Revision Anterior Cruciate Ligament Surgery: From Predictors of Revision and Causes of Failure to Clinical Outcomes and Osteoarthritis Development

Søren Vindfeld

Thesis for the degree of Philosophiae Doctor (PhD)
University of Bergen, Norway
2026

UNIVERSITY OF BERGEN

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Date of defense: 27.03.2026

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Year: 2026

Title: Revision Anterior Cruciate Ligament Surgery: From Predictors of Revision and Causes of Failure to Clinical Outcomes and Osteoarthritis Development

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Print: Skipnes AS / University of Bergen

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1. Scientific environment

The work presented in this thesis has grown out of my clinical interest in patients who experience failure after anterior cruciate ligament surgery. This research was carried out during my time as a consultant orthopedic surgeon at Haraldsplass Deaconess Hospital in Bergen, Norway. The studies included in this thesis were conducted within the Sports Traumatology and Arthroscopic Research Group (STAR), and Study II was performed in collaboration with the Norwegian National Knee Ligament Register.

I have been very fortunate to work under the supervision of Professor Eivind Inderhaug, Dr. Torbjørn Strand, and Professor Eirik Solheim, whose guidance, support, and encouragement have been invaluable throughout this process. I would also like to acknowledge the Department of Surgery at Haraldsplass Deaconess Hospital for providing the financial support that made this work possible.

This thesis is submitted as part of the PhD program at the Department of Clinical Medicine (K1), Faculty of Medicine, University of Bergen, Norway.

Haraldsplass
Diakonale sykehus

STAR
Sports Traumatology and
Arthroscopy Research Group

UNIVERSITY OF BERGEN
Faculty of Medicine

2. Acknowledgements

The main work of this thesis was carried out while I was a consultant doctor at Haraldsplass Deaconess Hospital. I would like to express my sincere gratitude to my colleagues at both Haraldsplass and Haukeland University Hospital, especially the knee sections at both hospitals, for their inspiration and support throughout these years. Also, thanks to the Surgical Department at Haraldsplass for their assistance in facilitating the work of this thesis. Finally, my heartfelt appreciation goes to all the patients who dedicated time and energy into the follow-up evaluations and made this thesis possible. A special thanks goes to:

Torbjørn Strand, this thesis grew out of your meticulous work in systemizing, documenting, and treating ACL patients over decades. Your attention to detail and foresight in establishing structured quality control for this large group of patients, decades ahead of your peers, have been a true inspiration. However, the most important lesson you have taught me is the value of genuine care and the tireless effort you dedicated to your patients.

Eivind Inderhaug, you were there when I came to HDS the first time. And you have been a close colleague and friend ever since. To me, your dedication to research, and, above all, your leadership in this field and in establishing STAR, are truly impressive and inspiring. I highly appreciate your guidance and the countless hours you have spent providing constructive feedback and challenging me to continuously improve.

Eirik Solheim, your precise and instant feedback, positivity and ideas has been very valuable to me throughout this process. Your ability making the complex simple, and bringing elegance into research is an example to follow.

Line Lindanger, although you have not officially been a supervisor, you have always had that role in my mind, and you have been an invaluable part of this project. Your door has always been open, and I greatly appreciate your wise, thorough, and

insightful feedback. Even more importantly, I truly appreciate you as a fellow orthopedic surgeon, sharing a common interest in improving our field.

Co-Authors: Andreas Persson, Håvard Visnes, Anne-Marie Fenstad, Anagha P Parker and Idunn M B Augland, Thank you for being part of this journey, and for the valuable discussions on data quality, radiographic assessment, and statistical methods. I sincerely hope our collaboration will continue in the future.

Thomas Harlem: Thank you for all the discussions on practical management of revision patients, for giving me the opportunity to grow, and for believing in me. I truly enjoy spending time in the operating room with you.

Anne Gro Faleide, Trine Hysing-Dahl and Ingunn Fleten Mo: Thanks to each one of you for all great talks over morning coffee, lunch or whenever needed in the STAR-coridoor. Each one of you are higly apprectiatied as close colleagues, always ready to share ups and downs, letting an ear, brainstorm or chat. I am very grateful that we have this close but informal collegial group, and I hope for continued collaborating in the future.

STAR: None mentioned, none forgotten — being part of this research group has been of great motivation. To be among researchers with a genuine interest in the academic growth and well-being of colleagues, as well as in interdisciplinary respect, is both humbling and rewarding.

I would like to thank my parents and siblings—Kaare, Bodil, Lars, and Karen—for their never-ending support, engaging discussions about medicine and life, and for always being there. To my three wonderful children, Aksel, Karoline, and Johan, who have grown up during this project: thank you for accepting a father challenged by writing, and for always reminding me what is most important in life. Finally, to my wife and life companion, Lene: thank you for bearing with me during frustrating and difficult times, and for supporting me in achieving this goal. Without your insights, feedback, and unwavering support, this would not have been possible.

3. Terms and abbreviations

ACL	Anterior Cruciate Ligament
aOR	Adjusted Odds Ratio
BMI	Body Mass Index
BPTB	Bone Patella Tendon Bone
CI	Confidence Interval
CT	Computed Tomography
HDS	Haraldsplass Deaconess Hospital
HR	Hazard Ratio
HT	Hamstring Tendon
HTO	High Tibial Osteotomy
IKDC	International Knee Documentation Committee
IKDC-SKF	International Knee Documentation Committee – Subjective Knee Form
IQR	Interquartile Range
JSN	Joint Space Narrowing
KOOS	Knee injury and Osteoarthritis Outcome Score
K-L	Kellgren – Lawrence
LEAP	Lateral Extra-Articular Procedure
MARS	Multicenter ACL Revision Study
MRI	Magnetic Resonance Imaging
NKLR	National Norwegian Knee Ligament Register
NSD	Norwegian Center for Research Data
OA	Osteoarthritis
PASS	Patient Acceptable Symptoms Score
PROMs	Patient Related Outcome Measures
PT	Patella Tendon
QoL	Quality of Life
RCT	Randomized Controlled Trial
REK	Regional Ethics Committee

4. Abstract in English

Background: Revision anterior cruciate ligament (ACL) surgery is complex and heterogenous with a wide range of factors related to failure of the primary surgery. Understanding failure after ACL reconstruction is essential to succeed with revision ACL surgery. The literature contains limited studies with long-term follow-up and comparable control groups. The occurrence of revision surgery is rare in most clinical settings and the use of community-based registries can further enlighten the reasons of failure.

Objectives: This project aims to improve the understanding of predictors and causes of failure after primary ACL surgery, and long-term outcomes after revision ACL surgery. Specifically, it will examine patient-related risk factors for inferior outcomes after primary surgery, describe surgeon-reported causes and timing of revision surgeries in Norway (2004–2023), and evaluate long-term results of revision procedures performed at Haraldsplass Deaconess Hospital (HDS) (2004–2016).

Methods: The thesis is based on a combination of institutional case–control studies and nationwide registry data to comprehensively investigate revision ACL reconstruction outcomes. Across three cohorts, comparing revision versus uneventful primary reconstructions to analyze demographic and surgical risk factors, and assess causes of failure leading to revision. Survival analyses will aim to quantify revision risk, while medium- to long-term follow-up including clinical outcome, radiological evaluation, and patient-reported outcomes to provide a broader understanding of revision ACL outcomes.

Results: Paper I: In 100 revision cases versus 100 controls (11-year follow-up), revisions were younger, had shorter injury-to-surgery time, smaller grafts, and more frequent meniscal repair failure, while surgeon experience showed no effect.

Paper II: Among 30,038 primary ACL reconstructions, 1,599 revisions (7.1% at 15 years) were identified, with younger age, male sex, hamstring tendon autograft, and absence of cartilage/meniscal injury all being associated with increasing risk. New trauma (38%) was the most reported cause of failure.

Paper III: Among 273 patients (140 revisions, 133 primary reconstructions), radiographic evidence of osteoarthritis (OA) was more common after revision (67% vs 33%). Higher body mass index (BMI), meniscal injury, and longer time to follow-up increased OA risk. Both groups improved clinically, but outcomes including achievement of patient acceptable symptom state (PASS) were superior after primary reconstruction.

Conclusions: This thesis demonstrates that younger age, shorter injury-to-surgery interval, failed meniscal repair, and small hamstring grafts are all associated with failure after primary ACL reconstruction leading to revision surgery. Hamstring grafts carry a higher risk of early failure, while new trauma is the most common cause of failure. Although revision patients had worse long-term outcomes and higher osteoarthritis prevalence than primary ACL patients, they still achieved meaningful improvements and reported high satisfaction.

Implications: This thesis draws on both an institutional matched cohort, providing a pragmatic view of a heterogeneous and unselected group of revision patients, and a large national Norwegian cohort, enabling robust analysis of the timing and causes of failure leading to revision. Clinically, careful graft selection and protection of meniscal repairs are essential to reduce the risk of revision. Younger patients should be counseled regarding their higher risk, and preventive strategies should be emphasized. As revision surgery yields less favorable long-term results, optimization of primary surgery should be a main goal to ensure the best possible long-term prognosis.

5. Abstract in Norwegian

Bakgrunn: Revisjonskirurgi etter fremre korsbåndsrekonstruksjon er komplekst og heterogent, med et bredt spekter av faktorer som kan være knyttet til svikt av primærkirurgien. For å lykkes med revisjonskirurgi er det avgjørende å forstå mekanismene bak svikt etter ACL-rekonstruksjon. Det finnes få studier i litteraturen som rapporterer langtidsoppfølging med en sammenlignbar kontrollgruppe. Forekomsten av revisjonskirurgi er lav i de fleste kliniske settinger, og bruk av befolkningsbaserte registre kan bidra til å belyse årsakene til svikt ytterligere.

Mål: Dette prosjektet har som mål å øke forståelsen av prediktorer og årsaker til svikt etter primær rekonstruksjon av fremre korsbånd, samt langtidsutfall etter revisjonskirurgi av fremre korsbånd. Mer spesifikt vil det undersøke pasientrelaterte risikofaktorer for dårligere resultater, beskrive kirurgrapporterte årsaker og tidspunkt for revisjonskirurgi i Norge (2004–2023), samt evaluere langtidsresultater etter revisjonsprosedyrer utført ved HDS (2004–2016).

Metode: Avhandlingen bygger på en kombinasjon av institusjonsbaserte kasus–kontrollstudier og nasjonale registerdata for å undersøke resultater etter revisjonskirurgi for fremre korsbånd. Tre ulike kohorter ble analysert, der revisjoner ble sammenlignet med ukompliserte primære rekonstruksjonsforløp for å identifisere demografiske og kirurgiske risikofaktorer og vurdere årsaker til svikt som fører til revisjon. Overlevelsesanalyser ble benyttet for å beregne revisjonsrisiko, mens middels- til langtidsoppfølging inkluderte kliniske resultater, radiologiske evalueringer og pasientrapporterte utfall for å gi en bredere forståelse av resultater etter revisjonskirurgi for fremre korsbånd.

Resultater: *Artikkel I:* I artikel I blev 100 revisjonstilfeller og 100 matchede kontroller (11 års oppfølging) sammenlignet. Pasientene i revisjonsgruppen var yngre, hadde kortere tid fra skade til kirurgi, oftere tynnere graft og høyere frekvens

av manglende tilheling etter tidligere meniskreparasjon. Man fandt ikke betydning av forskjelle i erfaringsnivået til kirurgen.

Artikkel II: Blant 30 038 primære ACL-rekonstruksjoner ble 1 599 revidert, noe som tilsvarer en revisjonsrate på 7,1 % etter 15 år. Yngre alder, mannlig kjønn, bruk av hamstringgraft og fravær av brusk- eller meniskskade ved primærkirurgi var assosiert med økt risiko for svikt, mens ny skade (38 %) var den hyppigst rapporterte *årsaken* til svikt.

Artikkel III: Blant 273 pasienter (140 revisjoner, 133 primære rekonstruksjoner) var radiologiske tegn til artrose mer vanlig etter revisjon (67 % mot 33 %). Høy kroppsmasseindeks, meniskskade og lengre tid til oppfølging økte risikoen for artrose. Begge grupper oppnådde kliniske forbedringer, men de primære rekonstruksjonene hadde bedre resultater og en større andel nådde pasientakseptabelt symptomnivå.

Konklusjon: Denne avhandlingen viser at yngre alder, kortere tid fra skade til kirurgi, manglende tilheling etter samtidig meniskreparasjon og små hamstringgraft er assosiert med økt risiko for revisjonskirurgi etter rekonstruksjon av fremre korsbånd. Hamstringgraft var særlig utsatt for tidlig svikt, og ny skade var den hyppigste årsaken til revisjon. Revisjonspasienter hadde dårligere langtidsresultater og høyere forekomst av artrose enn pasienter med primær rekonstruksjon, men oppnådde likevel klinisk meningsfulle forbedringer og rapporterte høy tilfredshet.

Implikasjoner: Denne avhandlingen bygger på både en institusjonell matchet kohort, som gir et pragmatisk bilde av en heterogen og uselektert gruppe revisjonspasienter, og en stor nasjonal norsk kohort, som muliggjør en robust analyse av tidspunkt og årsaker til svikt som fører til revisjon. Klinisk understreker funnene viktigheten av nøye graftvalg og beskyttelse av meniskreparasjoner for å redusere risikoen for revisjon. Yngre pasienter bør informeres om sin høyere risiko, og skadeforebyggende tiltak bør fremheves. Ettersom revisjonskirurgi gir mindre gunstige langtidsresultater, bør optimalisering av primærkirurgi være et hovedmål for å sikre best mulig langtidsprognose.

