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High prevalence of knee osteoarthritis at a minimum 10-year follow-up after knee dislocation surgery

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Abstract

Purpose Long-term outcomes and the prevalence of osteoarthritis after surgical treatment of knee dislocations are lacking in the literature. The purpose of this study was to investigate the prevalence of knee osteoarthritis and knee function at a minimum of 10 years after knee dislocation surgery.

Methods Sixty-five patients surgically treated for knee dislocations at a single level I trauma center between May 1996 and December 2004 were evaluated at a minimum of 10 years. Patients were evaluated with radiographs for knee osteoarthritis using the Kellgren–Lawrence (KL) grading system, Tegner activity score, Lysholm score, IKDC-2000, KOOS, subjective stability on physical examination, KT-1000 arthrometer, and single-leg hop tests. Osteoarthritis was defined as KL grades 2 or greater.

Results The median follow-up time was 12.7 years (range 10.0–18.8 years), and the median age was 46.9 years (range 26.8–76.1 years). Radiographic osteoarthritis was present in 42% (23, 14, and 5% in KL grades II, III, and IV, respectively) of the patients in the operated knee compared to 6% in the uninjured knee. Knee function was generally improved with a median Tegner activity score of 4 (range 1–8), an average Lysholm score of 84 ± 17, and an average IKDC-2000 score of 73 ± 19.

Conclusion Twenty-seven patients (42%) developed OA 10 years after surgical treatment of knee dislocations. Patients reported improved knee function and minimal-to-moderate pain. Age at surgery was a predictor of development of OA, with more patients > 30 years at the time of surgery developing OA. Meniscal and cartilage injuries at time of surgery were not associated with development of OA. Patients being treated for knee dislocation should be counselled about the increased long-term risk of post-traumatic OA.

Level of evidence III.

Keywords Knee dislocation · Knee · Multiple ligament knee injury · Osteoarthritis

Abbreviations

ACL	Anterior cruciate ligament
PCL	Posterior cruciate ligament
MCL	Medial collateral ligament
FCL	Fibular collateral ligament
PLC	Posterolateral corner
OA	Osteoarthritis
IKDC	International knee documentation committee
KOOS	Knee injury and osteoarthritis outcome score
CPM	Continuous passive motion
AL	Anterolateral
ROM	Range of motion

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Introduction

Knee dislocations are complex injuries, posing a challenge in both treatment and rehabilitation. The reported incidence is 0.02–0.2% of all orthopaedic injuries [1–5]. However, the incidence of these injuries may be underestimated, because it is reported that up to 50% of the knees spontaneously reduce before presentation [6]. Several studies have reported improved short-to-medium-term clinical outcomes with operative treatment of these injuries compared to non-operative treatment, and therefore, surgical treatment is often recommended [7–12]. Long-term outcome studies on knee dislocation are still lacking in the literature [13, 8]. Most studies published on the clinical outcomes after surgical treatment of knee dislocation injuries have a relatively short follow-up period [13–19]. A high prevalence of knee osteoarthritis has been reported 10–20 years after ACL injuries [20–22]. The prevalence of osteoarthritis after knee dislocations is reported to range from 23 to 87% in different patient series with short-to-medium-term follow-up [14, 23, 16, 10].

The goal of the present study was to follow a cohort of patients treated for traumatic knee dislocation at a Trauma Level I institution between May 1996 and December 2004. In the present study, knee dislocation was defined as both anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) tear, with or without an additional tear to the medial and/or lateral side. The hypothesis was that there was a high prevalence of knee OA despite good function in the medium-to-long term after surgical treatment of knee dislocations. The primary endpoints were: (1) prevalence of radiologic knee OA in the injured and normal knee after a minimum of 10 years after surgery for a knee dislocation; (2) patient reported subjective knee function using Tegner activity scores, Lysholm knee rating scale, subjective International Knee Documentation Committee 2000 (IKDC-2000), the Knee Injury, and Osteoarthritis Outcome Score (KOOS); (3) knee stability as evaluated by knee laxity clinical examination and KT-1000 arthrometer; and (4) knee function evaluated by single-leg hop tests.

