PODCAST
5-in-5

Effect on Patient-Reported Outcomes of Debridement or Microfracture of Concomitant Full-Thickness Cartilage Lesions in Anterior Cruciate Ligament–Reconstructed Knees

A Nationwide Cohort Study From Norway and Sweden of 357 Patients With 2-Year Follow-up

Jan Harald Røtterud,*†‡ MD, PhD, Einar Andreas Sivertsen,§ MD, PhD, Magnus Forssblad,‖ MD, PhD, Lars Engebretsen,¶#** MD, PhD, and Asbjørn Årøen,†‡¶ MD, PhD
Investigation performed at the Department of Orthopedic Surgery, Akershus University Hospital, Lørenskog, Norway

Background: The treatment of concomitant cartilage lesions in anterior cruciate ligament (ACL)–injured knees is debatable.

Purpose: To evaluate the effect of debridement or microfracture (MF) compared with no treatment of concomitant full-thickness (International Cartilage Repair Society [ICRS] grades 3-4) cartilage lesions on patient-reported outcomes after ACL reconstruction.

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

Methods: Six hundred forty-four patients who underwent primary unilateral ACL reconstruction and had a concomitant full-thickness cartilage lesion treated simultaneously by debridement (n = 129) or MF (n = 164), or underwent no treatment (n = 351) of the cartilage lesion, registered in the Norwegian and Swedish National Knee Ligament Registries from 2005 to 2008 were included. The Knee Injury and Osteoarthritis Outcome Score (KOOS) was used to measure patient-reported outcomes. At a mean follow-up of 2.1 ± 0.2 years after surgery, 357 (55%) patients completed the KOOS. Linear regression analyses were used to evaluate the effect of debridement or MF on the KOOS.

Results: No significant effects of debridement were detected in the unadjusted or adjusted regression analyses on any of the KOOS subscales at 2-year follow-up. The MF treatment of the cartilage lesions had significant negative effects at 2-year follow-up on the KOOS Sport and Recreation (Sport/Rec) (regression coefficient [β] = –8.9; 95% confidence interval [CI], –15.1 to –1.5) and Knee-Related Quality of Life (QoL) (β = –8.1; 95% CI, –14.1 to –2.1) subscales in the unadjusted analyses. When adjusting for confounders, MF had significant negative effects on the same KOOS subscales of Sport/Rec (β = –8.6; 95% CI, –16.4 to –0.7) and QoL (β = –7.2; 95% CI, –13.6 to –0.8). For the remaining KOOS subscales of Pain, Symptoms, and Activities of Daily Living, there were no significant unadjusted or adjusted effects of MF.

Conclusion: MF of concomitant full-thickness cartilage lesions showed adverse effects on patient-reported outcomes at 2-year follow-up after ACL reconstruction. Debridement of concomitant full-thickness cartilage lesions showed neither positive nor negative effects on patient-reported outcomes at 2-year follow-up after ACL reconstruction.

Keywords: knee; articular cartilage; anterior cruciate ligament; debridement; microfracture; KOOS

The combination of anterior cruciate ligament (ACL) injuries and full-thickness (International Cartilage Repair Society [ICRS] grades 3-4)[7,8] cartilage lesions is seriously damaging to the knee. It has been shown that the presence of a focal full-thickness cartilage lesion at the time of ACL reconstruction leads to impaired short-term and midterm patient-reported outcomes[12,33,35] as well as an increased risk of later osteoarthritis.[24,27] However, there is no consensus on the treatment of such cartilage lesions in ACL-injured knees.[9]

The American Journal of Sports Medicine, Vol. 44, No. 2
DOI: 10.1177/0363546515617468

Several treatment options of cartilage lesions exist,[18] and in addition to leaving the cartilage lesion untreated at the time of ACL reconstruction, debridement and microfracture (MF) are the most commonly used treatment options of concomitant full-thickness cartilage lesions.[35] Even though the treatments of isolated cartilage lesions have been extensively studied, there are only a few case series and case-control studies and only 1 randomized study published on the issue of the concomitant treatment of cartilage lesions and ACL reconstruction.[9,21] Hence, there is a need for larger, prospective population-based studies on this issue.

The aim of the present study was to evaluate the effect of debridement or MF of full-thickness cartilage lesions on patient-reported outcomes after ACL reconstruction as measured by the Knee Injury and Osteoarthritis Outcome Score (KOOS) at 2-year follow-up in a nationwide population-based study. The null hypothesis was that in ACL-reconstructed patients with concomitant full-thickness cartilage lesions treatment by debridement or MF would have no effect on patient-reported outcomes at 2-year follow-up compared with ACL-reconstructed patients undergoing no treatment of concomitant full-thickness cartilage lesions.

