supervised training, comprising two 1-hour sessions weekly for 5 to 8 months.

As the patients' compensatory functional stability gradually improved, they were allowed to increase their activity level. To lower the risk of secondary knee injuries, patients were strongly encouraged to avoid contact sports such as soccer and team handball. In case of >1 significant reinjury, unacceptable activity level from the patient's perspective with frequent "giving way," or a reinjury resulting in a symptomatic reparable meniscal tear (n = 6), a late ACL reconstruction was performed using a miniarthrotomy technique with a medial parapatellar incision and an isometrically placed ipsilateral bone–patellar tendon–bone graft.

Present Study and Review

All 100 patients were prospectively invited to participate in a 15-year posttrauma follow-up, including radiography, self-reported questionnaires, and clinical knee examination. The internal review board approved the study and written informed consent was obtained from all participants.

Radiography

Standing anteroposterior radiographs were obtained in standardized knee position with both knees in 20° of flexion and weightbearing using a General Electric Prestige II (GE Medical Systems, Milwaukee, Wisconsin) on a tilt table (film–focus distance, 1.5 m). A fluoroscopically positioned x-ray beam was used to optimize medial tibial plateau alignment. The radiographs were all independently read within a period of 2 days by 2 observers (P.N. and M.E.) blinded to clinical details. However, ACL-reconstructed knees could easily be detected by the graft fixation device. The presence of joint-space narrowing (JSN) and osteophytes was graded on frontal images on a 4-point scale (range 0-3; 0 = no evidence of JSN or bony change) according to the atlas from the Osteoarthritis Research Society International.[2] The interrater reliability (kappa statistic) was $\kappa = 0.78$ for JSN and $\kappa = 0.52$ for osteophytes. No discrepancy of >1 grade was observed. All discrepancies were reread and consensus was reached.

Radiographic tibiofemoral (TF) OA was considered present if any of the following criteria were fulfilled in any of the 2 TF compartments: JSN ≥ grade 2, sum of the 2 marginal osteophyte scores from the same compartment ≥2, or grade 1 JSN in combination with grade 1 osteophyte in the same compartment. This cutoff approximates grade 2 knee OA based on the Kellgren and Lawrence scale.[24]

Self-Reported Questionnaires

The Knee injury and Osteoarthritis Outcome Score (KOOS, Swedish version LK 1.09) is a 42-item self-administered, knee-specific questionnaire based on the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).[5] The KOOS comprises 5 subscales: pain, symptoms, activities of daily living (ADL), sports and recreation function (sport/rec), and knee-related quality of life (QOL). A score from 0 to 100 is calculated for each subscale, with 100 representing the best result. Patients were instructed to complete the KOOS form by considering their injured index knee. The instrument is suggested to be valid, reliable, and responsive in follow-up of ACL reconstruction and meniscectomy.[18,35,36]

A symptomatic knee was defined according to Englund et al[10] based on the patient's self-reporting from the KOOS questionnaire. Because no agreed-upon cutoff exists with regard to the definition of a symptomatic knee, they created a definition based on the patient's self-report from the KOOS questionnaire and consensus among the authors. This operational definition is aimed at identifying individuals symptomatic enough to possibly seek medical care. The score for the KOOS subscale QOL and 2 of the 4 additional subscales should be less than or equal to the score obtained as follows: at least 50% of the questions within the subscale were answered with at least a 1-step decrease from the best response (indicating no pain/best possible function, etc) on a 5-point Likert scale. After conversion to a 0 to 100 scale, the cutoffs were as follows: pain ≤86.1, symptoms ≤85.7, ADL ≤86.8, sport/rec ≤85.0, and QOL ≤87.5. A decrease in the subscale sport/rec was expected, because an avoidance of contact sports was prescribed in the treatment.

The Tegner score (range, 0-10) was used to assess the individual's physical activity level.[45] Grade 10 represents high-demanding knee activities such as professional soccer or American football and 0 represents sick leave or disability pension. Grade 4 represents noncompetitive activities like jogging, bicycling, and cross-country skiing.

The Lysholm knee score was also used to evaluate knee function.[27] In the Lysholm score, the highest obtainable score is 100. If the patient has impaired knee function with locking, instability, pain, swelling, limp, walking aid, or decreased ability to climb stairs and squat, the score is <100.