6. List of Publications

I. Vindfeld S, Strand T, Solheim E, Inderhaug E. Failed Meniscal Repairs After Anterior Cruciate Ligament Reconstruction Increases Risk of Revision Surgery. *Orthop J Sports Med*. 2020;8(10):2325967120960538. doi:10.1177/2325967120960538

II. Vindfeld S, Persson A, Lindanger L, Fenstad AM, Visnes H, Inderhaug E. Revision Anterior Cruciate Ligament Reconstruction: Surgeon-Reported Causes of Failure From the Norwegian Knee Ligament Register. *Am J Sports Med*. 2024;53(4):801-808. doi:10.1177/03635465251316308

III. Vindfeld S, Lindanger L, Strand T, Solheim E, Parkar A P, Augland I B M , Inderhaug E. Osteoarthritis Development and Clinical Outcomes After Revision Anterior Cruciate Ligament Surgery: A Matched Case-Control Study with 10-Year Follow-Up. *Orthop J Sports Med*. 2025;13(10). doi:10.1177/23259671251383083

The publication will henceforth be referred to by their corresponding roman numeral, Paper I, Paper II and Paper III, as noted above.

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7. Introduction

7.1 Background and Clinical Significance

7.1.1 Anterior Cruciate Ligament Injury and Treatment

The Anterior Cruciate Ligament (ACL) is a crucial ligament in the knee, responsible for stabilizing the joint by preventing excessive anterior translation of the tibia and controlling anterolateral rotational stability.[1,2] Injury to the ACL is common among the young and active population, with an annual incidence of 81 in 100,000 in the age group 10 – 64 reported previously.[3,4] An ACL injury can result in reduced knee function, decreased participation in sports, an increased risk of cartilage and meniscal injuries, and early onset of osteoarthritis in the knee. Treatment of ACL injury combines non-operative and operative approaches, with functional rehabilitation, dynamic stability, and neuromuscular control as the cornerstone of care. In the setting of persistent instability following ACL rupture the gold standard is an ACL reconstruction using an autograft, always followed by structured rehabilitation to optimize outcomes.[5,6] Significant improvements to surgical technique, graft options and rehabilitation have been made over the past decades.[7] Despite these improvements, failure after surgery remains high and often necessitates revision ACL reconstruction. Recent reports from the National Norwegian Knee Ligament Register (NKLR) have quantified this risk of failure, reporting a 7.1% revision rate at 15 years.[8] Each year, approximately 200 revision ACL reconstructions are performed in Norway. [9]

The first reported surgical treatment of ACL injury was performed by Mayo Robson in 1885 in Leeds, England, involving suturing of a torn cruciate in a 41-year-old patient. In 1917,[10] Hey Groves published in *The Lancet* what is regarded as the first presumed ACL reconstruction, using a strip of the iliotibial band.[11] While the potential for graft failure and the possible need for revision has existed since these earliest reconstructions, the topic did not gain attention in the literature until the late

1980s and early 1990s, with publications from the University of Pittsburgh group among others.[12]

7.1.2 ACL reconstruction failure, revision surgery and outcomes

Managing a patient who is dissatisfied following primary ACL reconstruction poses significant challenges to the surgeon. A thorough and comprehensive approach is crucial to identify specific issues contributing to patient dissatisfaction, to determine whether ACL reconstruction failure has occurred, and if the patient will benefit from further surgical treatment. Failure after ACL reconstruction is not clearly defined and is often multifactorial. There is no universal consensus on what constitutes failure, and definitions are possibly influenced by the authors' interpretation of the presumed cause.[13,14]

When counseling a patient with a failed ACL reconstruction, predictors of failure are rarely modifiable, but they remain valuable in identifying individuals at high risk. Understanding the underlying cause or causes of failure may allow the surgeon to avoid repeating prior errors and increases the likelihood of achieving a stable knee. In addition, a thorough knowledge of outcomes after revision surgery, and the factors that may influence them, supports effective shared decision-making with the patient regarding surgical techniques, rehabilitation, and return to activity. Such discussions should also emphasize the broader consequences of ACL injury to ensure realistic expectations.

A review of the existing literature identifies several predictors associated with an increased risk of ACL reconstruction failure, including younger patient age, participation in high-risk sports, inadequate rehabilitation, poor graft selection or fixation, and premature return to sport.[15–19] Currently, new trauma and tunnel malposition are regarded as the most significant causes of failure.[20] Outcomes after revision are also generally worse than after primary reconstruction, with lower patient satisfaction, reduced return-to-sport rates, and earlier onset of osteoarthritis.[13,21] These findings highlight the importance of comprehensive

preoperative assessment, meticulous surgical planning, structured rehabilitation, and clear discussions with patients regarding expectations and long-term implications.

For clarity throughout this thesis, revision ACL surgery will be defined as a surgical procedure in which a previously reconstructed ACL graft is replaced by a new graft in a single-stage or two-staged fashion and may include additional adjunctive procedures such as the treatment of meniscus or cartilage injuries, osteotomy, or other ligament repair or reconstruction.[22]

7.2 Epidemiology of ACL graft failure and revision surgery

ACL graft failure is reported with varying incidence in the literature, typically ranging from 3% to 12%, depending on patient populations, surgical techniques, graft selection, rehabilitation protocols, and the duration of follow-up. [23–27] Younger, active patients participating in high-demand sports, particularly those involving pivoting or jumping, demonstrate notably higher failure rates.[15] Since these studies involve a relatively small number of patients and graft failure is an uncommon event, community- or country-based clinical quality registries were established in Scandinavia from 2004 onward. However, these registries primarily report on *revision surgeries*, which are not synonymous with *graft failure.* Reported revision rates range from 2.7% to 6.6% over follow-up periods of 2.5 to 10 years.[8,28–30] The discrepancy between reports on *graft failure* and *revision surgery* is being addressed in a study by Crawford et al. proposing a definition of clinical failure being one or more of the following: an overall International Knee Documentation Committee (IKDC) objective score, pivot shift or Lachman grade C or D, Arthrometer measurement of >5 mm side-to-side difference or re-rupture. When applying this clinical cumulative failure rate in a systematic review of 14 studies including almost 3000 patients, failure after reconstruction went from 6.2% to 11.9%.[31,32]

Understanding the epidemiology of graft failure, including its demographic and clinical risk factors, is essential for surgeons to identify high-risk patients, improve surgical techniques, and develop targeted rehabilitation strategies to reduce ACL

graft failure and enhance long-term outcomes. However, graft failure encompasses more than just revision surgery, as shown in Figure 1.

Study design also plays a key role in assessing failure rates. While traditional research has primarily used revision surgery as the main endpoint, recent studies have increasingly focused on low patient-reported outcome measures (PROMs), highlighting a broader range of failures beyond revision alone.

What is ACL Failure ?

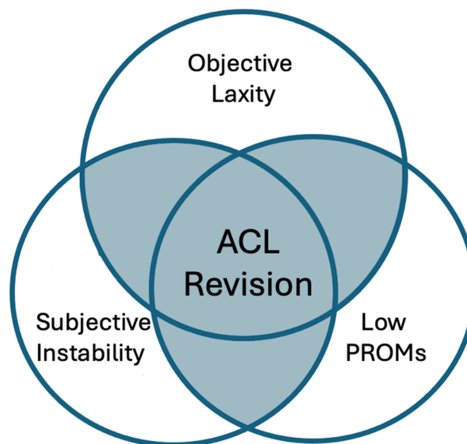

Figure 1. Illustration of failure vs. revision rates: one or more criteria may classify a case as "failure," yet this does not necessarily lead to revision ACL reconstruction. PROMs, patient-reported outcome measures.

7.3 Predictors of Failure in ACL surgery

Predictors are risk factors or patient characteristics present before or at the time of the initial surgery that, when present, statistically increase the likelihood of subsequent ACL reconstruction failure. Although these factors do not necessarily cause failure directly, their presence signals an increased probability of suboptimal outcomes based on their association with failure. This topic has been extensively studied, and numerous factors have been linked with an increased risk of failure.[33] Predictors can

be categorized into patient related and treatment/injury related factors. While not exhaustive, the following review summarizes some of the most important predictors.

7.3.1 Patient related factors

Numerous studies have identified younger age at injury and younger age at surgery to increase risk of failure.[17,29,34–38] It is thought that age reflects a more active lifestyle and possibly lower compliance with rehabilitation. However, measuring an active lifestyle is challenging, and there is a lack of evidence to support or refute this correlation.[39] Maletis et al.[40] demonstrated the increased risk in a study of 21,304 patients where age <21 years had an adjusted hazard ratio (HR) of revision of 7.8 (5.5 – 10.9) compared to age >40 years. Similar findings are reported by Persson et al. with four-fold increase in risk of revision for patients aged 15-19 years at surgery compared to ≥30 years.[38] Female sex has been shown to increase risk of ACL injury in both team handball and soccer, with a 5-fold increase in risk of injury.[41,42] The same association has not been found for risk of ACL reconstruction failure, with several studies finding an increased risk among male patients.[29,36,43,44] Whereas Persson et al. where not able to show sex-specific differences.[38] Increasing BMI has been shown to decrease the risk of revision surgery by Maletis et al.[36] this is supported by a systematic review from Zhao et al., however, Inderhaug et al. were not able to find the same association in a study of more than 4000 patients.[45,46] Cigarette smoking is known to increase risk of complications after surgery, and smokers can expect a worse result than non-smokers, [47] however the evidence to whether smoking increases risk of revision is diverging.[48,49] Other factors, but not an exhaustive list, include hormones, ligament laxity, skeletal maturity, non-steroidal anti-inflammatory drugs, and narrow notch width, all of which have been associated with an increased risk of failure.[46]

7.3.2 Treatment/injury related factors

Graft choice at primary surgery has been widely debated in recent decades, and significant regional variations have been observed.[50] Allograft has the benefit of no donor site morbidity, however, this comes with a cost. Several studies from North

America, where allograft is more common shows increased HR for revision between 1.7 and 3.0.[51,52] The use of a hamstring tendon autograft has also been shown to increase risk of revision by several authors, compared to bone patella tendon bone (BPTB) graft.[36,38] Harvesting technique naturally differs between graft types and smaller graft size for hamstring autografts have been proposed as an risk factor for revision. A study from the Swedish national knee ligament registry showed a 0.86 lower likelihood of revision surgery for every 0.5-mm increase in diameter from 7.0 to 10.0, however an adjusted cox-regression analysis from the NKLR was not able to replicate that finding.[45,53] Several studies from the Scandinavian registries have also identified different graft fixation devices that are associated with increased risk of revision.[54–56] The introduction of the "anatomical technique" and the shift from trans-tibial to antero-medial portal technique, that occurred over the course of the 2000s and 2010s was reflected in studies where the learning curve associated with the shift alone was associated with increased risk.[57] A posterior tibia tunnel placement or a shallow femoral tunnel placement has also been associated with increased risk of revision.[35,58–60] The menisci have long been recognized to play an important role in joint preservation, [61] and to act as a secondary knee stabilizer.[62] Concomitant meniscal repair has been shown to reduce risk of ACL revision.[17] failed repair, or meniscal deficiency has been associated with increased risk of revision.[35,60,63]

The Segond fracture, first described in 1879 by P. Segond, is a secondary radiological sign often closely related to ACL injury.[64] The avulsion has been proposed to be linked to Antero lateral injury – and maybe higher grade ACL injuries, however Gaunder et al.[65] were not able to find this association, and no increased risk of revision was found in a study by Slagstad et al.[66] Another radiological finding that has been proposed to increase the risk of failure is an increased posterior slope of the lateral tibial plateau, as this may increase strain on the ACL graft. However diverging results have been reported in the past decade, and a specific cut-off value for what increased slope is still unclear.[67–70]

Recognizing and understanding predictors for ACL graft failure allows surgeons to proactively manage risk, counsel patients effectively, and make informed decisions regarding surgical technique, graft choice, and rehabilitation strategies to improve overall outcomes for both primary and revision ACL reconstructions. Some surgical errors are more evident than others, and placement of the femoral tunnel outside the condyle will, unsurprisingly, result in failure (Figure 2).

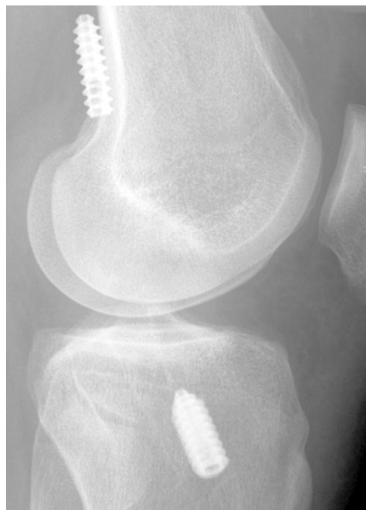

Figure 2. Lateral knee radiograph showing femoral tunnel placement outside the femur, resulting in early failure. Picture from a local patient with permission.