Materials and methods

One-hundred and eleven patients were treated surgically for knee dislocations between May 1996 and December 2004 at a single level 1 Trauma center (Oslo University Hospital). These patients were entered into a prospective database and followed since the time of surgery. In the present study, the inclusion criteria were follow-up of a minimum of 10 years or more from injury in patients with both anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) injuries, with or without an additional injury to the medial and/or lateral side, according to the classification of Schenck et al. (KD II-KD IV) [24, 6]. Patients were required to be skeletally mature at inclusion. The exclusion criteria were severe intra-articular fractures of the ipsilateral knee, non-operative treatment, and skeletal immaturity.

Preoperative evaluation

At the time of admission, acute patients had a thorough history and physical examination, and all injuries were documented. The patients' vascular and neurologic status were monitored clinically with serial examinations. Any asymmetry noted in pulses, warmth, and color between the injured and uninjured legs, and ankle-brachial index (ABI) below 0.8 was further evaluated with arteriography [25]. All patients underwent standard radiologic imaging of the injured knee. In the early years of the inclusion, the majority of the patients had chronic knee dislocations because of a lack of surgical treatment offered prior to 1996. In the acute patients, a hinged brace and a continuous passive motion (CPM) device were used in the hospital prior to surgery. Acutely injured patients underwent surgical reconstruction of their injured knee approximately 10 days after injury, when not contraindicated by other injuries, such as vascular and major skin injuries. Surgery after 21 days was defined as chronic in this study.

Surgical management

The ligamentous status of the injured knee was subjectively compared with the uninjured knee using the American Medical Association (AMA) guidelines [26, 27]. An arthroscopic transtibial anterior cruciate ligament (ACL) reconstruction technique was used. The posterior cruciate ligament (PCL) was reconstructed aiming for the anterolateral (AL) bundle. An arthroscopic-assisted transtibial PCL tunnel was reamed at the footprint of the PCL. If repairable, the fibular collateral ligament (FCL), popliteus, and the biceps tendon were repaired using suture anchors. In mid-substance and tears which were judged unrepairable in the posterolateral corner, reconstruction was performed as described by the studies of LaPrade et al., and Geeslin and LaPrade [28, 29]. For medial-sided injuries, avulsions or ligament tears to the deep MCL and distal MCL were repaired using suture anchors. When the MCL could not be repaired or the repair was regarded insufficient, the MCL repair was augmented with the use of a semitendinosus autograft [15]. The status of the menisci and the cartilage was evaluated intraoperatively and recorded.

Rehabilitation

Immediately postoperatively, patients were partial weight bearing for 8 weeks with a knee brace locked in full extension. During their hospital stay, a CPM was used twice a day at least 2 h between 0 and 60 degrees of knee flexion. The patients removed the brace daily for passive flexion of the knee while in the prone position. At 8 weeks, the brace was discontinued and knee range of motion (ROM) exercises in addition to active-assisted and full active ROM exercises were continued. Patients were allowed to return to full activity between 9 and 12 months after surgery. The same protocol was used during the follow-up period.

Follow-up evaluation

Follow-up evaluation at a minimum of 10 years consisted of radiographic evaluation, self-administered questionnaires; the Tegner activity level score [30], Lysholm knee rating score [30], KOOS and IKDC-2000 form [31], physical examination focused of ROM and knee stability using KT-1000 arthrometer, and knee performance tests (single-leg hop tests).

Radiologic evaluation of knee osteoarthritis

Standing radiographs were obtained on all patients at follow-up (minimum 10-year post operatively). The SynaFlexer™ system (Synarc, San Francisco, USA) for standardized positioning in a non-fluoroscopic fixed-flexion radiographic acquisition was used for the radiographs. A standardized degree of knee flexion (20°) and external foot rotation (5°) were achieved with the use of the SynaFlexer™ calibration and positioning frame [32]. The radiographs were evaluated using the Kellgren–Lawrence (KL) classification [33] by two board certified surgeons with experience in knee surgery and using this system. Grade 2 has been used as a cutoff for defining knee OA [34]. This classification system has been reported to have both high intrarater and interrater reliabilities [33]. Because of the high intrarater and interrater reliabilities reported for the KL classification, only one set of measurements was used.