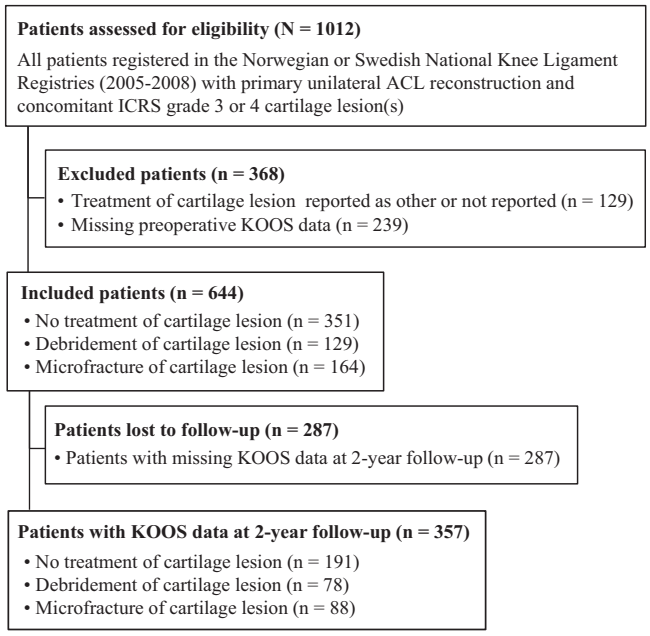

Figure 1. Flowchart of the patients during inclusion and follow-up. ACL, anterior cruciate ligament; ICRS, International Cartilage Repair Society; KOOS, Knee injury and Osteoarthritis Outcome Score.

METHODS

The Norwegian and Swedish National Knee Ligament Registries

The Norwegian National Knee Ligament Registry was established in June 2004 and the Swedish National Knee Ligament Registry in January 2005, with the main objective to prospectively register knee ligament surgeries and monitor outcomes.[15,19,20] Primary knee ligament surgeries, revision procedures, and reoperations are reported to the registries by the operating surgeons, who complete a form including specific baseline variables for the patient, knee, and surgical procedure. The surgeons' reporting rates for ACL surgeries are found to be satisfactory for both registries, with reporting rates above 85%.[37,39]

Cartilage lesions are classified in the registries' databases according to size as <2 cm^2 or ≥ 2 cm^2 and the ICRS grading system.[7,8] In the present study, patients with ICRS grade 3 or 4 cartilage lesions were classified as having a full-thickness lesion.

Both the Norwegian and Swedish National Knee Ligament Registries use the KOOS as a measure of patient-reported outcomes. The KOOS is a self-administered, knee-specific questionnaire that is validated for patients with knee osteoarthritis and several types of knee injuries, such as ACL injuries and cartilage lesions.[4,16,32] At the time of primary knee ligament surgery, the patients preoperatively complete the KOOS questionnaire, and at 1 (Sweden only), 2, 5, and 10 years postoperatively, the patients receive a postal or electronic request from the registries to complete follow-up KOOS questionnaires. In the present study, only KOOS data from the 2-year follow-up were used.

The Norwegian registry has been approved by the Norwegian Data Inspectorate as a national health registry. In Sweden, storage and processing of the data are protected by the Personal Data Act of Sweden.

Patients

There were 15,783 patients registered with unilateral primary ACL reconstruction between January 1, 2005 and December 31, 2008 in the Norwegian and Swedish National Knee Ligament Registries. This patient cohort

*Address correspondence to Jan Harald Røtterud, MD, PhD, Department of Orthopedic Surgery, Akershus University Hospital, 1478 Lørenskog, Norway (email: janhrot@medisin.uio.no).
†Department of Orthopedic Surgery, Akershus University Hospital, Lørenskog, Norway.
‡Institute of Clinical Medicine, Akershus University Hospital, Lørenskog, Norway.
§Diakonhjemmet Hospital, Oslo, Norway.
‖Stockholm Sports Trauma Research Center, Karolinska Institutet, Stockholm, Sweden.
¶Oslo Sports Trauma Research Center, Oslo, Norway.
#Department of Orthopedics, Oslo University Hospital, Oslo, Norway.
**Norwegian Cruciate Ligament Register, Bergen, Norway.
Presented at the 41st annual meeting of the AOSSM, Orlando, Florida, July 2015.
One or more of the authors has declared the following potential conflict of interest or source of funding: J.H.R. received support from Akershus University Hospital and the South-Eastern Norway Regional Health Authority.

TABLE 1
Baseline Characteristics at the Time of ACL Reconstruction[a]

	Patients Available for Follow-up (n = 357)			
	No Treatment (n = 191)	Debridement (n = 78)	Microfracture (n = 88)	Patients Lost to Follow-up (n = 287)
Age at surgery, mean ± SD, y	36 ± 10	36 ± 10	35 ± 10	32 ± 10
Time from injury to surgery, median (range), mo	21 (0-348)	19 (0-260)	20 (1-482)	13 (0-360)
Female sex, n (%)	90 (47)	26 (33)	36 (41)	87 (30)
Previous ipsilateral knee surgery, n (%)	95 (50)	25 (32)	24 (27)	108 (38)
Concomitant ligament injury,[b] n (%)	16 (8)	9 (12)	7 (8)	25 (9)
Concomitant meniscal lesion(s), n (%)	107 (56)	46 (59)	60 (68)	169 (59)
Meniscus resection, n (%)	78 (41)	37 (47)	49 (56)	131 (46)
ACL graft, n (%)				
Hamstring	145 (76)	59 (76)	74 (84)	219 (76)
Bone–patellar tendon–bone	43 (23)	15 (19)	14 (16)	63 (22)
Other/unknown	3 (1)	4 (5)	0 (0)	5 (2)
Preoperative KOOS, mean ± SD				
Pain	69.9 ± 19.5	72.2 ± 18.6	72.1 ± 14.6	68.4 ± 20.5
Symptoms	67.2 ± 20.0	69.1 ± 18.0	69.3 ± 16.5	66.2 ± 18.9
ADL	78.5 ± 18.7	81.5 ± 17.1	79.6 ± 16.5	76.4 ± 21.2
Sport/Rec	36.8 ± 27.8	39.5 ± 25.2	34.2 ± 24.2	35.1 ± 28.8
QoL	30.1 ± 19.5	33.5 ± 17.2	30.2 ± 16.6	30.5 ± 18.3