Statistical Analysis

P values for binary data in contingency tables were calculated with the Fisher exact test, and *P* values for continuous data by Mann-Whitney test or *t* test as appropriate. Any multivariate modeling of multiple risk factors was not suitable due to low incidence of radiographic knee OA and low sample size. All tests were 2-paired and $P \leq .05$ was considered statistically significant. The statistical analysis was performed with SPSS for Windows 14.0 software package (SPSS Science Inc, Chicago, Illinois).

RESULTS

Ninety-three patients completed the KOOS questionnaire; 84, the Lysholm score; 84, the Tegner score; and 79 consented to radiographic examination (Figure 1). The mean time (standard deviation) to follow-up was 15.7 (1.4) years. Patients who were lost to follow-up (n = 6) or did not consent to radiographic examination did not differ from the rest with regard to age, gender, baseline physical activity level, number of initial registered meniscal injuries, or mechanism of injury (Figure 1, Tables 1 and 2).

In the 25 patients who had a major meniscal tear rendering meniscectomy at the injury, 8 underwent another meniscectomy during follow-up. Among the 35 patients who sustained a minor meniscal tear left in situ at the index injury, a subsequent major meniscal tear rendering arthroscopic surgery occurred in 9 patients. Finally, in the 40 patients without any meniscal tear at injury, 12 underwent a meniscectomy during follow-up. This gives a total risk of a meniscectomy after initial treatment for the ACL injury of 31% (n = [8 + 9 + 12]/94). The cumulative number of meniscectomies were (25 + 9 + 12)/96, including 2 (of 6 patients lost to follow-up) whose knees were meniscectomized at the index ACL injury.

Anterior cruciate ligament reconstruction was performed on 22 (14 men) of the 94 included patients between

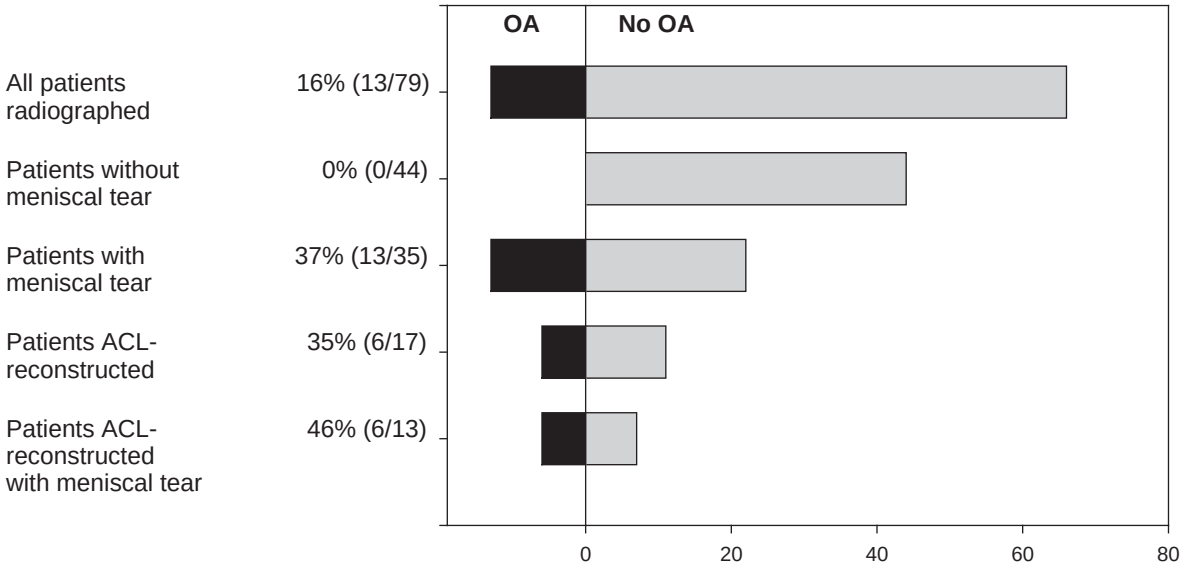

Figure 2. Prevalence of tibiofemoral osteoarthritis (OA) after anterior cruciate ligament (ACL) injury in different study subgroups. The cutoff value for defining radiographic tibiofemoral knee OA approximated Kellgren and Lawrence grade 2. A major meniscal tear was defined by a full-thickness tear in the substance or a peripheral tear that required excision or suturing. Only cases with cumulative major meniscal tears are represented in the figure.