Subjective knee function questionnaires

The Lysholm score was initially designed for use in patients following ACL reconstruction [35, 30]. Lysholm and Tegner scores were used in this study to enable comparisons to other previously published studies and due to the use of these questionnaires for previous follow-up studies. The IKDC-2000 has been recommended for use internationally to compare data [31]. For this 10-year follow-up, the KOOS functional score was also used.

Clinical test of knee stability

Patients underwent physical examination by one of the senior authors. Range of motion was measured with a standard goniometric technique. Knee joint laxity was evaluated using the Lachman, pivot shift, reverse pivot, posterior drawer, and varus/valgus stress tests compared to the uninjured contralateral limb. The PCL was examined using the posterior drawer test [27]. The posterolateral corner was evaluated with the reverse pivot shift, the dial test, and varus stability at 0° and 30°. Finally, tibial translation in the anterior and posterior direction was measured with the KT-1000 arthrometer (MEDmetric, San Diego, California). The KT-1000 arthrometer was used to record anterior tibial displacement (ATT) of the tibia relative to the femur at 134 N and the manual maximum force [26]. A side-to-side difference of 3 mm or more translation of tibia was defined as abnormal. In the analysis, the manual maximum force side-to-side difference is reported.

Single-leg hop tests

Knee function was evaluated using four single-leg hop tests (one leg hop, triple jump test, cross-over test, and timed hop test), as described by Noyes et al. as performance-based measures of knee function [36]. All testings were done by a senior physical therapist.

Institutional Review Board approval was obtained (Regional Committee for Medical and Health Research Ethics South East Norway, Section C—IRB00001870 REK Sør-Øst C), and the patients provided informed consent to participate.

Statistical analysis

The prevalence of radiographic OA using the KL grading system was compared between injured and uninjured knees using McNemar's test for paired nominal data and subgroup comparisons for OA prevalence were assessed with Fisher's exact test. Odds ratios (OR) were reported with 95% confidence intervals which indicate the precision around the OR estimate. Wide confidence intervals may signify lower statistical power associated with the test. Body mass index (BMI), age at surgery, meniscal injury at surgery, cartilage injury at time of surgery, mechanism of injury, and side of injury (medial versus lateral sided injuries) were investigated for associations with OA.

The association between continuous predictors and OA was evaluated using simple logistic regression models. Within these models, nonlinear effects were allowed via restricted cubic splines which were plotted and tested for statistical significance with the likelihood ratio test. Analyses involving the Tegner activity scale used Wilcoxon signed-rank tests (WSR), while analyses of other continuous outcomes utilized independent Welch's *t* tests and linear regression. Unless otherwise noted, medians were reported with the first and third quartiles in brackets and means were reported ± SD. *P* values were not adjusted for the number of outcome scales or potential predictors. The statistical programming language R was used for all analyses (R Development Core Team, Vienna, Austria) [37].

Results

One-hundred and eleven patients met the inclusion criteria. Sixty-five patients were available for follow-up. Five patients had total knee replacement surgery during the time of follow-up, 5 patients were reported as dead due to causes not related to the knee injury, and 5 patients had emigrated. Thirty patients were not available for follow-up (Fig. 1; Table 1). Patients' lost-to-follow-up was disproportionately male and was treated in the chronic phase, but did not significantly differ from the study sample with respect to age or injury pattern.

For patients available for follow-up ($n = 65$), the mean age at surgery was 36.0 ± 13.4 years and the mean follow-up time was 13.1 years (range 10–18.8 years) (Table 1).