[a]ACL, anterior cruciate ligament; ADL, Activities of Daily Living; KOOS, Knee Injury and Osteoarthritis Outcome Score; QoL, Knee-Related Quality of Life; Sport/Rec, Sport and Recreation.
[b]Medial collateral ligament, lateral collateral ligament, posterior cruciate ligament, or posterolateral corner.

has been previously described in a study on the incidence and risk of full-thickness cartilage lesions in ACL-injured knees[34] and in a study on the effects of meniscal and cartilage lesions on patient-reported outcomes after ACL reconstruction.[35]

Of the 15,783 patients, 1012 (6.4%) had full-thickness cartilage lesions at the time of ACL reconstruction and were considered eligible for the study. There were 644 patients who reported no treatment (n = 351), debridement (n = 129), or MF (n = 164) of the full-thickness cartilage lesions and completed preoperative KOOS questionnaires and thus were included in the study; 114 patients were excluded because the treatment of the cartilage lesion was not reported or specified; 15 patients were excluded because the treatment of the cartilage lesion was reported as other than no treatment, debridement, or MF (osteochondral autologous transplantation [OAT] [n = 6], autologous chondrocyte implantation [ACI] [n = 5], or periosteal flap [n = 4]); and 239 patients were excluded because of missing preoperative KOOS data.

At a mean follow-up of 2.1 ± 0.2 years and mean age of 38 ± 10 years, KOOS data were received from 357 (55%) of the 644 patients. There were 287 (45%) patients considered as lost to follow-up, as they did not return the 2-year follow-up KOOS questionnaire after the initial request or later reminders from the registries. The 287 patients lost to follow-up were distributed within the treatment groups as follows: 160 (46%) of the patients with no treatment of the cartilage lesion, 51 (40%) of the patients with debridement, and 76 (44%) of the patients with MF. A flowchart illustrating the patient flow during inclusion and follow-up is shown in Figure 1.

Baseline characteristics at the time of ACL reconstruction for the patients available for follow-up and for those lost to follow-up are shown in Table 1. The depth, area, and location of the cartilage lesions for the patients available for follow-up and for those lost to follow-up are shown in Table 2. The 95% CIs for all characteristics in Tables 1 and 2, stratified by availability for follow-up and by treatment, are shown in Appendix Table A1 (available in the online version of this article at http://ajsm.sagepub.com/supplemental).

Statistical Analysis

Statistical analyses were performed using SPSS Statistics software version 20 (IBM Corp). The study's objective was to evaluate the effect of debridement and MF of concomitant full-thickness cartilage lesions on patient-reported outcomes (KOOS) after ACL reconstruction. Treatment effects were estimated using linear regression. At first, crude mean KOOS values preoperatively and at 2-year follow-up were estimated and stratified by treatment (no treatment, debridement, and MF) of the cartilage lesions. Unadjusted regression analyses were performed with the treatment of cartilage lesions as the independent variable and with each of the KOOS subscales at 2-year follow-up as the dependent variable. In the adjusted regression analyses, the treatment variable was included together with possible confounders and predictors of patient-reported outcomes as independent variables and each of the KOOS subscales at 2-year follow-up as the dependent variable. Based on the current literature and clinical assumption, the variables of sex, age (continuous variable), previous ipsilateral knee surgery (yes [y]/no [n]), time

TABLE 2
Depth, Area, and Location of Full-Thickness Cartilage Lesions (ICRS Grades 3-4)[a]

	Patients Available for Follow-up (n = 357)			
	No Treatment (n = 191)	Debridement (n = 78)	Microfracture (n = 88)	Patients Lost to Follow-up (n = 287)
Depth				
ICRS grade 4	45 (24)	10 (13)	45 (51)	70 (24)
Area				
<2 cm^2	82 (43)	30 (38)	52 (59)	134 (47)
≥ 2 cm^2	107 (56)	48 (62)	36 (41)	145 (50)
Not reported	2 (1)	0 (0)	0 (0)	8 (3)
Location				
Patella	10 (5)	7 (9)	0 (0)	19 (7)
Trochlea	8 (4)	3 (4)	5 (6)	17 (6)
Medial femoral condyle	125 (65)	56 (72)	73 (83)	200 (70)
Lateral femoral condyle	28 (15)	11 (14)	7 (8)	30 (10)
Medial tibial plateau	5 (3)	1 (1)	2 (2)	8 (3)
Lateral tibial plateau	15 (8)	0 (0)	1 (1)	13 (4)