7.4 Outcome Measures, diagnostic tools and clinical examination

The nature of clinical research is to broaden the understanding of injury, disease and treatment. The main purpose of most orthopedic research is comparing the effect of different treatments, to report on a specific treatment, or the natural course of an injury or disease. Having proper measuring tools is essential to succeed. Measuring tools can be categorized depending on the field of research, datatype and method. In the current work quantitative measurements with self-reported, physiological and biometric instruments have been applied.[71] Two important aspects in all measurement

are validity and reliability. Validity meaning the ability of an instrument to measure what it is intended to, and reliability meaning the reproducibility of an instrument between subjects or observers.[72]

7.4.1 Patient related outcome measures

Patient related outcome measures are standardized, self-administered questionnaires that patients complete to provide information on their health status, quality of life, and treatment outcomes. They are widely used in healthcare to assess the effectiveness of treatments from the patient's perspective.[73] They can be categorized as either "generic" or "disease specific." The "generic" considers the general aspects of the patient's overall health – with the advantage of enabling comparison of different diseases or injuries but are not always able to detect important differences in treatment of a specific ailment. The "disease specific" measures are tailored to the symptoms and functional impact of the condition, and can detect small, but important disease specific changes.[71,74]

Knee Injury and Osteoarthritis Score (KOOS)

The KOOS is a self-administered disease specific questionnaire designed in the 1990s as an instrument to assess patients with ACL injury, meniscal injury or post-traumatic OA.[75] It´s a widely used questionnaire in both research and in monitoring knee injury specific disease load in patients. It consists of 42 questions, structured into five subscales: Pain, Symptoms, Activities of Daily Living, Sports and Recreation, and Knee-Related Quality of Life. All sub-scales receive a score from 0-100, where 100 suggest better function/fewer knee-related problems.[76] The sub-scales Sports and recreation and Knee related quality of life have been shown to have the most relevance for younger ACL patients.[77]

The use of KOOS as an instrument for evaluation of ACL patients has received a lot of criticism in the past decades. The subscale p*ain*, *symptoms* and *activities of daily living* seem to have little relevance for the population. *Sports and recreation* and *knee-related quality of life* have had the best responsiveness in this population,

therefore suggestions of selected parts of the 42 questions in the KOOS has been made (KOOS-12 and KOOS-ACL).[78]

International Knee Documentation Committee – Subjective Knee Evaluation Form (IKDC-SKF)

The IDKC-SKF was developed in 1994 and revised to its present version in 2001.[79] It is a self-administered disease specific instrument designed to examine knee symptoms, sports participation and daily activities.[80] It has been shown to be responsive to changes after surgical interventions but lacks documentation for evaluation of OA patients.[79] It consists of 18-items, making it ideal in both research and clinical settings.[71] It calculates into a score from zero to 100 (best) and has been shown to have little floor or ceiling effect for patients with knee conditions. [79]

Tegner Activity scale

The Tegner Activity score was developed in the 1980s to classify intensity of activities for patients suffering knee ligament injuries. It was a complement to the Lysholm score,[81] that was strictly measuring knee symptoms. The Tegner activity score is an ordinal scale from zero to ten where zero is no physical activity/disabled and ten is participation in pivoting sports such as soccer at national or international elite level.[81] The score is widely used in research to classify the average activity level of knee patients but has been met with criticism as to validity of how different sports and physical activities have been placed on the scale.[82]

7.4.2 Clinical evaluation

Clinical evaluation of the knee is a cornerstone in assessing ACL integrity and overall knee laxity. The evaluation is typically started with obtaining medical history, then clinical examination followed by evaluation of available imaging. After a thorough medical history, physical tests are performed to evaluate anterior-posterior and rotational laxity of the tibia relative to the femur. The Lachman test[83] is considered the most sensitive maneuver for detecting ACL insufficiency, with sensitivity

reported at 87% and specificity of 93%,[84] and its instrumented version, the KT-1000 arthrometer, provides an objective quantification of anterior translation.[83] The anterior drawer test can add information but is less reliable since it evaluates laxity in 70-90 degrees of flexion where the ACL is less active.[84] The pivot-shift test is valuable for assessing antero-lateral rotational instability, though technically demanding and reliant of experience and patient relaxation, the test is often more reliable under anesthesia.[85] Magnetic resonance imaging (MRI) or arthroscopic evaluation is considered the gold standard in the diagnosis of ACL injury, with sensitivity and specificity for MRI-based diagnosis reported at 94% and 95%. However, this does not always reflect the degree of laxity, and sensitivity and specificity for MRI-based assessment of ACL graft rupture is reportedly significantly lower at 60% and 87% respectively.[86,87] Together, these examinations provide essential information for diagnosing ACL rupture, grading instability, planning treatment, and monitoring outcomes; however, clinicians should be aware of the limitations in interrater reliability when using the Lachman and Pivot Shift tests, and consider supplementing with more directly quantifiable measurement methods.[88]

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7.5 Causes of ACL reconstruction failure

Direct *causes* of ACL reconstruction failure are typically described as technical errors during surgery, insufficient graft incorporation, or subsequent traumatic events, whereas *predictors* are more often related to patient- or graft-specific factors such as younger age, male sex, high activity level, and small graft size.[29,37,56,89–91] These categories, however, frequently overlap. For example, younger and possibly more active patients are at increased risk not only because of their demographic and activity profile, but also because participation in sports and more likely exposure to new trauma after reconstruction.[15,25]

A three-category model for understanding the causes of ACL reconstruction failure was originally proposed by the University of Pittsburgh group and later modified by

the Multicenter ACL Revision Study (MARS) group. [92,93] In this framework, failure causes are classified into three main categories: *traumatic*, *technical*, and *biological*. *Traumatic* failures typically result from re-injury or graft rupture, *technical* failures could arise from tunnel malposition or fixation errors, and *biological* failures may involve inadequate graft incorporation.[60,94,95]

There is limited available documentation regarding the development or rationale for the creation of the model. In the publication from the MARS group, it was reported that surgeons participating in the multicenter cohort had attended at least one training course in which cases were evaluated and classified into categories by consensus.[92] Nevertheless, several authors support this three-category model for understanding the causes of ACL reconstruction failure.[20,59,90,96] Further detail on the application of the model is provided by Jaecker et al.[59], who reported that classification of the cause as *traumatic* was based on a patient-completed pre-revision questionnaire. If no *traumatic* cause was indicated, the failure was classified as *non-traumatic* and further subclassified as either *technical* or *biological*. Classification as *technical* was based on the operating surgeon's assessment of preoperative computed tomography (CT) scans and clinical examination. The classification as *biological* was assigned in cases with a history of intra-articular infection, or when neither a *traumatic* nor a *technical* cause could be identified.

The three-category model provides a practical framework for grouping ACL reconstruction failures into technical, biological, and traumatic causes. In the following, each category will be reviewed in more detail to clarify definitions and relevance for clinical practice and research.

Technical factors are frequently cited as the leading cause of failure, with reported rates ranging from 22% to 64.5%.[20,59,60,94] Tunnel placement errors are the most frequent issue, with femoral tunnel malposition accounting for 60–79% of tunnel-related problems.[97,98] Drilling the *femoral* tunnel too anteriorly or vertically may lead to graft impingement against the intercondylar roof, residual instability, restricted range of motion or early re-rupture because of excessive strain on the graft.[99] *Tibial*

tunnel malpositioning may cause abnormal graft strain, increased laxity, or impingement.[58,99,100] Because of the close proximity to the posterior lateral condylar wall, femoral tunnel malposition may result in posterior wall blowout (Figure 3) If recognized intraoperatively, this complication can necessitate substantial changes in surgical technique; if unrecognized, it may lead to early graft failure due to loss of fixation. [101] Inadequate graft fixation, inappropriate graft choice, failure to address concomitant meniscal, chondral, or ligamentous injuries, and poorly structured rehabilitation protocols are also considered *technical* reason for failure.[102]

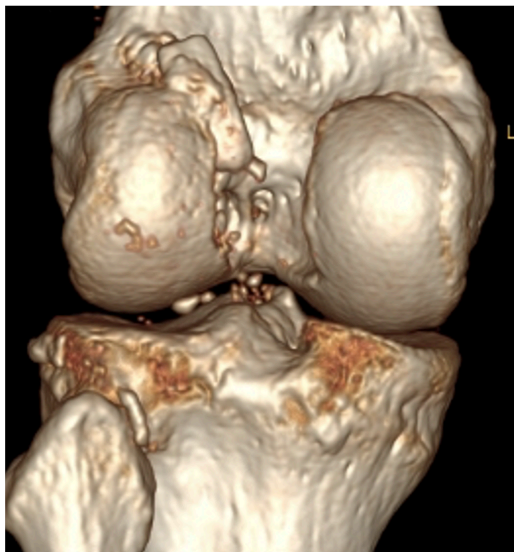

Figure 3. 3D CT reconstruction demonstrating a posterior wall blowout, with the patellar bone block and interference screw visible in the upper left quadrant. Image obtained from a local patient with permission.

Biological factors are reported less frequently, accounting for approximately 6–8% of failures.[20,59,92] These reflect the patient's healing capacity and graft incorporation. After reconstruction, the graft undergoes necrosis, revascularization, and remodeling over more than a year.[103] Poor revascularization, immune rejection, or weak tendon-to-bone healing increase vulnerability, while systemic factors such as age, genetics, smoking and metabolic disease further influence failure risk.[104–106] Intra-articular infection represents another important biological cause of graft failure, as it can

compromise graft integrity and healing.[104] Biological factors are, by some authors, also defined as cases in which no clear traumatic or technical cause of failure can be identified.[59,90]

Traumatic factors are by many authors reported as the most common cause of failure leading to revision, ranging from 24% to 38% of cases.[8,20,59,94,107] They are particularly prevalent in younger and highly active patients. High-energy reinjury, premature return to pivoting sports, or accidents during rehabilitation may directly damage the graft. Recurrent instability and microtrauma can also drive meniscal injury, cartilage wear, and long-term degeneration, even if the graft remains intact.[108,109]

Variation is seen in definitions and the classifications used in reporting the causes of ACL reconstruction failure across studies, and the heterogeneity contributes to inconsistent failure rates and complicates comparison between studies. Some authors also reflect on the multifactorial cause of failure and report on combinations of causes.[20,90] As a result, it is often difficult to clearly distinguish predictors from direct causes in both clinical and research contexts.[110]

7.6 Functional and clinical outcomes after revision ACL reconstruction

Functional and clinical outcomes after revision ACL reconstruction are consistently reported to be less favorable than those following primary reconstruction.[91,94,111–114] Although the procedure may still provide meaningful improvements in pain, stability, and quality of life, patients often demonstrate lower scores om PROMs compared to primary reconstructions and face a higher risk of complications and yet another failure.[115–117] Cristiani et al. found that revision patients demonstrated improvement only in the *Sports and Recreation* subscale of the KOOS, with no significant gains in the other domains.[118]

Clinical outcomes

Clinical outcomes after revision ACL reconstruction are commonly evaluated using a combination of PROMs and objective clinical assessments. The PROMs are valuable for capturing patient perspectives on symptoms, knee function, and activity level, while objective assessments provide complementary information on laxity and joint function. Findings from both cohort and comparative studies indicate that instrumented measurements of anterior–posterior laxity are often similar between primary and revision procedures,[118–121] whereas revision patients more frequently demonstrate residual rotational laxity on pivot-shift testing.[21,120,122] Consistent with this, the Danish Knee Ligament Reconstruction Registry reported on more than 1,000 revision cases and found no significant difference in instrumented laxity compared with primary reconstructions. However, the registry however does not contain data on rotational laxity.[91] Although most patients achieve improved postoperative stability, revision procedures are associated with higher rates of postoperative complications and carry a three- to fourfold increased risk of graft failure compared with primary ACL reconstruction.[116,123]

Return to sports

Return to sport and pre-injury activity level is considered a key outcome after ACL surgery, yet the likelihood of achieving this goal following revision ACL reconstruction is markedly reduced compared with primary reconstruction.[124–126] Systematic reviews and registry data report a high return to any sport between 50–90%, but at a lower rate of return to their pre-injury level, compared with primary procedures.[119,125,127] Revision patients therefore tend to remain active, but inconsistencies in how return-to-sport is defined across studies complicate comparisons.[126] Barriers to successful return include persistent functional deficits, concomitant meniscal or chondral pathology, psychological factors such as reduced confidence or fear of reinjury, and in some cases medical advice from the treating physician or rehabilitation therapist.[126,128] Additionally, patients undergoing a second ACL reconstruction tend to be older and may have naturally shifted focus from

competitive sports to other aspects of life, such as their professional career or family, and therefore often do not intend to return to sport at their previous level.

Osteoarthritis

Injury to the ACL has been shown to increase the risk of developing osteoarthritis.[129] The underlying mechanisms appear to be multifactorial; concomitant meniscal and chondral injuries, periods of increased laxity, and the added burden of the surgery itself have all been linked to the heightened risk observed in the ACL-injured knee.[130]Arianjam et al.[131] highlighted this, reporting meniscal injury in 55% and cartilage injury in 42% of patients undergoing revision ACL reconstruction, pathologies that compromise joint function and accelerate degenerative progression through altered load distribution and impaired shock absorption.[132] The literature is scarce in medium- to long-term studies directly comparing primary and revision procedures; this lack of evidence limits the ability to predict long-term outcomes following revision ACL reconstruction and makes it difficult to determine to what extent these patients face a higher burden of osteoarthritis than those undergoing primary ACL reconstruction. Nonetheless, available reports suggest radiographic osteoarthritic changes in 27–52% of patients 5–8 years after revision ACL reconstruction, compared with 12–27% following primary ACL reconstruction.[21,120] Taken together, these findings indicate that revision ACL reconstruction is frequently performed in a joint already subjected to considerable structural compromise, which may in part explain the less favorable long-term prognosis compared with primary ACL reconstruction and has important implications for both surgical decision-making and patient counselling.

7.7 Revision ACL Reconstruction Surgery

Revision ACL surgery poses unique challenges owing to the heterogeneity of prior procedures and pathology. Optimal outcomes require a comprehensive assessment of the knee, meticulous problem-oriented preoperative planning, and the technical

expertise to manage intraoperative difficulties as they arise, the following section will further elaborate on these issues.

7.7.1 Preoperative Evaluation and imaging

Understanding failure requires a clear grasp of prior injuries and surgeries, as well as the current status of the unstable knee. Preoperative evaluation should therefore compile a complete history, including the index injury and treatment, all prior operative reports (techniques, grafts, implants, and concomitant procedures), and both initial and current imaging. Taken together, these steps hopefully equip the surgeon to minimize technical errors, optimize biologic contributors to outcome, address concomitant pathology, and design rehabilitation and return-to-activity plans that reduce the risk of traumatic reinjury.