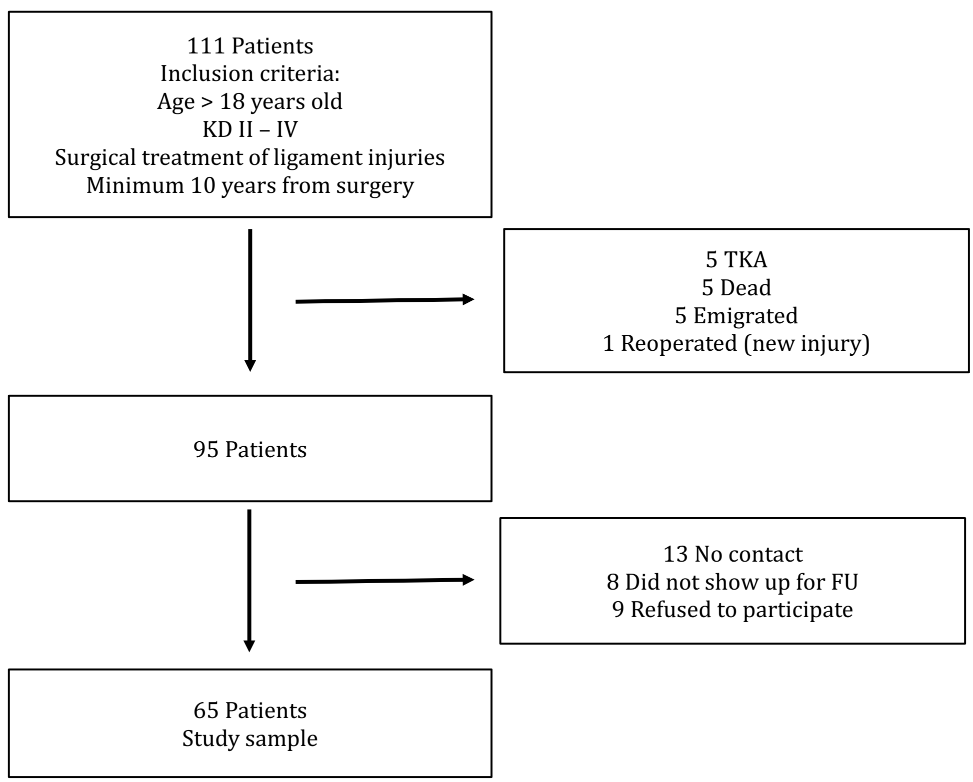

Fig. 1 Flow chart of the study. *KD* knee dislocation, *TKA* total knee arthroplasty, *FU* follow-up

Table 1 Patient characteristics for study cohort at follow-up and dropouts

	Sample cohort ($n = 65$)	Lost-to-follow-up ($n = 30$)	*p* value
Age at injury (years)	35.0 ± 14.1	30.0 ± 11.5	n.s
Days from injury to surgery (acute/chronic)	10 [8, 13]/279 [133, 628]	11 [7, 12]/368 [274, 981]	0.020
Gender (male/female)	$n = 36$ (55%)/$n = 29$ (45%)	$n = 24$ (80%)/$n = 6$ (20%)	0.024
Energy (high/low)	$n = 31$ (48%)/$n = 34$ (52%)	$n = 12$ (44%)/$n = 15$ (56%)	n.s
Acute/chronic	$n = 33$ (51%)/$n = 32$ (49%)	$n = 8$ (27%)/$n = 22$ (73%)	0.046

Data presented as count (%), mean ± SD, or median [first quartile, third quartile]. *P* values correspond to the independent *t* test, Wilcoxon signed-rank test or Fisher's exact test

Table 2 Ligament injury patterns for study cohorts and dropouts according to Schenck knee dislocation classification

	Sample cohort ($n=65$)	Lost-to-follow-up ($n=30$)
KD II	4	4
KD III-M	34	14
KD III-L	21	8
KD IV	6	4

Table 3 Radiographic assessment of the injured and uninjured knees using the Kellgren–Lawrence (KL) classification

	Injured	Uninjured
KL grade 0	10 (15%)	54 (83%)
KL grade I	28 (43%)	7 (11%)
KL grade II	15 (23%)	2 (3%)
KL grade III	9 (14%)	2 (3%)
KL grade IV	3 (5%)	0 (0%)

Thirty-one of 65 patients (48%) had low-energy trauma and 34 (52%) had suffered high-energy trauma as the cause of knee dislocation. Twenty patients (31%) had road traffic related injuries, while 31 (48%) had sports related injuries (including 18 (28%) with skiing injuries), and other activities accounted for 14 (21%) of the injuries. Twenty-five patients (39%) had concomitant meniscus injuries, and 25 (39%) had articular cartilage injuries. Fifteen (23%) patients had common peroneal nerve injuries, and five patients (8%) had vascular injuries. Nerve injuries were treated non-operatively, and vascular injuries were treated with saphenous vein by-pass grafts.