[a]Values are expressed as n (%). International Cartilage Repair Society (ICRS) grade 0, normal; grade 1, nearly normal (superficial lesions, soft indentation, and/or superficial fissures and cracks); grade 2, abnormal (cartilage lesions extending down to <50% of the cartilage depth); grade 3, severely abnormal (cartilage lesions extending down to >50% of the cartilage depth as well as down to the calcified layer); and grade 4, severely abnormal (osteochondral lesions, extending just through the subchondral bone plate, or deeper lesions down into trabecular bone).

from injury to surgery (continuous variable), concomitant ligament injury (y/n), concomitant meniscal lesion(s) (y/n), meniscus resection (y/n), type of ACL graft (hamstring, patellar tendon, or other), area of cartilage lesions (<2 cm^2 or ≥ 2 cm^2), depth (ICRS grade 3 or ICRS grade 4) of cartilage lesions, location of cartilage lesions (patella, trochlea, medial femoral condyle, lateral femoral condyle, medial tibial plateau, or lateral tibial plateau), and respective preoperative KOOS subscale values (continuous variable) were considered as possible confounders and predictors of patient-reported outcomes and included in the adjusted analyses. In all regression analyses, no treatment of cartilage lesions was used as the reference for the effect of debridement and MF. All data used in the analyses were extracted from the Norwegian and Swedish National Knee Ligament Registries' databases.

All P values $<.05$ were considered statistically significant. All baseline characteristics, mean KOOS values at follow-up, and standardized regression coefficients (β) are presented with 95% CIs.

RESULTS

The crude mean KOOS values at 2-year follow-up after ACL reconstruction for patients undergoing no treatment, debridement, or MF of concomitant full-thickness cartilage lesions are shown in Table 3. The changes in mean KOOS values from preoperatively to 2-year follow-up after ACL reconstruction for the treatment groups (no treatment, debridement, and MF) are illustrated in Figure 2, which shows the KOOS profiles of the patients undergoing no treatment, debridement, or MF of concomitant full-thickness cartilage lesions preoperatively and at 2-year follow-up.

Effects of Debridement and MF of Cartilage Lesions on the KOOS at 2-Year Follow-up

Table 4 shows the results for the unadjusted and adjusted effects of debridement and MF of cartilage lesions on each KOOS subscale at 2-year follow-up after ACL reconstruction. With no treatment of the cartilage lesions as the reference, no significant effects of debridement were detected in the unadjusted or adjusted regression analyses in any of the KOOS subscales at 2-year follow-up. The MF treatment of the cartilage lesions showed significant negative effects at 2-year follow-up on the KOOS subscales of Sport and Recreation (Sport/Rec) ($\beta = -8.9$; 95% CI, –15.1 to –1.5) and Knee-Related Quality of Life (QoL) ($\beta = -8.1$; 95% CI, –14.1 to –2.1) in the unadjusted analyses. When adjusting for confounders, MF showed significant negative effects on the same KOOS subscales of Sport/Rec ($\beta = -8.6$; 95% CI, –16.4 to –0.7) and QoL ($\beta = -7.2$; 95% CI, –13.6 to –0.8). For the remaining KOOS subscales of Pain, Symptoms, and Activities of Daily Living (ADL), there were no significant unadjusted or adjusted effects of MF. However, there was a trend toward negative effects of MF also in these subscales. The unadjusted and adjusted effects on the KOOS of debridement and MF in the subset of cartilage lesions located at the medial femoral condyle are shown in Appendix Table A2 (available online). As in the overall results, debridement showed no significant unadjusted or adjusted effects on the KOOS in the subset of patients with medial femoral condyle lesions. For MF, the negative effects tended to be larger for the subset of medial femoral condyle lesions than for the overall group, with significant negative effects in the subscales of Pain (adjusted), Symptoms (unadjusted), Sport/Rec (unadjusted), and QoL (unadjusted and adjusted).

TABLE 3
Crude Mean KOOS Values by Treatment of Cartilage Lesions at 2-Year Follow-up After ACL Reconstruction[a]

KOOS Subscales	No Treatment (n = 191)	Debridement (n = 78)	Microfracture (n = 88)
Pain	82.2 (79.6-84.7)	82.8 (78.8-86.7)	79.7 (76.5-83.0)
Symptoms	75.5 (72.9-78.2)	77.2 (73.4-80.9)	72.3 (68.5-76.1)
ADL	88.3 (86.0-90.5)	91.2 (88.2-94.2)	86.3 (83.0-89.5)
Sport/Rec	60.4 (56.2-64.5)	61.9 (55.4-68.4)	51.5 (45.5-57.5)
QoL	59.8 (56.3-63.3)	62.6 (57.3-67.9)	51.7 (47.1-56.3)

[a]Values are expressed as mean (95% CI). ACL, anterior cruciate ligament; ADL, Activities of Daily Living; KOOS, Knee Injury and Osteoarthritis Outcome Score; QoL, Knee-Related Quality of Life; Sport/Rec, Sport and Recreation.