Imaging should include flexed, weight-bearing anteroposterior radiographs (Rosenberg view), lateral, and axial patellofemoral views to detect osteoarthritic changes. Standing long-leg anterior-posterior and lateral views enable assessment of lower-limb alignment. An MRI is crucial for comprehensive evaluation of the status of ligaments, graft, cartilage and menisci. A CT scan with 3-D reconstructions can be useful to define tunnel position and possible widening, guiding decisions on tunnel reuse, bypass, or bone grafting, as well as single- versus two-stage revision.[22]

7.7.2 Tunnel management and staging strategy

Managing existing tunnels is a defining challenge in revision ACL surgery. Malpositioned, widened, or converging tunnels can compromise graft placement and fixation.[133] When evaluating tunnel placement and widening, four general scenarios are typically encountered. The simpler cases include: (1) well-placed tunnels that are not widened, which can be reused after clearing and decorticating the walls; and (2) tunnels so malpositioned that a new tunnel can be drilled without interference from the old. More complex cases include (3) well-placed but extensively widened tunnels, which may be managed with large bone blocks from a BPTB graft, and (4) “nearly correct” tunnels where correction would overlap with the old tunnel. Both of these more complex scenarios may require staged procedures with bone grafting.[133–]

[136] Proficiency in alternate tunnel drilling techniques enables the surgeon to vary the trajectory, and thereby bypass exiting tunnels.[137] When needed tunnel grafting can be performed with autograft, allograft, or synthetic substitutes: autologous iliac crest or tibial cancellous bone provides reliable incorporation but adds donor-site morbidity, whereas allograft bone dowels or particulate grafts offer practical alternatives, but without osteoconductive abilities.[138] Demonstrating solid incorporation is essential, as inadequately healed tunnels increase the risk of recurrent failure. Incorporation can be assessed with radiographs or CT and usually takes 4-6 months. Single-stage reconstructions are the preferred method and are reportedly performed in between 84-92% of cases.[92,135] Available evidence for comparing one-stage and two-stage revision is limited, but a systemic review from 2021 suggest similar results when appropriate patient selection is used.[139] A recent study from a single-center case-series, demonstrated higher re-rupture rate for the one-stage group, with increased anterior pain and decrease pain but decreased pain and function scores.[140] Figure 4 illustrates different aspects of tunnel management.

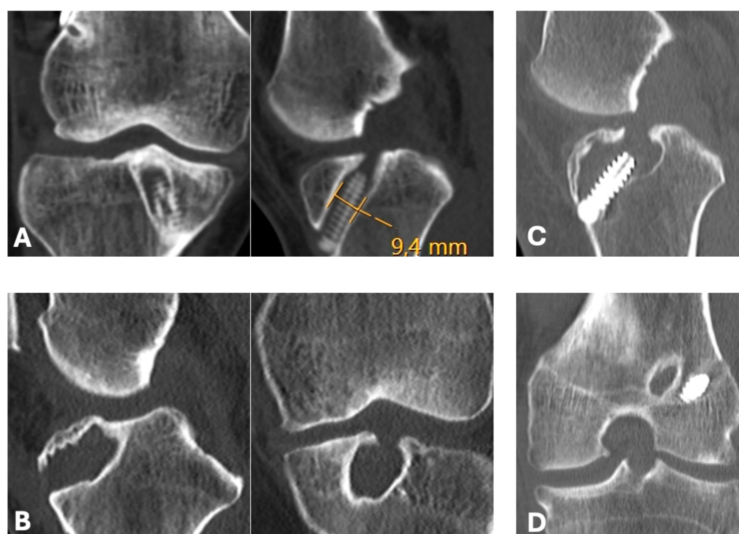

Figure 4. CT reconstructions illustrating: (A) adequate tunnel position permitting reuse; (B) anterior tunnel position with widening; (C) cystic tunnel widening; (D) femoral tunnel bypass. All images are from local patients with permission.

7.7.3 Graft Choice and Fixation

Selecting an appropriate graft for revision should be individualized and requires consideration of prior grafts, patient biology, and sport demands. Autografts such as BPTB, quadriceps tendon, or hamstrings remain preferred when available, given their superior incorporation rates compared to allografts. It is therefore important for the revision surgeon to be proficient in the use of all of these options, and consideration can be given to the use of autograft from the contralateral leg when needed.[141] However, allografts can be considered in multiligament injuries, in cases of limited autograft availability, or to reduce morbidity.[142]

Fixation must be strong and reliable, especially given potentially compromised bone stock.[137] Interference screws, suspensory devices, and hybrid fixation may all be used in the revision setting. In cases of widened tunnels or poor bone quality, alternative fixation strategies, such as post-and-washer constructs or cortical buttons, or the use of "sandwich technique" with additional interference screws may be necessary.[102,136]

7.7.4 Adjuvant treatment – biologics

Graft incorporation represents an underappreciated factor in revision surgery. Failure may occur not solely from mechanical problems but also from impaired biologic healing at the graft–bone interface.[143] Over the past decade, there has been growing interest in biologic adjuncts such as platelet-rich plasma, bone marrow aspirate concentrate, and stem-cell–enhanced scaffolds to stimulate graft-to-bone healing; although the evidence remains mixed, these approaches represent a potential frontier in improving revision outcomes.[144–146]

7.7.5 Concomitant ligament injuries

Unrecognized concomitant ligament injuries are another known risk factor for failure after ACL reconstruction, however, the available literature remains limited. A case series from a large tertiary center in Denmark reported on 128 first-time revision ACL reconstructions, where 23% required additional medial or lateral collateral

ligament surgery (including posterolateral corner procedures but excluding posterior cruciate ligament injuries).[107] This is in contrast with data from the Danish Ligament Registry and the MARS cohort, which indicate that concomitant ligament injury was cited as the cause of failure in only 3% of cases, highlighting the heterogeneity of the revision ACL reconstruction population in both surgical procedures and causes of failure.[91,92]

In a study by Svantesson et al., non-surgical treatment of medial collateral ligament injuries was associated with a 47% increased risk of revision. In contrast, a study from the Scandinavian register collaboration did not find a significant association between such injuries and revision risk. [147,148]

Although revision surgery is rare—and the presence of concomitant ligament injury even rarer—expert consensus is clear: concomitant ligament injuries should be carefully diagnosed and appropriately addressed in cases of ACL revision, to avoid additional strain on the ACL graft and increased risk of failure. [149]

7.7.6 Realignment and Adjunctive Procedures

Patients undergoing revision ACL reconstruction represent a highly heterogeneous group, with failure arising from a wide range of factors. Meniscal injury or deficiency, cartilage damage, and malalignment of the lower extremity are all recognized contributors to graft re-rupture, surgical failure and inferior clinical outcome.[35,128,150]

A posterior tibial slope greater than 12° and sagittal malalignment have been associated with increased stress on the ACL graft, thereby accelerating meniscal and chondral injury. High tibial osteotomy (HTO), particularly slope-reducing techniques, has been shown to decrease anterior tibial translation, reduce graft forces, and lower the risk of re-rupture in revision ACL reconstruction. [151–153] In addition, correction of varus or valgus malalignment is essential to restore normal joint loading and to protect meniscal and cartilage structures.[154]

Another modifiable factor that has been shown to increase stress on the ACL graft are meniscal lesions and deficiency.[35] Meniscal repair at revision surgery is highly recommended including tears of the posterior root and meniscal ramp tears. Additionally, meniscal allograft transplantation is seeing growing support, especially in the cases where meniscal deficiency is believed to be the reason for the repeated failure.[155]

Lateral extra-articular procedures (LEAP) have attracted growing interest over the past decade, with several techniques emerging or re-emerging and accumulating evidence to support their role in controlling rotational instability and protecting or offloading the ACL graft.[156–159] Revision surgery has been considered a potentially strong indication for this adjunctive procedure. In a case series by White et al., LEAP was considered in patients younger than 18 years, with knee hyperextension >7°, grade 3 Lachman, pivot shift grade 2 or 3, high posterior tibial slope >12°, or a persistent pivot shift after ACL graft passage. In this cohort, 85% underwent LEAP.[136] The STABILITY I trial, a multi-center randomized control trial evaluating ACL reconstruction with hamstring autograft with or without LEAP, demonstrated that adding LEAP reduced the risk of graft rupture from 11% to 4%.[158] More recently, reports from the Norwegian registry indicate that LEAP is performed in approximately 20% of primary ACL reconstructions, although the optimal level of use remains uncertain. [160]

8. Backgroud for the Thesis

In 1994, approximately 85,000 ACL reconstructions were performed annually in the United States. By 2006, this number had increased to around 130,000 procedures per year, corresponding to an incidence of 43.5 reconstructions per 100,000 person-years, which further rose to 73.5 per 100,000 person-years in 2014.[161,162] In Norway, registry data show a relatively stable incidence of primary ACL reconstructions over the past two decades, ranging between 30 and 45 procedures per 100,000 inhabitants annually, while revision reconstructions have accounted for an additional 2–5 per 100,000 inhabitants each year.[9] Despite improvements in surgical techniques, revision rates have remained relatively stable at 3–10%.[9,30,51,91] Graft failure and the subsequent need for revision surgery can be devastating for young, active patients, potentially jeopardizing their athletic careers and increasing the risk of early-onset OA.[163,164] Even though the Norwegian figures have not shown the same development as in the United States, the importance of expanding our knowledge on outcomes, risk factors, and causes of failure in ACL reconstruction does not diminish.

Previous studies have reported a wide range of outcomes following revision ACL reconstruction. A higher prevalence of radiographic OA, increased knee laxity, and poorer PROMs are frequently described. However, findings vary between studies and are often based on small case series or limited cohorts, frequently without appropriate control groups. In the clinical setting, such uncertainty complicates both surgical planning and patient counseling, particularly for young and active patients for whom reduced knee function can have substantial long-term consequences. Strengthening the knowledge base on long-term outcomes is therefore essential to support everyday clinical shared decision-making and to provide patients with realistic expectations after revision surgery.

At the same time, gaining insight into why primary ACL reconstructions fail is crucial to preventing repeat surgery. Recognition of pre- and perioperative risk factors can provide important guidance for both surgical decision-making and patient selection. Studies comparing the primary surgeries leading to revision with matched

controls who recovered without complications may contribute to this understanding, but the evidence to date remains limited and inconclusive.

Registry-based research enables large sample sizes and facilitates the study of relatively rare events such as revision surgery and can provide important insights. While data from the NKLR have been widely applied to study outcomes after primary ACL reconstructions, comparatively little attention has been directed toward distinguishing patients who ultimately require revision surgery. The registry allows systematic investigation of the who, why, and when of revision surgery.

Nevertheless, there is still a paucity of knowledge on the long-term outcomes after revision ACL reconstruction, and particularly so in the Norwegian patient population. As a clinician working daily with these patients, I encounter the challenges of reduced knee function, uncertainty about prognosis, and the complex decision-making that follows revision surgery. Against this background, the overall aim of this thesis is to improve the understanding of the predictors for failure, causes of failure, and long-term outcomes after revision ACL surgery. A further aim is to broaden the perspective from simply reporting revision rates toward a more clinically meaningful discussion of failure, including functional limitations and patient-reported outcomes.

9. Aims of the Thesis

The overall objective of this thesis was to improve the understanding of predictors for failure, cause of failure and long-term outcomes after revision ACL surgery. Secondly to broaden the perspective from reporting revision rates to discussing clinical failure.

The specific aims of the three studies included were:

Paper I

- To investigate patient-related risks of inferior outcome, leading to revision after ACL reconstruction.

Paper II

- To describe the patients that undergoes revision surgery.
- To describe the surgeon´s reported cause of failure.
- To evaluate revision rates and the risk of undergoing early versus late revision surgery.

Paper III

- To evaluate medium to long-term results of revision surgery at HDS between 2004-2016.

10. Materials and Methods

10.1 Haraldsplass Deaconess Hospital internal quality accessment database

The origin of the data used for study I and III has grown out of work done over several decades by Dr. Torbjørn Strand, during his extensive work with joint preservation surgery at Kysthospitalet Hagavik, Haukeland University Hospital and at Haraldsplass Deaconess Hospital. A prospectively held internal quality assessment database was started at Haraldsplass Deaconess Hospital in 1998, and many surgeons and physiotherapist have over the years contributed to the data collection. Data included details on the primary injury, preoperative clinical evaluations, intraoperative findings and treatments, postoperative follow-up at defined intervals, all additional surgeries, and multiple PROMs reflecting the period of collection. In relation to the studies presented in Papers I and III, the datasets were supplemented with information obtained from medical records, in accordance with ethical approvals.

10.2 The Norwegian National Knee Ligament Register

The NKLR was established in 2004 to prospectively collect data on all knee ligament surgery in Norway, to identify underperforming surgical methods and implants, provide knowledge on epidemiology and monitor results after surgery over time.[165] Data comprises surgeon completed postoperative questionnaire with pre- and perioperative information. Compliance rates have been monitored since the start of the register and was found to be 88% at the latest audit in 2020.[9]

10.3 Paper I

A retrospective case-control study from a prospectively collected cohort of primary ACL reconstructions without concomitant ligament injuries. The study compares pre- and perioperative data from two groups of patients undergoing primary ACL reconstruction. Data included demographic, clinical findings and patient reported outcome measures. The first group (n = 100) was patients undergoing primary ACL reconstructions and later revision ACL reconstruction surgery between 1999-2015 at HDS, and the second group (n = 100) was all “uneventful primaries” matched for time of primary surgery, to adjust for changes in surgery over the span of the inclusion period.

10.4 Paper II

A retrospective cohort study from the NKLR, all primary ACL cases without concomitant ligament injury and surgery from 2004 throughout 2023. The study included descriptive analyses on preoperative demographics, intraoperative findings and procedures as well as survival analysis and adjusted regression analysis. The Kaplan-Meier method was used to calculate revision rates at 2, 5, 10 and 15 years. A multivariable Cox regression model, adjusted for known confounders, was used to calculate HR of revision. Descriptive analysis on surgeon reported cause of failure leading to revision including changes with the introduction of digital reporting were conducted.