Thirty-three patients (51%) were treated in the acute phase, while 32 (49%) were treated in the chronic phase (≥21 days). The mean time to surgery was 10 and 279 days in patients treated acutely and in chronic phase, respectively (Table 1). The ligament injury patterns according to the Schenck classification [24] are listed in Table 2.

Knee osteoarthritis at minimum 10-year follow-up

Radiographic osteoarthritis was significantly more prevalent in the injured knee compared to the uninjured knee (42 versus 6%, $p<0.001$). In 50 out of 65 patients, the injured knee exceeded the uninjured knee by at least one K–L grade (Table 3). The probability of osteoarthritis in the injured knee was significantly associated with higher patient age at surgery (likelihood ratio test, $p=0.0186$, Fig. 2). BMI was not a significant predictor for OA in the injured knee (n.s).

Lateral-sided injury [versus medial-sided injury, OR = 0.577, 95% CI (0.146, 2.087), n.s], meniscus injury [OR = 2.602, 95% CI (0.838, 8.400), n.s], and cartilage injury [OR = 1.990, 95% CI (0.644, 6.289), n.s] were not significantly associated with OA. High-energy injury [OR = 0.454, 95% CI (0.145, 1.371), n.s], chronic injury [OR = 1.382, 95% CI (0.462, 4.207), n.s], and sport injury (sport versus motor) [OR = 0.855, 95% CI (0.221, 3.157), n.s] were also not significant. Of the six patients who had injury to all four ligament structures (KD IV), four developed OA.

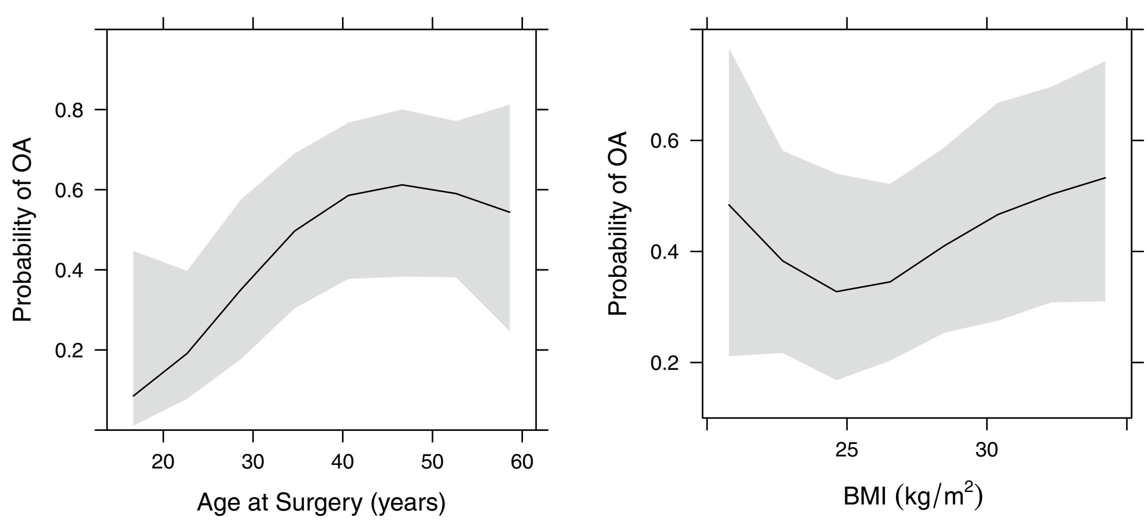

Fig. 2 Modeled probability of OA in the injured knee derived from logistic regression models with restricted cubic spline relationship allowed for age at surgery and BMI. Each effect is unadjusted for other predictors. The shaded region represents a 95% confidence band for the modeled probability