6 months and 11 years after the injury (mean, 4 years) because of >1 significant reinjury, unacceptable activity level with frequent giving way, or a reinjury resulting in a symptomatic reparable meniscal tear (n = 6).

The mean Lysholm knee score at follow-up was higher in nonreconstructed patients than in ACL-reconstructed patients (86 and 82, respectively; $P = .049$).

At injury, 92 of 100 patients participated on a regular basis in activities like soccer, handball, tennis, and skiing (the 2 highest levels of activity in the International Knee Documentation Committee [IKDC] Subjective Knee Evaluation Form, levels 1 and 2), compared with 44 of 79 patients (56%) at follow-up ($P < .0001$). The median Tegner activity score in all patients decreased from 7 (range, 3-9) at index injury to 4 (range, 0-7) at 15-year follow-up (n = 84). Patients having reconstructive surgery had the same Tegner activity score at the initial index injury as patients not reconstructed. At 15-year follow-up, reconstructed patients had a tendency for a higher Tegner activity score, 4.5 compared with 3.7 for nonreconstructed ($P = .085$).

Radiographic OA

Radiographic TF OA was present in 13 of 79 knees (15%; 9 men) (Figure 2). Seven patients had medial, 3 had lateral, and the remaining 3 had OA in both compartments. The mean age of patients with and without TF OA was 45 and 41 years, respectively ($P = .09$). There were no significant differences in body mass index or Tegner activity score at 15-year follow-up between patients with or without TF OA. All 13 patients with TF OA underwent meniscectomy due to a major meniscal tear, regardless if this was performed at index (n = 5) or follow-up (n = 8). In contrast, none of the remaining radiographed patients with no known tear or with a minor meniscal tear developed TF OA (n = 44; $P < .0001$). The TF OA developed in the same compartment as the meniscal tear. In 2 of the 3 patients with both medial and lateral OA, only 1 compartment had a known major meniscal tear.

In the ACL-reconstructed patients, TF OA was present in 6 of 17 knees, whereas the corresponding number for nonreconstructed knees was 7 of 62 ($P = .03$). No TF OA occurred in the 4 patients having an ACL reconstruction without known major meniscal injury.

Symptoms

The most common outcome 15 years after a total ACL rupture was having a more or less healthy knee (ie, being relatively free of symptoms [as assessed by the binary cutoff from KOOS data]) with no TF OA (59%), followed by being symptomatic but no TF OA (24%), having symptomatic TF OA (9%), and having asymptomatic TF OA (8%). The mean (standard deviation) scores for all patients (n = 93) on KOOS were as follows: pain, 90 (13); symptoms, 88 (16); ADL, 94 (10); sport/rec, 76 (25); and QOL, 74 (24) (Figure 3). Patients with intact menisci and nonreconstructed knees achieved the best KOOS scores. Patients with ACL reconstruction reported more KOOS knee pain than those without reconstructions ($P = .035$), and those who had meniscal surgery due to a major meniscal tear had more KOOS pain than those without meniscal surgery ($P = .042$) (Figure 4). Patients with radiographic TF OA tended to score lower in all subscales of KOOS compared with patients without TF OA (Figure 5).