10.5 Paper III

Retrospective case-control study from the HDS internal quality assessment database. The study compares pre-, peri- and postoperative data from a group of revision ACL reconstruction patients treated at HDS from 2004 throughout 2016, with a group of “uneventful” primary ACL reconstruction patients. Matching of the control group was done for age and sex to account for known confounders and time of surgery to

account for changes in surgical methods over time. The follow-up evaluation was done between November 2020 and September 2022 and included clinical examination, patients reported outcome measures and radiological evaluation of the knee.

10.6 Outcome Evaluation

Outcome evaluation was conducted using clinical examination, paper or electronic versions of PROMs prospectively collected pre-surgery and at standard postoperative follow-up visits, as well as at the final follow-up, together with radiographic imaging.

10.6.1 Patient related outcome measures

Several PROMs were used for the studies included in the thesis. In paper I and III KOOS, IKDC-SKF and Tegner activity scale were used, and for paper III additional questions on patient satisfaction with knee function using both a Likert scale and a single assessment numeric evaluation and overall treatment satisfaction was administered.

For paper I and III, printed versions of the PROMs were collected in conjunction with pre-operative evaluation and later digitized in the internal quality assessment database.

For the follow-up in paper III, questionnaires were collected prior to the follow-up visit via a web-based digital solution.

10.6.2 Clinical examination

Clinical data from pre- and postoperative evaluations were used in paper I and III and originated from the pre-operative examination, the surgical records and the clinical examination at follow-up for paper III. The preoperative examination was performed by a range of experienced surgeons setting indication for surgery and/or performing the primary reconstruction. The follow-up evaluation was performed by an experienced knee surgeon (SV) not involved in most of the procedures. Knee laxity evaluation included the lachman test, pivot shift test and arthrometer measurements

10.6.3 Radiographic evaluation

Data from radiographic evaluation was included and presented in Paper III.

Standardized bilateral weight-bearing radiographs were obtained at long-term follow-up using a Synaflexer positioning frame (BioClinica, San Francisco, USA). Posteroanterior views of the tibiofemoral joint were acquired with the knees positioned in 45° flexion and a 15° cranio-caudal beam, and lateral views were taken in full extension. The Synaflexer frame was chosen to ensure reproducible and standardized knee positioning, thereby minimizing measurement error. [166]

Radiographic osteoarthritis was graded according to the Kellgren–Lawrence (K–L) classification, which is the most widely used and validated system for defining structural osteoarthritis in epidemiological and clinical studies.[167] The classification defines OA as follows:

- **Grade 0:** No radiographic features of OA
- **Grade 1:** Doubtful joint space narrowing (JSN) and possible osteophytic lipping
- **Grade 2:** Definite osteophytes and possible JSN on anteroposterior weight-bearing radiograph
- **Grade 3:** Multiple osteophytes, definite JSN, sclerosis, possible bony deformity
- **Grade 4:** Large osteophytes, marked JSN, severe sclerosis, and definite bony deformity

For the purposes of this study, osteoarthritis was defined as K–L grade ≥2.[167,168]

Radiographs were evaluated by one experienced musculoskeletal radiologist. Intrarater reliability was evaluated in 50 randomly selected examinations (100 knees) with at least 6 weeks interval, and interrater reliability by a second experienced musculoskeletal radiologist. Both radiologists were blinded to prior evaluations to avoid bias. Participation in the radiographic follow-up was entirely voluntary and free of charge.

10.7 Statistics

All Statistical analyses were performed using the SPSS software versions 23.0 and 29.0 (IBM Corp, Chicago, Ill, USA). An a priori significance level of .05 was chosen to denote statistical significance. Normality of data was investigated using QQ plots and Shapiro-Wilks test.

In paper I, mean and standard deviation or median and range were used as measures of central location and spread of data. Normally distributed continuous variables were tested using independent-samples t-test, otherwise the non-parametric Mann-Whitney U test was applied. Chi-Square test was used for testing distribution of categorical variables. A post hoc group size calculation was performed, aiming to detect a minimally clinical important difference for the IKDC-SKF score of nine points.[169] A group size of 58 was found to be sufficient.

In paper II, mean and standard deviation or median and interquartile range (IQR) were used. Independent-samples t tests were used for normally distributed continuous data, independent-samples median tests or the Mann-Whitney U test were used when data was not normally distributed. Chi-square tests were used for categorical variables. The Kaplan-Meier method[170] with overall revision as the endpoint was used to assess revision rates. A multivariable Cox regression model[171] adjusted for confounders was used to calculate the HR with the 95% confidence interval (CI).

In paper III, mean and standard deviation or median and IQR were used. Independent-samples t tests were used for normally distributed continuous data, independent-samples median tests were used when data was not normally distributed. Chi-square tests were used to test categorical variables. When testing paired categorical data the McNemar test was used. Cohen's weighted Kappa was used to test intra- and interrater reliability. Logistic binomial regression was used for both the univariate and multivariate analysis, the later with a backwards stepwise model to confirm findings. A post hoc group size calculation was performed, aiming to detect a difference in OA prevalence between primary ACL patients (18%) and revision patients (40%). The prevalences were calculated as the average of the values reported

by Gifstad and Kievit.[21,120] With a two-sided alpha of 0.05 and a power of 80%, a group size of 66 patients per group was found to be sufficient.

10.8 Ethical considerations

Paper I was a retrospective study, based on a local quality assessment database, patients were not exposed to any further examinations. The access to data and medical history was secured with an ethical approval from the Regional Committee for Medical and Health Research Ethics, Western Norway (REK Helse Vest ID No. 2015/2176.)
Paper II was based on data from the NKLR. All patients registered in the NKLR have provided signed informed consent. The Norwegian Data Protection Authority has authorized the register for data collection, analysis and publication. The Regional Committee for Medical and Health Research Ethics has confirmed that no further ethical approval is necessary.
Paper III was based on selection for eligibility for inclusion from a local quality assessment database. Eligible patients were contacted and informed about the study and the voluntary nature of participation in the study, before written consent was aquired. The study was approved by The Regional Committee for Medical and Health Research Ethics (REK Helse Vest ID No. 2020/100644.) Data was stored on a dedicated access-controlled research server, provided by Helse Vest IKT. Data protection was approved and monitored by Norwegian Center for Research Data (NSD, later SIKT.)

The large language model available at chatgpt.com (GPT-5) was used solely for text editing and proofreading purposes. It was not used to generate content. The entirety of this thesis is the original work of the author.

11. Results / Summary of Papers

11.1 Paper I

Failed Meniscal Repairs After Anterior Cruciate Ligament Reconstruction Increases Risk of Revision Surgery.

Vindfeld S, Strand T, Solheim E, Inderhaug E. *Orthop J Sports Med*. 2020;8(10):2325967120960538. doi:10.1177/2325967120960538

This study investigated patient-related risk factors associated with failure after ACL reconstruction, with particular emphasis on demographic, clinical, and surgical parameters that may predispose patients to revision surgery. A retrospective case–control design was applied to a prospectively collected database. One hundred patients who underwent revision ACL surgery between 1999 and 2015 were identified and matched with 100 controls who experienced an uneventful primary ACL reconstruction. All procedures were performed at a single center, with a median follow-up of 11 years. Data from preoperative assessments—including KT-1000 laxity testing, Lachman and pivot shift examinations, Tegner activity scale, IKDC subjective score, and KOOS score—were analyzed. Perioperative variables, such as graft type and diameter, meniscal and cartilage treatment, and surgeon experience, as well as patient demographic characteristics, were also included in the analysis.

With a median follow-up of 11 years, patients who underwent revision surgery were significantly younger at the time of reconstruction and had a shorter time from injury to surgery compared with controls ($p = 0.006$ and $p = 0.041$, respectively). No differences were observed for gender, BMI, injured side, preinjury Tegner activity level, KOOS, IKDC, or preoperative laxity measures. Meniscal repair at the time of primary ACL reconstruction was more frequent in the control group ($p = 0.024$), while later meniscal repair failure was more common in the revision group ($p = 0.038$). Mean graft size did not differ, but grafts < 8 mm were more frequently used

in patients requiring revision (p = 0.018). Neither graft type nor surgeon experience were associated with revision risk.

The main findings of this study were that failed meniscal repair and hamstring autograft diameter < 8 mm were associated with increased likelihood of ACL revision surgery. In addition, younger age and shorter time from injury to surgery were linked to higher revision risk, consistent with previous evidence suggesting that younger, more active patients are more likely to re-injure their grafts. These results align with prior registry-based studies highlighting meniscal deficiency and graft size as critical predictors of ACL graft survival. The protective effect of successful meniscal repair may be explained by its role as a secondary stabilizer, whereas smaller graft diameters exhibit lower load-to-failure and, consequently, a higher risk of re-rupture.

Limitations include the retrospective design, potential underestimation of failure (since only patients undergoing revision were defined as failures), and lack of detailed data on return to sport and osteoarthritis development. Nevertheless, the matched design, long follow-up, and prospectively collected data strengthen the findings.

In conclusion, failed meniscal repair, hamstring graft diameter < 8 mm, younger patient age, and shorter time from injury to surgery were all associated with higher risk of revision after ACL reconstruction. These results underscore the importance of optimizing graft size, prioritizing meniscal repair when feasible, and counseling younger patients on activity-related risks to reduce revision rates.

11.2 Paper II

Revision Anterior Cruciate Ligament Reconstruction: Surgeon-Reported Causes of Failure From the Norwegian Knee Ligament Register.

Vindfeld S, Persson A, Lindanger L, Fenstad AM, Visnes H, Inderhaug E. *Am J Sports Med*. 2024;53(4):801-808. doi:10.1177/03635465251316308

In this study, revision after primary ACL reconstruction in Norway was examined using nationwide registry data, with the aims of characterizing patients who undergo revision, identifying predictors of early (< 2 years) versus late (≥ 2 years) revision, and describing surgeon-reported causes of failure. We analyzed 30,038 primary ACL reconstructions recorded in the Norwegian Knee Ligament Register from June 2004 to 2023, among which 1,599 underwent revision. Demographics, activity at injury, graft type, concomitant meniscal and cartilage injuries, surgical period, and surgeon-reported failure causes were evaluated. Kaplan–Meier methods estimated cumulative revision; multivariable Cox regression (adjusted for sex, age, graft type, activity at injury, meniscal and cartilage injury, and surgical period) provided HR with 95% CIs.

The estimated cumulative revision rates at 2, 5, 10, and 15 years were 2.1%, 4.5%, 6.6%, and 7.1%, respectively. Patients who were revised were younger at primary surgery than those not revised (median age 20.4 vs 26.5 years overall; $p < .001$) and had a shorter injury-to-surgery interval (median 6.0 vs 7.3 months; $p < .001$). Activity at injury was predominantly IKDC level I. In multivariable models, early revision was associated with male sex (HR 1.2, $p = .022$), younger age (0–20 years HR 4.5; 20–30 years HR 2.1; both $p < .001$ vs > 30 years), hamstring tendon (HT) versus patellar tendon (PT) graft (HR 2.3, $p < .001$), absence of cartilage injury (HR 1.3, $p = .025$), and surgeries performed in 2010–2014 versus 2015–2023 (HR 1.4, $p = .002$). Late revision was associated with younger age (0–20 years HR 3.8; 20–30 years HR 2.6; both $p < .001$), HT versus PT graft (HR 1.5, $p < .001$), and absence of meniscal injury (HR 1.3, $p < .001$); a slightly lower risk was observed for surgeries in 2004–2009 versus 2015–2023 (HR 0.8, $p = .007$).

Surgeon-reported causes of failure (n = 1,599) were most commonly new trauma (38.1%), graft failure (24.5%), and the combination of new trauma with graft failure (10.3); tunnel malposition was reported in 5.2%. The transition from paper to mandatory digital reporting (from 2017) altered distributions, with fewer missing causes, higher reporting of new trauma, and increased recognition of tunnel malposition.

The main strength of this study is the large nationwide cohort with long-term follow-up, enabling reliable estimates of revision risk despite its relatively rare occurrence. Limitations include incomplete registration of some surgical variables, possible reporting bias in surgeon-reported causes of failure, and lack of patient-reported outcomes, which may underestimate the true rate of graft failure beyond revision.

Overall, younger age at primary surgery, use of hamstring autograft, and certain time periods of surgery were associated with higher revision risk, with distinct profiles for early versus late failure. New trauma and graft failure predominated as reported causes. These findings support targeted counseling of younger, high-demand patients, careful graft selection, and continued refinement and standardization of failure-cause definitions to improve comparability across centers and registries.

11.3 Additional analyses Paper II (unpublished)

To explore whether the distribution of reported causes of failure differed between early and late revisions, additional analyses were performed. A statistically significant difference in distribution was observed, primarily driven by differences in the proportions of *No cause provided*, *Graft failure*, and the combination of *Graft failure* and *New trauma* (Figure 5).

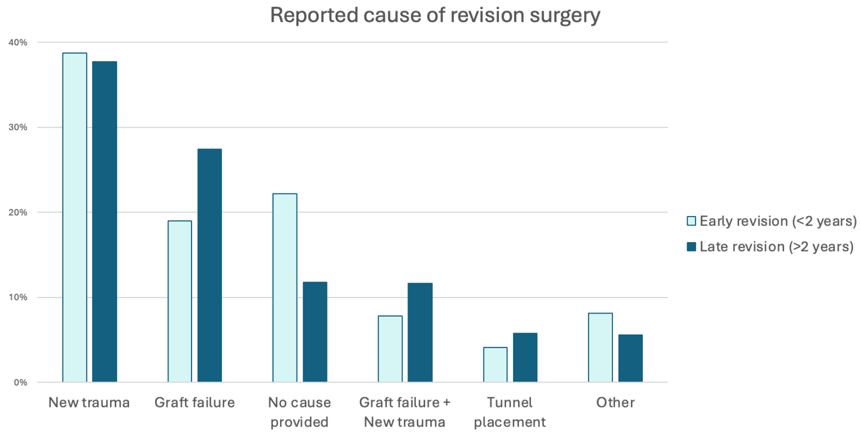

Figure 5. Distribution of Reported cause of failure between early (<2 years) and late (>2 years) revision. Data are presented as percentages for each interval. (Unpublished)

11.4 Paper III

Osteoarthritis Development and Clinical Outcomes After Revision Anterior Cruciate Ligament Surgery: A Matched Case-Control Study with 10-Year Follow-Up.