Subjective outcome scores at follow-up

Postoperatively, the median Tegner activity score of the cohort was 4 (range 1–8). Mean Lysholm score was 84 ± 17, and the mean IKDC-2000 subjective score was 73 ± 19. Mean scores of 78, 81, 87, 54, and 64 were observed for the symptoms, pain, ADL, sport, and QoL subscales of the KOOS score, respectively. The KOOS subscales of symptoms, ADL and QOL, were significantly different between the OA and no OA groups ($p < 0.05$), while the subscales of pain and sport were not significantly different between the two groups. Patients with cartilage injury at surgery had significantly lower IKDC-2000 scores compared to those without cartilage injury. The results are summarized overall and by injury detail in Table 4, and the KOOS scores are plotted in Fig. 3.

Knee function assessed by physical exam

Eighty-three percent of the patients had full extension compared to the contralateral side on examination at a minimum 10 years of follow-up. Median flexion was 120° [115, 130]. KT-1000 knee arthrometer using the maximum manual side-to-side test showed a median ATT difference of 2 mm [0, 15]. The patient's age, sex, BMI, chronicity, and injury pattern were non-significantly associated with KT-1000 (maximum manual) side-to-side difference. The subjective knee laxity tests scores are reported in Table 5.

Table 4 Unadjusted patient reported knee function scores at follow-up

Subgroup	Tegner	Lysholm	IKDC	KOOS Symptoms	KOOS Pain	KOOS ADL	KOOS Sport	KOOS QOL
All knees	4 [3, 5]	84 ± 17.2	73 ± 18.9	77.5 ± 16	81.2 ± 19.4	87 ± 16.4	54.3 ± 31	64.4 ± 28.2
No meniscus tear	4 [3, 5.75]	84.1 ± 17.5	75.5 ± 17.2	80.3 ± 15	84.8 ± 17.7	89.7 ± 13.8	58.6 ± 30.3	69 ± 27.1
Meniscus tear	3 [3, 4]	83.7 ± 17.3	69.6 ± 21.1	73.3 ± 16.9	75.7 ± 20.8	82.9 ± 19.2	47.8 ± 31.5	57.6 ± 29
No cartilage injury	4 [3, 5]	86.1 ± 16.3	77.3 ± 19*	78 ± 16.6	83.8 ± 18.8	90.2 ± 13.5	58.3 ± 32.4	69.2 ± 25.7
Cartilage injury	3 [3, 4]	80.9 ± 18.4	67.4 ± 17.7	76.8 ± 15.5	77.2 ± 19.9	82 ± 19.2	48.2 ± 28.2	57.3 ± 30.9
Low energy	4 [3, 4]	84.9 ± 17	73.7 ± 18.4	80.6 ± 15.1	82.1 ± 18.5	86.6 ± 16.2	57.8 ± 31.6	62.3 ± 32.1
High energy	3.5 [3, 6]	83 ± 17.8	72.4 ± 19.8	74.9 ± 16.5	80.4 ± 20.3	87.3 ± 16.7	51.3 ± 30.6	66.3 ± 24.8
Sport	4 [3, 5]	88.6 ± 14.9	78.4 ± 15.6	82 ± 15.4	84.4 ± 19.3	90.1 ± 14.6	64.2 ± 28.6*	69 ± 28.7
Traffic	3 [2.5, 4]	80.6 ± 18	69.4 ± 20.7	73.7 ± 14.6	77.5 ± 21	84 ± 19.4	45 ± 27.9	63.5 ± 24.8
Chronic	4 [3, 5]	81 ± 19	70.5 ± 18.3	72.8 ± 17.7*	78 ± 22.3	83.7 ± 18.6	50 ± 29.1	63.2 ± 25.9
Acute	4 [3, 4.25]	86.9 ± 15	75.6 ± 19.5	81.8 ± 13.2	84.1 ± 16.1	90 ± 13.7	58.2 ± 32.6	65.6 ± 30.6

Data is reported as mean ± SD or median [1st quartile, 3rd quartile]