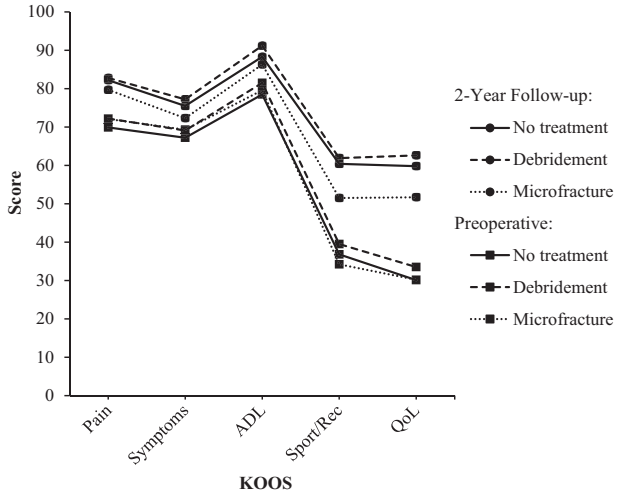

Figure 2. Profiles of mean Knee Injury and Osteoarthritis Outcome Score (KOOS) values of patients undergoing no treatment, debridement, or microfracture of concomitant full-thickness cartilage lesions (International Cartilage Repair Society [ICRS] grades 3-4) preoperatively and at 2-year follow-up after anterior cruciate ligament reconstruction. ADL, Activities of Daily Living; QoL, Knee-Related Quality of Life; Sport/Rec, Sport and Recreation.

DISCUSSION

The main finding of the present study is that in reference to no treatment of concomitant full-thickness cartilage lesions, MF showed significant negative effects on patient-reported outcomes at 2-year follow-up after ACL reconstruction. In addition, debridement of full-thickness cartilage lesions showed neither positive nor negative significant effects on patient-reported outcomes. These are new findings, and they add important information about the concomitant treatment of cartilage lesions and ACL reconstruction to the literature. Both MF and debridement are frequently used and commonly referred to as first-line treatments of cartilage lesions in ACL-injured knees. The findings from the present study add reasons for concern to this approach.

Debridement of concomitant cartilage lesions showed no effect on the KOOS at 2-year follow-up in the present study. Because debridement primarily aims to relieve symptoms through the removal of unstable cartilage, and not to regenerate cartilage, it is possible that a beneficial but temporary effect would have been evident with a shorter follow-up period than 2 years. Because of the lack of 1-year postoperative KOOS results from the Norwegian registry, only the KOOS data from 2-year follow-up were analyzed. Hence, the present study was not able to evaluate early effects of cartilage treatment. However, MF, which aims to regenerate cartilage, showed adverse effects on the KOOS at 2-year follow-up. The negative effects of MF were most evident and statistically significant in the KOOS subscales of Sport/Rec and QoL, ranging from –7.2 to –8.9 points on the KOOS. This is probably in the range of what should be considered as clinically relevant effects.[16,32] However, not statistically significant, there was consistency in the findings, with a trend toward negative effects of MF also in the remaining subscales of Pain, Symptoms, and ADL. These differences in treatment effects between the KOOS subscales are in line with previous studies, which have shown that for patients with ACL injuries and cartilage lesions, the subscales of Sport/Rec and QoL are more responsive than the subscales of Pain, Symptoms, and ADL.[11,14,16]

One possible explanation for the adverse effects of MF could be that MF is not well suited for ACL-reconstructed knees. So far, no method of ACL reconstruction has, in a clinical setting, proven to completely restore a normal knee, and it is possible that biomechanical or biochemical abnormalities present after ACL reconstruction could be unfavorable for MF. Together with the possibility of pre-existing cartilage lesions, it is also possible that the relatively older age of the included patients could have affected the outcomes of MF, as chronic lesions and/or age above 30 years have been shown to reduce patient-reported outcomes of cartilage repair.[13] However, the age distribution among the included patients reflects the epidemiology of concomitant cartilage lesions and ACL injuries, as these are found to be more frequent with increasing age.[10,34] Furthermore, age was included as a factor in the adjusted analyses.

Concomitant drilling, MF, periosteal flap, OAT, and ACI of cartilage lesions and ACL reconstruction have shown acceptable and promising results in the previous literature.[1,2,6,17,23,25,29,30] However, these studies have been case series or case-control studies with relatively small numbers of patients included in the different treatment groups, making it difficult to conclude and generalize about the treatment of choice. The only randomized trial on the concomitant treatment of cartilage lesions and ACL

TABLE 4
Unadjusted and Adjusted Regression Analyses of the Associations Between the KOOS Subscales and Treatment of Cartilage Lesions at 2-Year Follow-up After ACL Reconstruction[a]