Vindfeld S, Lindanger L, Strand T, Solheim E, Parkar A P, Augland I B M, Inderhaug E. *Orthop J Sports Med*. 2025;13(10). doi:10.1177/23259671251383083

In this study, long-term radiographic and functional outcomes after ACL revision reconstruction were investigated and compared with matched, uneventful primary ACL reconstructions. We conducted a case–control follow-up of first-time revisions performed between 2004 and 2016, matching controls on age, sex, and time of surgery. In total, 273 patients participated (revision n = 140; primary n = 133) at a median of 9.7 years (IQR 5.2–17.7) after index surgery. Radiographic OA was assessed on standardized weightbearing views using K-L grading (OA ≥ 2). Knee laxity (KT-1000, Lachman, pivot-shift) was examined by an independent knee surgeon, and patient-reported outcomes (IKDC-SKF, KOOS, Tegner, patient satisfaction) were collected. Group comparisons and multiple logistic regression were used to analyze data.

Radiographic OA of the operated knee was more frequent after revision than after primary reconstruction (67% [83/124] vs 33% [42/124], $p < .001$); contralateral knees did not differ. In univariate analyses, longer time from injury to follow-up, any meniscal injury, cartilage injury at index surgery, smoking, higher BMI at index surgery, undergoing revision, and greater cumulative surgical burden increased OA odds; multivariable modeling identified three independent correlates of OA: time from injury to follow-up (aOR 1.14 per year, 95% CI 1.06–1.22, $p < .001$), any meniscal injury (aOR 3.55, 1.71–7.40, $p < .001$), and BMI at index surgery (aOR 1.14 per unit, 1.05–1.25, $p = .003$). Both groups showed significant improvements in objective laxity from pre- to follow-up, but primaries improved more. At follow-up,

mean IKDC-SKF was higher in primaries than revisions (79.7 ± 15.4 vs 71.7 ± 14.6, $p < .001$); the IKDC-SKF PASS threshold (76.2) was reached by 67.7% of primaries versus 43.6% of revisions. KOOS scores favored primaries across all subscales at follow-up, with the largest gaps in Sports/Rec and QoL. Patient satisfaction was high in both groups but greater after primary reconstruction (85.0% vs 72.2%). Surgical burden over time was higher in the revision cohort (mean 4.1 vs 1.8 procedures), and all knee arthroplasties (n = 4) occurred in the revision group.

Strengths include one of the largest mid- to long-term case–control cohorts of revision ACL patients, high follow-up (90%), standardized weightbearing radiographs with blinded dual-rater reliability, and independent clinical examination alongside validated PROMs. Limitations include the retrospective design, heterogeneity in surgical techniques across the inclusion period, potential information gaps on rehabilitation and detailed meniscal treatment, and inability to blind the clinical examiner—all of which may introduce residual confounding and measurement bias.

Overall, revision ACL reconstruction was associated with a markedly higher long-term prevalence of radiographic OA and inferior objective stability and patient-reported outcomes when compared with matched primary reconstructions. Meniscal injury, time since injury, and higher BMI emerged as independent correlates of OA, underscoring the importance of meniscal preservation, weight management, and realistic counseling for revision candidates. Despite these risks, most revision patients achieved substantial improvement and satisfactory knee function at 10-year follow-up.

11.5 Additional analyses Paper III (unpublished)

To explore whether the distribution of radiographic and symptomatic OA differed between groups, additional analyses were performed. Differences in proportional distributions between the revision and control groups reflected the impact of increasingly strict definitions of symptomatic OA. Radiographic OA was defined as

K-L ≥ 2. Symptomatic OA was defined as the presence of radiographic OA combined with one of the following: KOOS QoL <44, IKDC-SKF <76.2, or the criteria set by Englund et al. (KOOS QoL <87.5 and at least two of the following: KOOS Pain <86.1, KOOS Symptoms <85.7, KOOS ADL <86.8, or KOOS Sports/Rec <85.0), reflecting radiographic OA in combination with substantial clinical symptoms (Figure 6).[61,172,173]

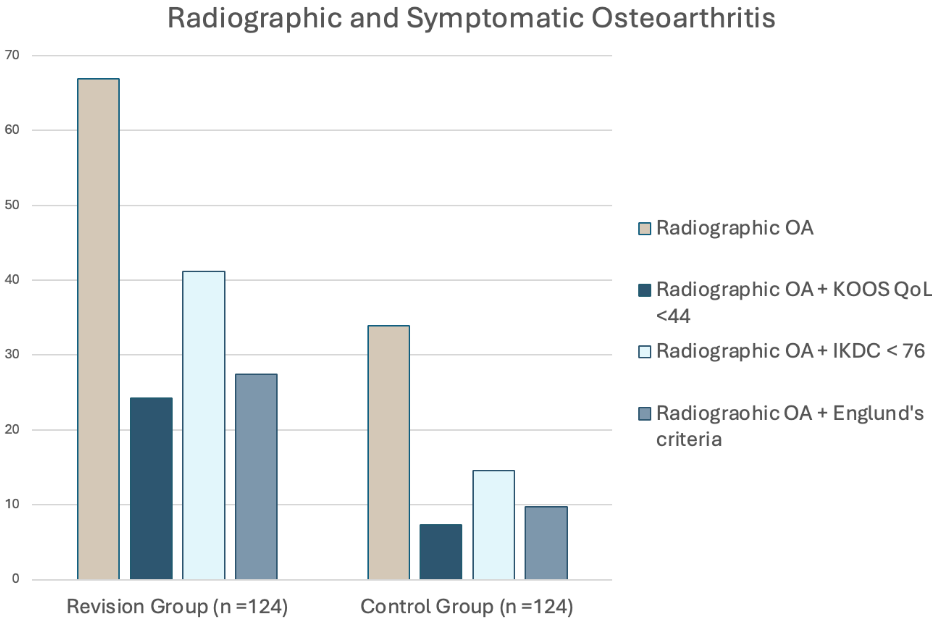

Figure 6. Distribution of radiographic and symptomatic OA, defined by varying criteria, in the revision and control groups. Data are presented as percentages within each interval. (Unpublished)

12. Discussion

A substantial proportion of patients will continue to experience failure after primary reconstruction. Despite advances in diagnosis, non-operative care, surgical techniques as well as rehabilitation, revision ACL reconstruction is unlikely to diminish as a global clinical challenge the coming decades. This thesis examines revision ACL surgery, aiming to clarify predictors and causes of primary reconstruction failure and to evaluate outcomes after subsequent revision procedures.

12.1 Methological considerations

In clinical research, the goal is to generate evidence that deepens the understanding of conditions and therefore guides effective interventions. Study designs fall broadly into interventional and observational categories. Interventional studies, most notably the randomized**,** blinded controlled trial (RCT)**,** in which the investigator assigns the exposure, remain the benchmark for causal inference because randomization balance confounders and blinding reduce bias.[174] Observational studies, by contrast, do not assign exposure, they follow individuals and their conditions in routine care, prospectively or retrospectively, using designs such as cohort, case–control, cross-sectional, and registry-based studies. These designs enhance feasibility and real-world generalizability but are more susceptible to confounding and bias, which must be addressed through design (e.g., matching) and analysis (e.g., multivariable adjustment, time-to-event models). Studies have been rated in terms of quality of the evidence and reduced risk of bias, with the highest quality and lowest risk of bias in the top of the "Evidence pyramid", as illustrated in Figure 7 adapted from Yetley et al.[175] Interventional studies, on the other hand, are resource-intensive and can have limited external validity because strict inclusion/exclusion criteria, protocolized care, and intensive monitoring may not reflect routine practice.

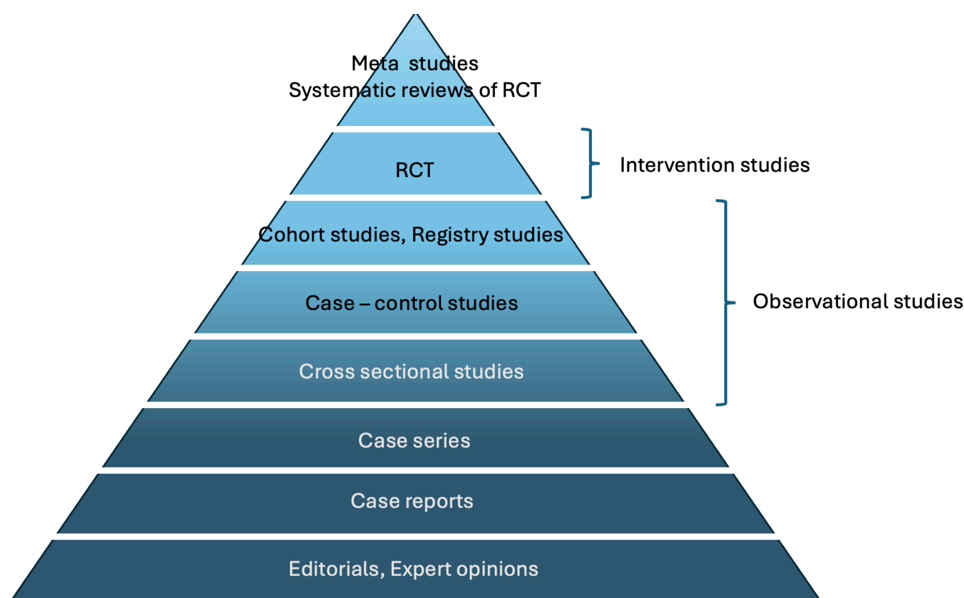

Figure 7. Evidence pyramid in health science. Study design in ascending levels according to increasing quality of evidence and reduced risk of bias. Adapted from Yetley et al, 2017

Revision surgery is relatively rare and occurs in a heterogeneous patient population, making RCTs impractical in this context.[176] Therefore, in this thesis, observational designs; a case–control study, a registry-based cohort study, and a medium- to long-term follow-up of a single-centre case–control study were employed, providing a multifaceted perspective on revision ACL surgery. The next section briefly reviews these designs, highlighting their strengths and limitations.

Case-control study:

A retrospective case–control study aims to explore the relationship between suspected risk factors (exposures) and a specific outcome. Investigators select a group with the outcome (cases) and a comparable group without it (controls), then look back, typically using medical records, to compare how often the exposures occurred in each group.

This design is efficient for rare outcomes, but it cannot establish incidence or prove causality and is vulnerable to selection and information (recall/measurement) bias. [177]

Registry-based cohort studies

A registry-based cohort study identifies a population from prospectively recorded clinical registries and follows individuals forward in time to ascertain outcomes. Exposures are defined at baseline from registry fields, outcomes are captured through ongoing registry updates, and absolute risks, rates, and adjusted HR are estimated. Strengths of registry-based cohort studies are the large, real-world samples; long follow-up at relatively low cost; reduced recall bias; and adequate power to study rare outcomes. Some of the more important limitations are that variables and definitions are fixed by the registry, potential misclassification of exposures/outcomes, temporal changes in variables, incomplete capture (loss to follow-up, under-reporting, missing PROMs).[177]

In general registry studies have some inert strength. They have high generalizability in the community where the data is collected. Interventional studies can influence clinical practice, and, in turn, the data collected, a phenomenon known as the Hawthorne effect.[178] For example, initiating a study on meniscal repair versus resection may heighten diagnostic scrutiny and lower the threshold for operative treatment. This "indication creep" can lead to interventions in patients who previously would not have been treated, introducing surveillance and selection biases that undermine comparability and generalizability. Registry studies should reduce this effect, but one might speculate if the introduction of registries themselves, or changes in variables collected could have a Hawthorne effect on its own.

Paper I and III

Both studies are retrospective studies but planned using prospectively collected data from an internal quality-assurance database to assemble a single-center cohort of revision cases. In Paper I and III the control group was matched by time to account for temporal changes in surgical indications, techniques, rehabilitation protocols, and outcome assessment to mitigate confounding. Additional matching for already known confounders, such as sex and age, were done in Paper III.

A potential limitation arises from the control-selection procedure: patients lost to follow-up and controls who were subsequently revised were replaced with the second-best match. This approach may, by design, cause unwanted selection bias and yield a control group that is healthier than expected. Alternatively, had we not replaced these individuals, some participants would have contributed to both the case and control groups—first as controls and later as cases—thereby violating the independence assumption of case–control analyses, diminishing the contrast between groups, and biasing effect estimates toward the null.

The study shares design features with registry-based data collection; however, registries typically lack granular detail on subsequent surgical procedures and their outcomes (for example the success of meniscal repair). In contrast, the extensive follow-up and active verification of later medical history and procedures in Paper I and III enabled a more specific analysis incorporating surgical variables. Nevertheless, the modest sample size limits statistical power and sub-group analysis, and the findings should be interpreted with caution.

Although the studies for both Paper I and III is retrospective, the risk of selection bias was mitigated by grounding the work in a prospectively maintained internal quality-assurance database with predefined inclusion criteria and systematic follow-up. Generalizability may be limited by the single-centre setting and possible specific indications, surgical techniques, rehabilitation protocols, and patient mix; thus, external validity may be constrained.

The studies are further limited by unavailable data on several known risk factors for revision, including tunnel placement, timing of return to sport, and patient adherence to rehabilitation. Consequently, residual confounding cannot be excluded.