*Statistically significant difference between subgroups

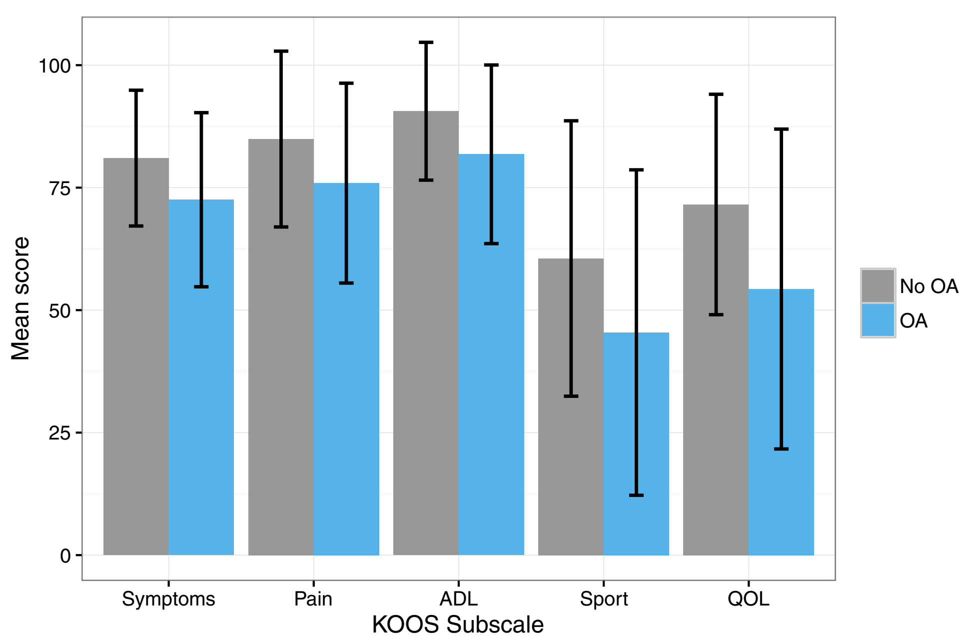

Fig. 3 Mean (unadjusted) KOOS sub-scores at follow-up by OA classification. Error bars represent 1 standard deviation

Table 5 Subjective knee joint laxity tests expressed in percentage of total patients ($n=65$)

Test	Negative	1+	2+	3+
Lachman	54	33	11	2
Valgus	57	38	5	0
Varus	74	13	13	0
Posterior drawer	59	38	3	0
Pivot shift	80	19	1	0
Reverse pivot shift	95	5	0	0
Dial test	92	8	0	0

Among the four single-leg hop tests, the mean score for the injured leg ranged from 88 to 93% of the uninjured leg (Table 6).

Discussion

The most important finding of this study was that after a minimum of 10 years after knee dislocation surgery, 27 (42%) of the patients had radiologic osteoarthritis in the injured knee compared to 4 (6%) on the non-injured knee. However, not all patients with radiologic osteoarthritis had symptoms [38, 20, 22]. The majority of the patients in this study obtained good functional outcomes with a median Tegner score of 4, an average Lysholm of 84 and subjective IKDC-2000 of 73, without much pain (KOOS pain subscale 81). In the follow-up period, only five patients underwent total knee arthroplasty in the injured knee.

Patients older than 30 years at the time of surgery had a significantly higher risk of developing OA in the injured knee compared to those below 30 years of age. Age at surgery was a predictor of Tegner activity score with younger patients having significantly higher scores than older ones. There was no significant difference in IKDC-2000 and Lysholm scores based on age. Levy et al. [38] reported that patients > 30 years of age that undergo multiligament knee reconstruction for knee dislocation have inferior IKDC and Lysholm scores compared to those ≤ 30 years of age; however, there was no significant difference in IKDC-2000 and Lysholm scores based on age in the current study. In the present study, cartilage injury was associated with significantly lower subjective IKDC-2000 scores, and similar findings were reported by King et al. [39] in a mid-term follow-up of 6 years, but there was no significant difference in IKDC-2000 scores for meniscal injuries.