		Debridement[b]			Microfracture[b]		
KOOS Subscales	n	β	95% CI	*P* Value	β	95% CI	*P* Value
Pain							
Unadjusted	356	0.6	–4.0 to 5.2	NS	–2.5	–6.9 to 2.0	NS
Adjusted	332	0.1	–4.2 to 4.5	NS	–4.2	–8.6 to 0.2	NS
Symptoms							
Unadjusted	357	1.6	–3.1 to 6.4	NS	–3.3	–7.8 to 1.3	NS
Adjusted	335	1.0	–3.8 to 5.7	NS	–3.3	–8.2 to 1.5	NS
ADL							
Unadjusted	357	2.9	–1.1 to 6.9	NS	–2.0	–5.9 to 1.8	NS
Adjusted	333	1.8	–2.1 to 5.7	NS	–2.7	–6.6 to 1.2	NS
Sport/Rec							
Unadjusted	356	1.5	–6.1 to 9.1	NS	–8.9	–15.1 to –1.5	.018
Adjusted	334	–0.2	–7.9 to 7.5	NS	–8.6	–16.4 to –0.7	.032
QoL							
Unadjusted	357	2.7	–3.5 to 9.0	NS	–8.1	–14.1 to –2.1	.008
Adjusted	335	2.1	–4.3 to 8.4	NS	–7.2	–13.6 to –0.8	.028

[a]Adjusted for sex, age, previous ipsilateral knee surgery, time from injury to surgery, concomitant ligament injury, concomitant meniscal lesion(s), meniscus resection, type of ACL graft, area of cartilage lesion, depth (International Cartilage Repair Society grade) of cartilage lesion, location of cartilage lesion, and preoperative KOOS values. ACL, anterior cruciate ligament; ADL, Activities of Daily Living; β, regression coefficient; KOOS, Knee Injury and Osteoarthritis Outcome Score; n, number of patients included in the regression analyses; NS, not significant; QoL, Knee-Related Quality of Life; Sport/Rec, Sport and Recreation.
[b]No treatment of cartilage lesions used as the reference.

reconstruction is a recent study by Gudas et al,[21] which compared patients undergoing debridement, MF, and OAT of concomitant cartilage lesions at 3-year follow-up after ACL reconstruction. Gudas et al[21] found that patients treated with OAT reported significantly better outcomes by International Knee Documentation Committee subjective scores than did patients treated with MF or debridement and that there were no differences between the patients treated with MF and debridement. However, Gudas et al[21] did not include a control group of patients with cartilage lesions left untreated, so it is not possible to evaluate if debridement or MF had an actual effect compared with no treatment. The present study is, to our knowledge, the first study to include a control group of patients with full-thickness cartilage lesions left untreated at the time of ACL reconstruction, making it possible to evaluate the actual treatment effect of debridement or MF.

The main strength of the present study is the nationwide population-based design, which should ensure that the results reflect clinical everyday practice among a wide range of orthopaedic surgeons and that the findings are applicable to comparable populations. In addition, the large sample size allowed for a comprehensive adjustment for predictors and confounders in the analyses, which strengthens the validity of the findings.

However, the present study has limitations. The main limitations are the lack of randomization and the rate of patients lost to 2-year follow-up with a potential of selection bias. However, a validation study from the Danish Knee Ligament Reconstruction Register, which is similar to the Norwegian and Swedish registries, found comparable KOOS values for responders and nonresponders and concluded that the registry data were valid despite a high rate of loss to follow-up.[31] With the exception of the sex and age distribution, and the time from injury to ACL reconstruction, the baseline characteristics of the patients available for follow-up and those lost to follow-up were comparable for all reported baseline variables. The patients lost to follow-up were younger and had a larger proportion of men than the patients evaluated at follow-up. In addition, the time from injury to ACL reconstruction was shorter among the patients lost to follow-up. This can be explained by the age difference, as younger patients tend to have their knees ACL reconstructed earlier after an injury than older patients. However, there is a possibility that these patients lost to follow-up might have affected the results, as cartilage surgery on more recent cartilage lesions and younger patients tends to improve the results.[13] Because of the observational study design, there was no randomization between the treatment groups. In observational studies such as the present one, there is a possibility of confounders not being controlled for. Among these, it was not possible to account for whether the surgeons performed the MF procedure adequately and provided the patients with the recommended postoperative rehabilitation regimen. Even though the MF technique and its rehabilitation are thoroughly described,[22,36] and it has been a well-known and commonly used procedure among surgeons who perform ACL surgery for many years, recent studies have shown that surgeon

performance with the surgical technique and the rehabilitation of MF vary.[26,38] Hence, it cannot be ruled out that some ACL surgeons in Norway and Sweden systematically or randomly perform the MF procedure and provide rehabilitation in a disadvantageous manner, in such a way that the results are negatively affected. Other possible confounders that are not controlled for in the present study include body mass index,[28] containment of the cartilage lesion, knee alignment,[3] and activity level.[5] Unfortunately, none of these parameters were available from both registries. However, the factors most likely to have affected the prognosis (such as age; preoperative KOOS values; concomitant injuries; meniscus resection; and size, depth, and location of the cartilage lesion) were adjusted for.