Paper II

Paper II uses the NKLR as its data source. The registry’s nationwide coverage, together with validation studies reporting capture rates of approximately 88% for primary ACL reconstructions and 91% completeness for revisions, reduces the

likelihood of systematic underreporting and supports the representativeness of the data.[9]

The nationwide design strengthens external validity within the Norwegian setting by capturing a broad and representative patient population. However, differences in surgical techniques, rehabilitation protocols, and patient characteristics across regions or healthcare systems may limit generalizability to other contexts. Some under-registration is unavoidable, and missing cases may not be random; for example, revisions performed at smaller hospitals, private institutions, or among patients lost to follow-up could be underrepresented, introducing potential bias.

Registry based studies have several limitations that are relevant for Paper II**.** First, pre-collected data constraints: variables, definitions, and measurement schedules are fixed by the registry, limiting control over what is captured and how. Important confounders may be absent, definitions can change over time, and clinician-reported fields may introduce misclassification. Notably, Matava et al. reported low inter-rater agreement for assigning cause of failure and assessing tunnel position, underscoring this risk.[95] Second, data granularity: many registries lack fine-detail on exposures and outcomes (e.g., exact tunnel placement, rehabilitation content/adherence, imaging findings, return-to-sport timing), restricting subgroup analyses. Third, data completeness: under-reporting of procedures and loss to follow-up can bias estimates.

Lastly, the sheer volume of registry data increases the risk of data-dredging and chance findings, underscoring the need for hypothesis-driven analyses, pre-specified outcomes, and appropriate adjustment for multiple comparisons. Interpretation should include explicit assessments of statistical versus clinical significance. Although the overall cohort size was large, some subgroup analyses may have been underpowered, potentially limiting the precision and robustness of these findings.

12.2 Results

12.2.1 Paper I

In paper I, patient and surgical factors from primary ACL procedures were compared between patients who later required revision ACL reconstruction and matched controls, showing that those needing revision more often had a unsuccessful meniscal repair, more frequently received hamstring autografts <8 mm, were younger, had shorter time from injury to surgery, but that surgeon experience did not affect revision risk.

Meniscal repair is thought to play an important role in restoring knee stability, with the menisci acting as secondary stabilizer alongside the reconstructed ACL. Experimental work by Stephen et al.[179] demonstrated that normalization of sagittal and rotational stability was achieved only when a posteromedial tear was repaired in conjunction with ACL reconstruction. Clinical studies have similarly shown improved functional outcomes and graft survival with meniscal repair rather than resection, and meniscal deficiency has been shown to be an important factor for graft failure.[17,35,60] In a recent study from the MARS cohort, meniscal repair using an all-inside device, showed 84-88% successful repair after 10 years, indicating the method of repair is feasible.

In the current material, the rate of meniscal repair was higher in the control group compared to the revision group; therefore, this higher repair rate could have partially contributed to their better outcomes, potentially confounding the comparison and overestimating the true effect of meniscal repair. The findings, however, seem in line with a marked shift in registry data from NKLR, where the proportion of ACL reconstructions with concomitant meniscal repair rose from 7% to 69%, while resections decreased from 73% to 26% between 2005 and 2024.[9] (Figure 8) Successful meniscal repair is, however, also influenced by factors similar to those affecting ACL reconstruction, as shown by Rahardja et al.[180] This suggests that the use of multiple regression models could have strengthened the analysis in Paper I,

although the number of patients included may not have been sufficient to support such an analysis.

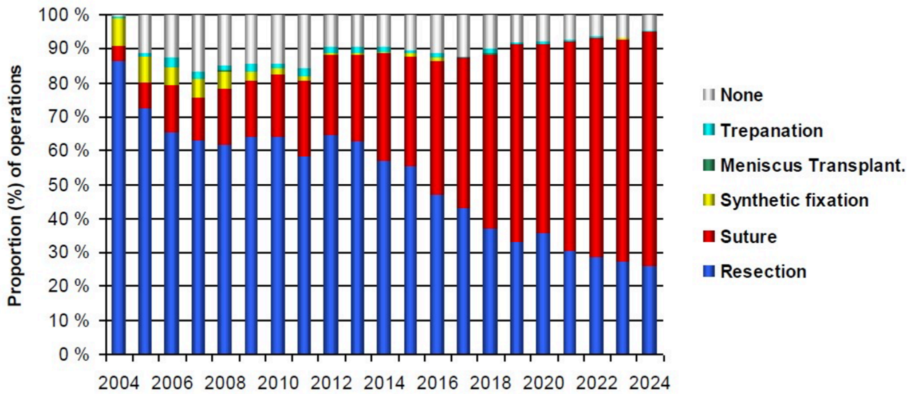

Figure 8. Treatment of meniscal lesions in primary ACL reconstruction. Data from the NKLR annual report 2024, reprinted with permission.

Paper I found no difference in mean graft diameter between groups, but hamstring autografts <8 mm were associated with an increased risk of revision surgery. Hamstring graft diameter is believed to influence graft failure: a large 2025 meta-analysis of over 43,000 hamstring autografts reported 46% greater odds of failure for grafts <8 mm, whereas a similar effect was not observed for patellar tendon grafts.[181] Hamstring autografts have been associated with a greater risk of revision compared to patellar tendon autografts.[38] However, a recent study from the Swedish and Norwegian registries found that, in contrast, hamstring autografts >9 mm were protective against early revision (<2 years) compared to PT grafts. [182] The debate regarding the optimal graft choice is unlikely to reach a definitive conclusion and is increasingly recognized as a matter of individualized, patient-specific decision-making.[183]

Younger age at surgery and shorter time from injury to surgery were both found to be associated with an increased risk of revision. Younger patients, particularly those under 25 years of age, have consistently been shown to carry a higher risk of graft failure and revision.[16,25,89] This likely reflects that younger age serves as a proxy for

higher activity levels and greater exposure to re-injury risk.[184] In the Norwegian setting, early surgery is often performed in the context of concomitant meniscal injury requiring repair or in patients participating at higher activity levels with defined return-to-sport goals, which may further increase their risk of reinjury.[185]

12.2.2 Paper II

Paper II analyzes revision rates, timing of revision, and surgeon-reported causes of failure in 30,035 patients from the NKLR between 2004 and 2023, of whom 1,599 underwent revision. The 10-year revision rate was 6.6%, with younger patients and those receiving hamstring tendon grafts at higher risk, especially for early revision, and to a lesser extent for late revision. New trauma was the most commonly reported cause of failure.

Revision rates have traditionally been used to monitor ACL surgery. They are useful because they indicate the success and durability of the reconstruction, help surgeons evaluate techniques, implants, and rehabilitation protocols, and guide patients on expected recovery and re-injury risks. Prior to Paper II, revision rates from the NKLR had not been published since 2014 and only included patients treated up to 2012.[38] Included in Paper II were patients treated from June 2004 throughout 2023, and estimated cumulative revision rates at 2, 5, 10 and 15 years were 2.1%, 4.5%, 6.6% and 7.1% respectively. The revision rates were consistent with reports from the Danish registry[91] (2-year rate of 2.9%) and the Swedish registry[28] (5-year rate of 4.1%), but comparable 10- and 15-year revision rates from other community-based registries could not be found. The gradual increase in revision rates from 2 to 15 years is expected, as graft re-rupture may occur at any time after reconstruction. In addition, patients who experience failure often attempt non-operative treatments before deciding on revision surgery, and this process can be time-consuming. These factors, together with the increase in revision rates over time, highlight the importance of long-term follow-up when reporting surgical outcomes.

There have been major changes in surgical technique, graft choice, rates of meniscal repair and rehabilitation protocols over the span of the cohort, so a stratification of survival was also done as illustrated in figure 9. Significant differences in the risk of revision were observed in this stratification, with patients from the 2010–2014 period showing a 42% increased risk compared to the 2015-2023 group. The reasons for differences in the risk of revision are not entirely clear. However, several authors have suggested that the transition from the transtibial drilling technique to the anteromedial portal drilling technique is technically demanding and associated with a learning curve, which may explain part of the increased risk.[57,186] The period from 2010 to 2014 in Norway saw many hospitals undergoing this transition. As shown by the ‘At risk’ numbers in Figure 9, the 2015–2023 group diminishes by the 5-year follow-up, so the analysis is stronger for assessing the risk of early revision (<2 years), as the number of patients who have completed longer follow-up is relatively low compared with the other time periods.

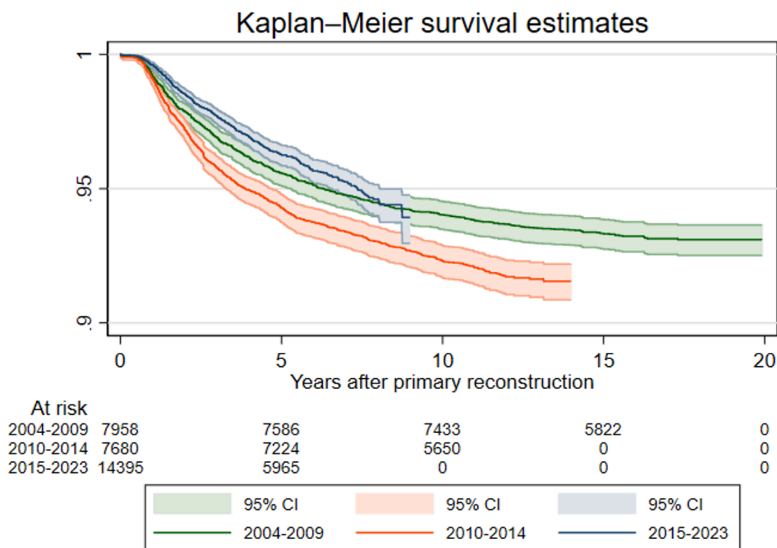

Figure 9: Kaplan-Meier Survival estimates, stratified for surgical period

There is no consensus on when a revision is classified as early or late, but it is generally believed that the etiology differs between the two. Some studies, including

Paper II, have used a 2-year cutoff to distinguish early from late revisions.[16,49,52] Early revisions are most often associated with surgical technical errors, unrecognized concomitant injuries, infection, poor rehabilitation, or premature return to sport, while late revisions are typically linked to traumatic re-rupture or delayed recognition of instability after return to sport.[187] A comparison of the reported causes of revision between early and late revisions was performed, as shown in Figure 5. Although the distribution differed, it is not considered to have clinical implications. Furthermore, the categories provided by the NKLR are difficult to compare with international literature. Apart from '*new trauma*' being the most common cause, consistent with findings from the Danish registry and the MARS cohort, [90,91] the category '*graft failure*' is ambiguous and would benefit from a clearer definition or revision of the term.

Significant changes in the distribution of reported causes of failure were observed when the reporting system shifted from paper to digital forms and the option of not providing a cause was removed. This change in distribution reflects the growing emphasis in international literature on femoral tunnel placement as a leading factor in ACL reconstruction failure.[188]

An aspect of the NKLR that can be seen as both an advantage and a limitation is that procedures are documented at the hospital or clinic level rather than by individual surgeons. This may promote more candid reporting of failure causes, since the data are not directly attributed to a specific surgeon. On the other hand, bias could occur if the same surgeon performed both the primary and revision ACL reconstruction and is hesitant to critically evaluate their own work. Additionally, variability in how surgeons interpret and apply the definitions of cause of failure across cases may reduce the consistency of the results. Further studies with validation of the classification system are needed to improve reliability and comparability of the data.

In accordance with Paper I, younger age at surgery was found to increase the risk of revision, and specific graft types were also associated with a higher risk of revision. These findings are consistent with previous studies from the NKLR.[38] However in

Paper II, the increased risk for hamstrings graft compared to BPTB were seen to diminish from early (HR 2.3) to late (HR 1.5) revisions. This may possibly reflect less robust tendon-to-bone healing, resulting in a weaker construct more prone to failure during rehabilitation and return to demanding activities. The higher revision risk in the early period may also indicate that hamstring grafts benefit from a more gradual rehabilitation and delayed return to high-risk sports.

12.2.3 Paper III

Paper III was a medium- to long-term follow-up study that assessed radiographic OA, clinical outcomes, and patient-reported outcome scores in patients undergoing revision ACL reconstruction compared with primary uneventful ACL reconstructions. Including more than 270 patients and achieving a follow-up rate of 90.4%, the study represents one of the largest case-controls available. At a median 10-year follow-up, the revision group had higher rates of OA. Meniscal injury, longer time from injury to follow-up, and higher BMI increased the risk of developing OA. Outcomes were superior in the primary group, though both groups showed significant improvements in knee function and patient satisfaction and most patients still reported a high level of satisfaction.

OA is recognized as a frequent long-term consequence of ACL injury.[129] The risk of OA increases substantially when the injury is accompanied by concomitant meniscal or chondral damage, which accelerates joint degeneration and compromises long-term knee function.[129,189–191] Prolonged periods of knee instability further aggravate this process, leading to abnormal joint loading and progressive cartilage wear.[192] Consequently, patients with combined injuries, delayed or repeated attempts at stabilization may face a worse prognosis and a higher likelihood of developing OA in the years following the initial trauma.

Paper III shows that revision ACL reconstruction carries a markedly higher risk of radiographic OA than primary ‘uneventful’ ACL reconstructions, with 67% versus 33% affected at a median 10-year follow-up (K-L ≥ 2). These findings align with

previous reports suggesting that revised knees, as well as knees subjected to prolonged periods of instability, are particularly vulnerable to progressive joint degeneration.[21,120,192] The higher OA prevalence in revision patients could be explained by the cumulative impact of repeated injuries, residual laxity, and altered joint biomechanics on cartilage integrity over time.