These results show a somewhat higher prevalence of radiologic osteoarthritis than what was reported by Fanelli et al. [23, 28]. In a medium-to-long-term follow-up (5–22 years) of 44 patients with surgical treatment of knee dislocation, Fanelli et al. reported radiographic degenerative joint disease in 23% of patients [23]. Hirschman et al. [16] reported on 68 consecutive patients with a knee dislocation at a mean follow-up of 12 years, and the prevalence of knee osteoarthritis was 30.9%. The wide range of follow-up time (1–27 years) makes comparison to the present study difficult. In a study by Plancher et al. [18], 48 patients (50 knees) were retrospectively evaluated after a mean of 76.8 months. Patients treated surgically ($n=31$) were less likely to develop severe radiographic degenerative changes (47.4%) versus patients treated non-operatively (88%; $n=19$). The long-term negative effects of knee laxity on cartilage and menisci has been documented [40–43]. However, in the present study, chronicity was not found to be associated with development of osteoarthritis.

Patient reported outcomes were comparable to previous studies. Previous studies reported Tegner scores of 4–5 and Lysholm scores of 83–84 [23, 16]. However, previous studies included patients with a shorter follow-up, compared to the present study. The present study demonstrated that good functional outcomes can be achieved even at longer follow-up. To the knowledge of the authors, this is the first study with a minimum 10-year follow-up of patients treated surgically for knee dislocations.

This study has some limitations. Unfortunately, not all patients were available for follow-up. Since the patients included in the study were from the whole country, some were not available to follow-up due to long travel distances and time constraints. It is possible that only the patients who were satisfied with outcomes showed up for follow-up. In addition, given the present study's sample size, and the highly multifactorial nature of subjective outcomes

Table 6 Single-leg hop test comparing the injured (operative) to the injured extremity

	Number tested (n)	Number unable to perform test	Injured side in percentage to uninjured side (%)	
			*Mean ± SD	*Median [1st Q, 3rd Q]
Single-leg hop test	52	13	88 ± 27	89 [74, 108]
Triple hop test	50	15	88 ± 18	93 [80, 100]
Cross-over hop test	45	20	92 ± 23	96 [83, 105]
Six meter timed hop test	49	16	93 ± 21	91 [81, 105]

*Calculated from number tested

and progression to OA, a multiple predictor model was not pursued. Future research is required to uncover the interdependence among important predictors of outcomes following surgical treatment of knee dislocation. Improved medium-to-long-term patient outcomes can be expected after knee dislocation surgery. Patients being treated for knee dislocation should be counselled about the increased long-term risk of post-traumatic OA.

Conclusions

Twenty-seven patients (42%) developed OA 10 years after surgical treatment of knee dislocations. Patients reported improved knee function and minimal-to-moderate pain. Age at surgery was a predictor of development of OA, with more patients > 30 years at the time of surgery developing OA. Meniscal and cartilage injuries at time of surgery were not associated with development of OA. Patients being treated for knee dislocation should be counselled about the increased long-term risk of post-traumatic OA.

Author contributions L.E, S.L, and T.L were involved in patient treatment, study design, data analysis, and manuscript writing. R.F.L, G.M, and G.D were involved in study design, data analysis, and manuscript writing.

Compliance with ethical standards

Conflict of interest One or more of the authors have declared the following potential conflict of interest or source of funding: L.E.: Acta Orthopaedica: Editorial or governing board, AOSSM: Board or committee member, BJSM: Publishing royalties, financial or material support, ESSKA: Board or committee member, JBJS–American: Editorial or governing board, Knee: Editorial or governing board, KSSTA: Editorial or governing board. Research grants from Health South East Norway, Smith and Nephew and Biomet. Arthrex Inc. (consultant, IP royalties), R.F.L.: Arthrex Inc. (consultant, IP royalties, research support), Ossur (consultant, research support), Smith & Nephew (consultant, IP royalties, research support). G.M: South Eastern Norway Health Authorities (research grant), Arthrex Inc. (research grant). The other authors report no potential conflict of interest.

Ethical standards Institutional Review Board approval was obtained (Regional Committee for Medical and Health Research Ethics South East Norway, Section C—IRB00001870 REK Sør-Øst C).

Informed consent Informed consent was obtained from all individual participants included in the study.

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