All these limitations must be taken into account when interpreting the findings of the present study into clinical practice. However, because of the even distribution of patients lost to follow-up between the treatment groups, the similarities between the treatment groups at baseline, and the comprehensive adjustment for possible confounders and predictors in the regression analyses, it is not very likely that a higher rate of follow-up or further adjustment would alter the results substantially. At least, it is highly unlikely that the results would be altered to the extent that they would show a beneficial effect of MF.

We suggest that the findings in the present study should be taken into account when decisions are made on the treatment of concomitant full-thickness cartilage lesions at the time of ACL reconstruction. Debridement should be performed restrictively, and especially MF of concomitant full-thickness cartilage lesions in ACL-injured knees should probably be avoided until future studies have identified if there are any subgroups of patients that might benefit from debridement or MF of cartilage lesions at the time of ACL reconstruction. The present study also proposes that future studies on the concomitant treatment of full-thickness cartilage lesions and ACL reconstruction should include a control group of patients undergoing no treatment of cartilage lesions.

CONCLUSION

In reference to leaving concomitant full-thickness cartilage lesions untreated at the time of ACL reconstruction, MF showed adverse effects on patient-reported outcomes, and debridement showed no effects on patient-reported outcomes at 2-year follow-up after ACL reconstruction. Hence, MF and debridement of concomitant full-thickness cartilage lesions in ACL-injured knees should be performed restrictively.

ACKNOWLEDGMENT

The authors thank the Norwegian and Swedish National Knee Ligament Registries for providing data for the current study, the Oslo Sports Trauma Research Center for advisory support, and Akershus University Hospital and the South-Eastern Norway Regional Health Authority for economic support while conducting the study.

REFERENCES

1. Alfredson H, Thorsen K, Lorentzon R. Treatment of tear of the anterior cruciate ligament combined with localised deep cartilage defects in the knee with ligament reconstruction and autologous periosteum transplantation. *Knee Surg Sports Traumatol Arthrosc*. 1999;7(2):69-74.
2. Amin AA, Bartlett W, Gooding CR, et al. The use of autologous chondrocyte implantation following and combined with anterior cruciate ligament reconstruction. *Int Orthop*. 2006;30(1):48-53.
3. Behery O, Siston RA, Harris JD, Flanigan DC. Treatment of cartilage defects of the knee: expanding on the existing algorithm. *Clin J Sport Med*. 2014;24(1):21-30.
4. Bekkers JE, de Windt TS, Raijmakers NJ, Dhert WJ, Saris DB. Validation of the Knee Injury and Osteoarthritis Outcome Score (KOOS) for the treatment of focal cartilage lesions. *Osteoarthritis Cartilage*. 2009;17(11):1434-1439.
5. Bekkers JE, Inklaar M, Saris DB. Treatment selection in articular cartilage lesions of the knee: a systematic review. *Am J Sports Med*. 2009;37(suppl 1):148S-155S.
6. Bobic V. Arthroscopic osteochondral autograft transplantation in anterior cruciate ligament reconstruction: a preliminary clinical study. *Knee Surg Sports Traumatol Arthrosc*. 1996;3(4):262-264.
7. Brittberg M, Peterson L. Introduction of an articular cartilage classification. *ICRS Newsletter*. 1998;1(1):5-8.
8. Brittberg M, Winalski CS. Evaluation of cartilage injuries and repair. *J Bone Joint Surg Am*. 2003;85(suppl 2):58-69.
9. Brophy RH, Zeltser D, Wright RW, Flanigan D. Anterior cruciate ligament reconstruction and concomitant articular cartilage injury: incidence and treatment. *Arthroscopy*. 2010;26(1):112-120.
10. Chhadia AM, Inacio MC, Maletis GB, Csintalan RP, Davis BR, Funahashi TT. Are meniscus and cartilage injuries related to time to anterior cruciate ligament reconstruction? *Am J Sports Med*. 2011;39(9):1894-1899.
11. Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). *Arthritis Care Res (Hoboken)*. 2011;63(suppl 11):S208-S228.
12. Cox CL, Huston LJ, Dunn WR, et al. Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. *Am J Sports Med*. 2014;42(5):1058-1067.
13. de Windt TS, Bekkers JE, Creemers LB, Dhert WJ, Saris DB. Patient profiling in cartilage regeneration: prognostic factors determining success of treatment for cartilage defects. *Am J Sports Med*. 2009;37(suppl 1):58S-62S.
14. Ebert JR, Smith A, Wood DJ, Ackland TR. A comparison of the responsiveness of 4 commonly used patient-reported outcome instruments at 5 years after matrix-induced autologous chondrocyte implantation. *Am J Sports Med*. 2013;41(12):2791-2799.
15. Engebretsen L, Forssblad M. Why knee ligament registries are important. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(2):115-116.
16. Engelhart L, Nelson L, Lewis S, et al. Validation of the Knee Injury and Osteoarthritis Outcome Score subscales for patients with articular cartilage lesions of the knee. *Am J Sports Med*. 2012;40(10):2264-2272.
17. Gaweda K, Walawski J, Weglowski R, Patyra M. Rehabilitation after one-stage anterior cruciate reconstruction and osteochondral grafting. *Int Orthop*. 2006;30(3):185-189.
18. Gomoll AH, Farr J, Gillogly SD, Kercher J, Minas T. Surgical management of articular cartilage defects of the knee. *J Bone Joint Surg Am*. 2010;92(14):2470-2490.
19. Granan LP, Bahr R, Steindal K, Furnes O, Engebretsen L. Development of a national cruciate ligament surgery registry: the Norwegian