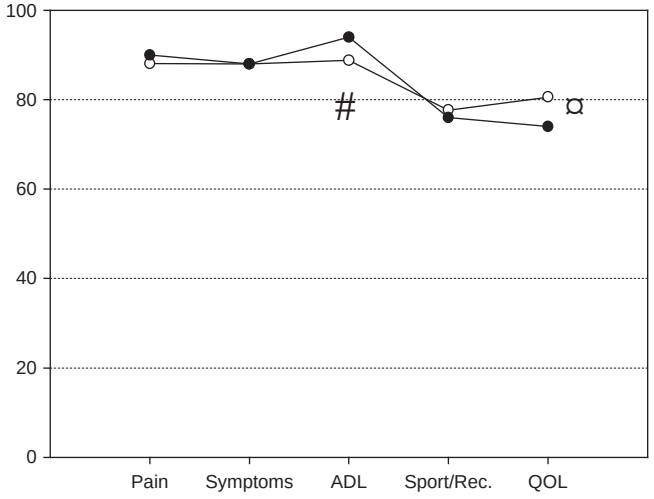

Figure 3. The mean Knee injury and Osteoarthritis Outcome Score profile for the anterior cruciate ligament (ACL)–injured study sample (-•-, n = 93) and a random population-based reference group of individuals aged 35 to 54 years (-○-, n = 158, 51% women).[34] The ACL-injured sample had a significantly higher activities of daily living (ADL) score but a lower knee-related quality of life (QOL) score compared with the reference group (#*P* = .0074 and ¤ *P* = .032, respectively). Sport/Rec, sports and recreation function.

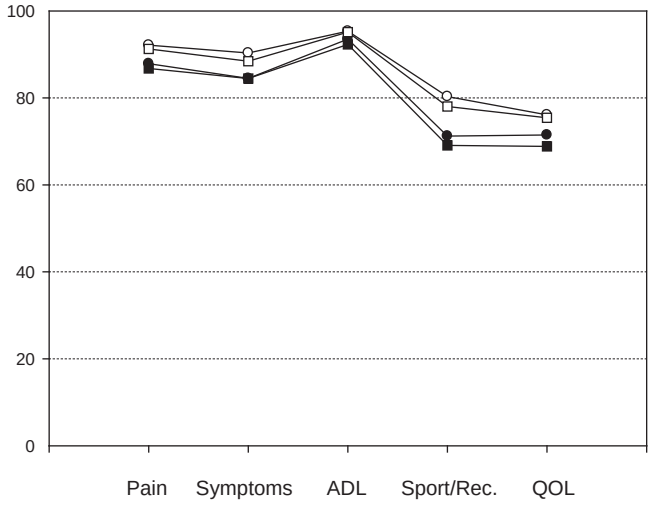

Figure 4. The mean Knee injury and Osteoarthritis Outcome Score profile at follow-up in patients having a major meniscal injury or an anterior cruciate ligament (ACL) reconstruction. A major meniscal tear was defined by a full-thickness tear in the substance or a peripheral tear that required excision or suturing. There was a difference in the subscales of pain (*P* = .042) and symptoms (*P* = .049) between patients with (-•-, n = 43) or without (-○-, n = 50) a major meniscal injury and in the pain subscale between those who had (-■-, n = 22) or did not have (-□-, n = 71) an ACL reconstruction (*P* = .035). ADL, activities of daily living; QOL, knee-related quality of life; Sport/Rec, sports and recreation function.

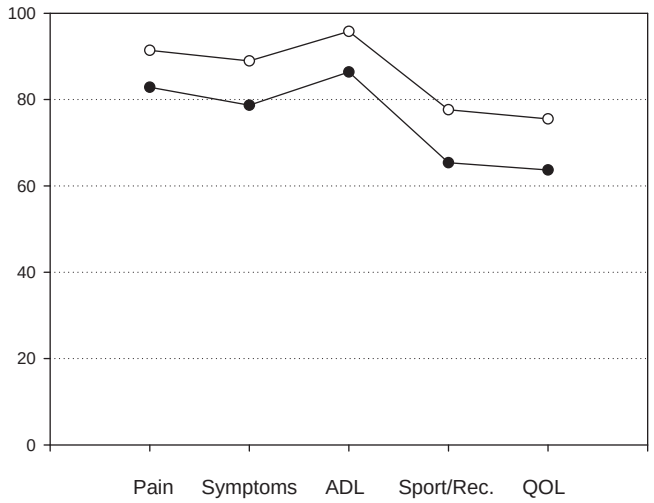

Figure 5. The mean Knee injury and Osteoarthritis Outcome Score (KOOS) profile for patients with tibiofemoral osteoarthritis (-•-, n = 13) compared with cases without tibiofemoral osteoarthritis (-○-, n = 66). There were no statistical differences in the five different subscales of KOOS. ADL, activities of daily living; QOL, knee-related quality of life; Sport/Rec, sports and recreation function.