National Knee Ligament Registry. *Am J Sports Med*. 2008;36(2):308-315.
20. Granan LP, Forssblad M, Lind M, Engebretsen L. The Scandinavian ACL registries 2004-2007: baseline epidemiology. *Acta Orthop*. 2009;80(5):563-567.
21. Gudas R, Gudaite A, Mickevicius T, et al. Comparison of osteochondral autologous transplantation, microfracture, or debridement techniques in articular cartilage lesions associated with anterior cruciate ligament injury: a prospective study with a 3-year follow-up. *Arthroscopy*. 2013;29(1):89-97.
22. Hurst JM, Steadman JR, O'Brien L, Rodkey WG, Briggs KK. Rehabilitation following microfracture for chondral injury in the knee. *Clin Sports Med*. 2010;29(2):257-265, viii.
23. Imade S, Kumahashi N, Kuwata S, et al. A comparison of patient-reported outcomes and arthroscopic findings between drilling and autologous osteochondral grafting for the treatment of articular cartilage defects combined with anterior cruciate ligament injury. *Knee*. 2013;20(5):354-359.
24. Janssen RP, du Mee AW, van Valkenburg J, Sala HA, Tseng CM. Anterior cruciate ligament reconstruction with 4-strand hamstring autograft and accelerated rehabilitation: a 10-year prospective study on clinical results, knee osteoarthritis and its predictors. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(9):1977-1988.
25. Klinger HM, Baums MH, Otte S, Steckel H. Anterior cruciate reconstruction combined with autologous osteochondral transplantation. *Knee Surg Sports Traumatol Arthrosc*. 2003;11(6):366-371.
26. Kroell A, Marks P, Chahal J, et al. Microfracture for chondral defects: assessment of the variability of surgical technique in cadavers [published online December 23, 2014]. *Knee Surg Sports Traumatol Arthrosc*. doi:10.1007/s00167-014-3481-8.
27. Li RT, Lorenz S, Xu Y, Harner CD, Fu FH, Irrgang JJ. Predictors of radiographic knee osteoarthritis after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2011;39(12):2595-2603.
28. Mithoefer K, Williams RJ III, Warren RF, et al. The microfracture technique for the treatment of articular cartilage lesions in the knee: a prospective cohort study. *J Bone Joint Surg Am*. 2005;87(9):1911-1920.
29. Osti L, Papalia R, Del Buono A, Amato C, Denaro V, Maffulli N. Good results five years after surgical management of anterior cruciate ligament tears, and meniscal and cartilage injuries. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(10):1385-1390.
30. Peterson L, Minas T, Brittberg M, Nilsson A, Sjogren-Jansson E, Lindahl A. Two- to 9-year outcome after autologous chondrocyte transplantation of the knee. *Clin Orthop Relat Res*. 2000;374:212-234.
31. Rahr-Wagner L, Thillemann TM, Lind MC, Pedersen AB. Validation of 14,500 operated knees registered in the Danish Knee Ligament Reconstruction Register: registration completeness and validity of key variables. *Clin Epidemiol*. 2013;5:219-228.
32. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health Qual Life Outcomes*. 2003;1:64.
33. Røtterud JH, Risberg MA, Engebretsen L, Årøen A. Patients with focal full-thickness cartilage lesions benefit less from ACL reconstruction at 2-5 years follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(8):1533-1539.
34. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Årøen A. Effect of gender and sports on the risk of full-thickness articular cartilage lesions in anterior cruciate ligament-injured knees: a nationwide cohort study from Sweden and Norway of 15 783 patients. *Am J Sports Med*. 2011;39(7):1387-1394.
35. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Årøen A. Effect of meniscal and focal cartilage lesions on patient-reported outcome after anterior cruciate ligament reconstruction: a nationwide cohort study from Norway and Sweden of 8476 patients with 2-year follow-up. *Am J Sports Med*. 2013;41(3):535-543.
36. Steadman JR, Rodkey WG, Rodrigo JJ. Microfracture: surgical technique and rehabilitation to treat chondral defects. *Clin Orthop Relat Res*. 2001;391(suppl):S362-S369.
37. Swedish National Knee Ligament Register. The Swedish ACL Register Annual Report: 2012. Available at: www.aclregister.nu. Accessed August 15, 2014.
38. Theodoropoulos J, Dwyer T, Whelan D, Marks P, Hurtig M, Sharma P. Microfracture for knee chondral defects: a survey of surgical practice among Canadian orthopedic surgeons. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(12):2430-2437.
39. Ytterstad K, Granan LP, Ytterstad B, et al. Registration rate in the Norwegian Cruciate Ligament Register. *Acta Orthop*. 2012;83(2):174-178.