Medial Collateral Ligament and Chondral Injuries

There was no difference in TF OA or symptoms according to KOOS between patients with medial collateral ligament injuries (grades 1-3) or no medial collateral ligament injury. Of the 10 patients with chondral or osteochondral contusions identified at the index arthroscopy, 1 of 8 who consented to radiographic examination developed TF OA. This patient also had a concomitant lateral meniscal tear treated with partial meniscectomy.

DISCUSSION

The present prospective cohort study of ACL-injured patients had a high follow-up rate and used standardized, valid, and reliable outcome measures. Compared with previous reports having 40% to 90% OA occurrence 5 to 15 years after the injury, we show a considerably smaller fraction (16%) with radiographic knee OA (Kellgren and Lawrence ≥2) 15 years after the injury.[7,8,14,23,26,28-31,37,39-41,44,46]

In another prospective study from Sweden, with a similar 15-year radiographic follow-up using the Fairbank and Ahlbäck system to classify OA, 48 of 93 patients (52%) had radiographic OA Fairbank and Ahlbäck grade 1 or worse.[29] Different OA scoring systems are not easily compared. However, a reclassification of patients in the present study using the former system showed less advanced TF OA in our patients than in that study. No subject in the present study, as compared with 8 patients in the above-mentioned study, had grade 3 OA according to the Fairbank and Ahlbäck system, despite the fact that the study by Meunier et al[29] excluded patients >30 years of age at recruitment.

In the present study, TF OA occurred in 14% (8 of 56) of the patients ≤30 years of age.

In 2 previous cohort studies using the same radiographic technique and OA criteria as in the present study, an OA prevalence of 51% was found in female and 41% in male soccer players 12 and 14 years after ACL rupture.[26,46] In these historical cohort studies, where roughly two-thirds consented to radiographic examination, it is possible that the OA prevalence is overestimated because symptomatic patients may be more interested in participation. However, the association between radiographic knee OA and symptoms is often weak, as in the present study. Two major reasons for the difference in OA prevalence between these studies and the present study include, but are not limited to, (1) the present study included a wider range of ACL-injured patients (selection bias; ie, not only soccer players, who may constitute a particular high-risk category with regard to knee OA due to the high knee load and frequent knee injuries) and (2) an effect of the rehabilitation and treatment. Both reasons mentioned relate to physical activity level and risk of concomitant knee injuries, which may have a crucial role in OA development in ACL-injured patients. The neuromuscular rehabilitation in combination with the strong recommendation to modify sports activity and avoid contact sports, as well as the careful monitoring of the knee condition and of signs of meniscal injuries, are unique factors of the present study.

We had rates of acute meniscal tears corresponding to other studies.[8,22,29,32,33] However, verified subsequent cumulative numbers of meniscectomies during follow-up seems to be lower in the present study (48%, or 46 of 96) compared with the previously reported 80%.[13,22] Additionally, 35 of the 60 patients had an acute meniscal tear that was left in situ (ie, they did not undergo meniscectomy). These 2 factors may be substantial contributors to the lower incidence of OA. All patients with established TF OA in the present study had meniscal surgery performed at least once during the study period. Our study thus clearly confirms that in the ACL-injured knee, reconstructed or not, a meniscectomy is a potent risk factor for OA.[7,29,31,37,41,42] Preservation of the meniscus seems beneficial irrespective of whether an ACL reconstruction was performed, corroborating earlier results.[15] We found no relationship between an osteochondral injury diagnosed at primary arthroscopy after an ACL injury and subsequent knee OA. This is in accordance with the findings of Shelbourne et al,[43] who evaluated untreated articular defects in 125 knees without meniscal injuries that were ACL reconstructed and radiographed 6 years later, without any statistical difference in degenerative changes.

In the present study, the outcome with respect to patient satisfaction is in line with the low prevalence of OA. Accordingly, our study sample scored very similarly on KOOS compared with a random population-based postal survey of inhabitants in southern Sweden (n = 158, age range 35-54 years [Figure 3]).[34] Furthermore, at follow-up, most patients rated their knee function as normal or nearly normal, and the average patient-administered Lysholm knee score was 85, which is considered a good result.[25] This relationship between patient satisfaction and the low OA prevalence in the present study emphasizes restrictiveness to early reconstruction of ACL-injured patients who agree to moderate their activity level. The average decrease in Tegner activity score from 7 to 4 and in the number of patients who actually participated in sports with jumping and knee-pivoting movements after 15 years may be caused by several factors not all related to the ACL injury. Likely reasons are an active choice due to given information and recommendations, a consequence of knee symptoms and/or reduced knee function, and a natural decrease in activity level with aging. It is noteworthy that the study sample's median activity level is almost comparable with the Tegner score of 5 found in a Swedish reference group with a mean age of 43 years without any knee symptoms or injuries.[4]

In conformity with previous studies, there was a higher OA prevalence in patients with ACL reconstruction than in nonsurgically treated patients.[8,14] However, neither our study nor studies by others were designed to compare surgery versus no surgery. Patients in our study sample committed to reconstructive surgery had sustained more cumulative major meniscal injuries (18 of 22) compared with patients who managed to cope with their ACL injury without reconstruction (26 of 72). Patients with ACL reconstruction also had a decreased knee function preoperatively, according to the Lysholm score, compared with patients who did not have reconstruction (data unpublished). Furthermore, the increased ability to return to sports with pivoting movements and joint compression after a meniscal injury and ACL reconstruction may be disadvantageous with regard to the risk for developing knee OA.[38] On the other hand, some individuals not able to participate in sports because of a knee injury may be more affected in their QOL than affected by degenerative changes at radiography. We have previously shown that subjects injured in contact sports score significantly worse at follow-up in the QOL subscale in KOOS.[25]

There is a complex interplay of factors determining the long-term outcome in the ACL-deficient knee. The treatment decision includes stability and performance issues in the short term and the risk of developing knee OA in the long term. Randomized controlled trials using validated patient-relevant outcome measures comparing surgical techniques, rehabilitation protocols, and optional nonsurgical treatments are scarce and not easily designed. An ethical problem is the need to randomize patients to an operation they may not need or not be interested in, or vice versa, and not randomize patients to an operation that they might need early. Despite the fact that our study was designed to provide information on outcome of a nonsurgical approach, the prevalence of OA for all study patients was exceptionally low compared with any other treatment regimen. However, if subgroups of patients that eventually will need an ACL reconstruction could be identified earlier, the knee OA incidence will become lower and patient satisfaction may become even higher than in the present study.

The main limitation of this prospective cohort study is that it included patients who were not entirely consecutive. However, no selection bias is suspected, as the single

recruiter to the study was off duty at irregular intervals during the 4-year inclusion period. Compared with other long-term studies on ACL injuries, the follow-up rate was exceptionally high (94%). Because of geographical and practical reasons, 79 of the 100 patients were radiographed. We find it unlikely that this shortcoming can fully explain the low observed OA prevalence. In a worst-case scenario, the 21 nonradiographed patients would have developed TF OA, which would have yielded an OA occurrence of 34% ([13 + 21]/100). Another radiographic limitation is the lack of patellofemoral evaluation in this study, as patellofemoral degenerative changes are also known to be associated with a previous ACL injury. Our sample size did not allow multivariable analysis, making estimates of main determinants of knee OA difficult. Magnetic resonance imaging was not an established method for detection of chondral and osteochondral lesions when patients were included in the study. Consequently, this is a limitation because we have not been able to investigate the significance of bone bruises on the outcome of degenerative changes in the knee after an ACL injury. Even so, we have probably accounted for the most significant osteochondral injuries that were detectable at index arthroscopy.

The presented nonoperative treatment, for the vast majority of ACL-injured patients, had a favorable long-term outcome regarding incidence of radiographic knee OA, knee function and symptoms, and need for ACL reconstruction. Development of knee OA after ACL injury is multifactorial. The treatment algorithm with early activity modification and neuromuscular knee rehabilitation as the primary treatment after an acute ACL injury might be responsible for the exceptionally low prevalence of OA, but this is difficult to prove and to determine to what extent. However, the nonoperative treatment was aimed at protecting meniscal integrity, and in this study the loss of meniscal integrity is clearly standing out as a prime risk factor for knee OA. We conclude that in patients with ACL injury willing to moderate their activity level, initial treatment without ACL reconstruction should be considered.

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