Multivariate analysis identified three independent predictors of OA development: *time from injury to follow-up*, *meniscal injury*, and higher *BMI*. Each additional year from injury to follow-up increased the risk of OA by 14%, highlighting the increased risk over time.
Meniscal injury was observed in 39% of patients, yet only 11% underwent repair, reflecting historical practice patterns.[9] The low repair rate may have contributed to the high OA incidence, and the fact that only 5.6% of revision patients and 14.2% of primary patients underwent meniscal repair may partially explain the observed differences in OA development. Similarly, higher BMI was independently associated with OA risk, suggesting that modifiable factors such as weight management should be considered in the long-term care of ACL-injured patients.

Osteoarthritis is a chronic degenerative joint disease characterized by progressive cartilage loss, subchondral bone changes, and varying degrees of pain, stiffness, and functional impairment.[193] It is important to distinguish between radiographic OA and symptomatic OA, as structural changes visible on imaging do not always correlate with clinical symptoms.[194] It is also important to note that the correlation between radiographic OA and arthroscopic findings is at most moderate, further highlighting the importance of distinguishing between different OA definitions.[195] In the present cohort, although revision patients had higher rates of radiographic OA, many reported satisfactory knee function and improvement in patient-reported scores, indicating that structural degeneration does not necessarily equate to severe clinical impairment in all individuals. A high proportion of revision ACL patients exhibit radiographic evidence of OA, and a limitation of this study is that these findings were not directly linked to the presence of significant pain, functional limitations, or reduced quality of

life. No universally accepted definition of symptomatic OA exists. Englund et al. [61] proposed criteria based on KOOS subscale cut-off values, while other definitions have been suggested by Granan et al.[172] and Urhausen et al.[173] based on clinically meaningful symptoms following ACL reconstruction. Additional unpublished analyses were performed applying these various definitions to the patients included in Paper III. Here, the rates of symptomatic OA were significantly lower, ranging from 24–41% in the revision group and 7–15% in the control group, depending on the definition applied. However, the proportional distribution of radiographic versus symptomatic OA remained constant, while the relative distribution of OA versus no OA varied according to the strictness of the symptomatic OA definition. Guermazi et al. have shown that radiographic progression can precede the onset of symptoms by several years, and that factors such as meniscal injury, cartilage damage, and residual instability contribute to both radiographic changes and symptomatic disease.[196] This discrepancy highlights the importance of evaluating both imaging findings and patient-reported outcomes when assessing long-term knee health. No studies reporting the development of symptomatic OA after long-term follow-up of revision ACL surgery were identified for comparison. Future research should investigate how evolving surgical techniques—including increased use of meniscal repair and concomitant procedures—affect long-term outcomes and OA development in this high-risk population.

The K-L classification, used in Paper III, is widely applied and facilitates comparison across studies; however, it has been criticized for limited sensitivity to early degenerative changes, poor correlation with symptoms, and subjectivity due to its focus on osteophyte formation and joint space narrowing. Consequently, early cartilage changes or soft tissue pathology may be overlooked.[197] An alternative, the IKDC classification, offers a more detailed evaluation of joint structures, capturing a broader range of abnormalities.[195] Nevertheless, given the existing literature on OA development after ACL revision, K-L was the most commonly used system and was chosen in this study to ensure comparability across studies.

The goal of knee ligament reconstruction surgery is to restore biomechanical stability as close as possible to the pre-injury state. Both revision and primary groups showed significant improvements in knee laxity from preoperative assessments to follow-up. Despite these improvements, a notable proportion of patients in both groups continued to exhibit abnormal knee laxity. In the revision group, 52.1% had an IKDC Objective score of C or D, compared with 28.0% in the primary group, indicating worse outcomes than previous studies reported, 34% at 9 years without a control group[107] and 22% in revisions versus 5% in primaries with shorter follow-up,[122] with the possibility of deterioration over time. LEAP have been shown in the past decade to reduce graft failure after ACL reconstruction.[158] and revision surgery is an obvious indication for LEAP, however a recent study did not find clinical improvements with the addition of the procedure.[157] In the current cohort, only two of 140 revision cases and none of the controls underwent an LEAP, making it impossible to draw any conclusions.

In Paper III, PROMs were used to measure patient satisfaction and demonstrated significant improvements in IKDC-SKF scores for both revision and primary groups (15.4 and 21.1), exceeding the MCID of 11.5.[198] However, group-level MCID does not capture individual variability, as some patients improve substantially while others show little change or deterioration. PASS offers a patient-centered alternative, reflecting satisfaction. While no PASS studies exist for revision ACL patients, a 10-year cohort study on ACL tears suggested a PASS threshold of 76.2.[173] In the current study, 43.6% of revision and 67.7% of primary patients reached this threshold ($p < .001$), yet 72.2% and 85.0%, respectively, reported being satisfied or better, when asked at follow-up, indicating the threshold may not fully apply. KOOS scores showed similar trends, exceeding the MCID of 8–10 points. Using KOOS QoL <44 to define ACL reconstruction failure, 29.9% of revision and 14.3% of primary patients met this criterion.[199] Although KOOS has been criticized for limited responsiveness in pain, symptoms, and ADLs, its widespread use in ACL research and its design for OA assessment make it a valuable tool in the present study.[78]

Satisfaction reflects surgical success but is influenced by expectations. Revision outcomes are generally less favorable than primary reconstructions, yet many patients remain satisfied despite residual laxity or radiographic OA. In this cohort, 28% of revision and 15% of primary patients were dissatisfied. Future improvements in patient selection, surgical techniques, including meniscal repair and LEAP, and rehabilitation may enhance outcomes.

13. General considerations and future perspectives

Success and failure following ACL reconstruction can be defined through multiple lenses, depending on the perspective and the outcomes prioritized. For athletes and coaches, success is often measured by the ability to return to play at the pre-injury level. For surgeons, objective measures such as graft integrity, knee stability, and residual laxity at follow-up are key indicators. For the average patient, success may be defined by the ability to maintain an active lifestyle. For physiotherapists guiding rehabilitation, the ability to perform standardized hop and isokinetic strength tests can be a critical benchmark. From the perspective of community-based registries, the need for revision surgery is often considered a failure. Long-term clinical outcomes may be evaluated based on the development of osteoarthritis 20–25 years post-reconstruction or the eventual need for total knee replacement. Additionally, more standardized definitions have been proposed, such as the clinical failure criteria outlined by Crawford et al. [31] and the three-category model developed by the University of Pittsburgh group.[12] These divergent definitions highlight the absence of a single, universally accepted standard for determining "success" or "failure" after ACL reconstruction and reflect the differing priorities and expectations of the various stakeholders involved in patient care. A good medical classification is clear, reliable, and clinically relevant. It should use well-defined criteria that allow different clinicians to reach the same conclusions, reflect real differences in injury mechanism, prognosis, or treatment, and provide information that meaningfully guides management decisions. Additionally, it should be practical to use, widely understood, and adaptable as medical knowledge evolves. One could argue that the most commonly used classification of failure, the three-category model, does not sufficiently meet these requirements. Future research should therefore be aimed at clearly defining failure and developing a classification system that provides the surgeon with meaningful guidance: highlighting what is important, what benefit the information offers, whether it might change their perspective on further treatment, and how it could influence decision-making in revision surgery. Ultimately, the

classification should serve as a practical tool to improve understanding, guide management, and optimize patient outcomes.

Defining failure in ACL reconstruction is increasingly recognized as a nuanced, patient-centered process rather than a simple binary outcome. Revision surgery provides a clear, easily quantifiable endpoint in research, allowing comparisons across cohorts. However, relying solely on revision underestimates the true spectrum of suboptimal outcomes, as many patients experience persistent instability, pain, or functional limitations without undergoing further surgery.

The concept of clinical failure broadens this definition by integrating both objective measures and PROMs. A patient may have an intact graft yet still perceive their knee as “failed” due to residual laxity, pain, limited function, or inability to participate in desired activities. Conversely, some patients achieve structural success but are dissatisfied due to unmet expectations or limitations in high-level athletic performance.

Viewing ACL reconstruction outcomes along a continuum, from complete success to varying degrees of functional limitation, allows for a more realistic assessment of surgical impact. Success can be graded based on graft integrity, PROMs, functional performance, and satisfaction relative to individual goals, rather than reduced to a single binary endpoint. By adopting this perspective, clinicians can identify patients at risk of dissatisfaction, guide individualized rehabilitation, and refine surgical strategies.

Future research in this field should place greater emphasis on systematically capturing the rationale behind indications for revision surgery and the corresponding choice of surgical strategy. A prospective collection of such data would provide deeper insights into clinical reasoning, highlight potential variations in practice, and ultimately allow for the identification of best practices that may improve patient care.

In addition, the development of a more nuanced and standardized classification system for the underlying causes leading to revision is essential. Current

categorizations often lack the granularity needed to distinguish between multifactorial contributors. A refined classification would not only facilitate more accurate comparisons across studies but also provide a stronger foundation for tailoring interventions to patient-specific needs.

Equally important is the implementation of improved outcome measures. These should extend beyond traditional clinical endpoints to encompass functional recovery, patient-reported outcomes, and long-term quality of life. By adopting a broader and more sensitive set of evaluation criteria, future studies will be better equipped to capture the true effectiveness of different treatment approaches.

Finally, progress in this field depends on the establishment of a structured framework for data collection that spans the entire patient journey. Standardized documentation of findings from clinical examinations, intraoperative observations, and rehabilitation progress will enable a more comprehensive understanding of patient trajectories. Such an integrated approach would create opportunities for large-scale registries, cross-institutional collaboration, and the application of advanced analytical tools, including predictive modeling and personalized treatment algorithms.

Together, these directions outline a pathway toward more evidence-based, patient-centered, and effective management strategies in revision surgery.

14. Conclusion and clinical implications

In this thesis, patient-related and surgical factors influencing, predictors, causes, and outcomes after ACL reconstruction and revision ACL reconstruction were evaluated.

Paper I

• Failed meniscal repair and grafts <8 mm were linked to primary ACL reconstruction failure.

• Younger age and shorter time from injury increased revision risk.

• Surgeon experience did not affect revision risk.

Paper II

• The 10-year revision rate was 6.6%.

• Hamstring grafts increased early revision risk.

• Younger age was associated with early and late revision.

• Male sex, hamstring graft, and no cartilage injury increased early revision risk.

• Younger age, hamstring graft, and no meniscal injury increased late revision risk.

• New trauma (38%) was the most common cause of revision.

Paper III

• Revision ACL reconstruction patients had worse long-term function and higher OA prevalence.

• Radiographic OA (K-L ≥2) was present in 67% of revisions vs 33% of primary ACL reconstruction at median 9.7 years follow-up.

• Longer time to follow-up, meniscal injury, and high BMI all independently increased OA risk.

• Knee laxity and patient-reported outcomes improved in both groups but more in primary ACL reconstruction.

• Revision patients still experienced significant improvements and high satisfaction.

The findings from this thesis provide important insights that can help reduce the risk of future ACL reconstruction failures by highlighting key patient- and surgery-related

risk factors. Additionally, they can support clinicians in guiding patients through shared decision-making when faced with a revision, allowing individualized discussions about treatment options, expected outcomes, and potential risks.

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16. Appendix

16.1 Paper I-III

I

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Original Research

Failed Meniscal Repairs After Anterior Cruciate Ligament Reconstruction Increases Risk of Revision Surgery

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Background: Failed anterior cruciate ligament (ACL) reconstruction (ACLR) can lead to reduced quality of life because of recurrent episodes of instability, restrictions in level of activity, and development of osteoarthritis. A profound knowledge of the causes of a failed surgery can ultimately help improve graft survival rates.

Purpose: To investigate the patient-related risks of inferior outcomes leading to revision surgery after ACLR.

Study Design: Case-control study; Level of evidence, 3.

Methods: From a prospective cohort of primary ACLRs performed at a single center, patients who required later revision surgery were matched with a control group of uneventful primary ACLRs. Patient characteristics, data from the preoperative examinations, KT-1000 arthrometer laxity testing, Tegner activity scale, International Knee Documentation Committee subjective score, Knee injury and Osteoarthritis Outcome Score, and perioperative data from the initial surgery were included.

Results: A total of 100 revision cases and 100 matched controls, with a median follow-up time of 11 years, were included in the study. Those who had undergone revision surgery were younger at the time of reconstruction and had a shorter time from injury to surgery than their matched controls ($P = .006$). The control group—of uneventful ACLRs—had a higher incidence of meniscal repair at reconstruction ($P = .024$). Also, the revision group more frequently experienced later failure of the previous meniscal repair ($P = .004$). Surgeon experience was not found to affect the risk of revision ACL surgery. Those who had undergone ACL revision surgery had more frequently received a hamstring tendon graft size of $<$8 mm ($P = .018$) compared with the controls.

Conclusion: The current study demonstrated that failed meniscal repair and a hamstring tendon graft size of $<$8 mm were associated with primary ACLR failure. Also, younger age at the time of surgery and shorter time from injury to surgery were found to affect the risk of undergoing revision ACL surgery.

Keywords: revision surgery; anterior cruciate ligament; meniscal repair

Despite efforts to improve outcomes after anterior cruciate ligament (ACL) reconstruction (ACLR) for many decades, there is still a persistent and significant failure rate.[5] ACL registries commonly report an overall revision rate of 3%-10%,[1,5,20] but in subgroups of patients, up to 22%-30% experience failure.[6,38] Graft rerupture can have detrimental effects on quality of life because of recurrent episodes of instability, restrictions in the level of activity, and potential early development of osteoarthritis.[2,7] Also, results after revision surgery are commonly described as inferior to what is seen after the first reconstruction.[7]

Failure can in part be because of return to high-risk sports, as is commonly seen in the youngest group of patients.[37] The greatest risk is found in those returning to pivoting sports.[37] Also, the magnitude of injury at the initial ACL tear, defined as concomitant injures to other structures, can affect the outcome after surgery.[35] Further, predispositions such as female sex, a high posterior tibial slope, or a joint hyperlaxity add to patient-related risks.[13,18,19] Finally, factors related to surgery, such as choice of the graft, size of the graft, and choice of fixational devices, have also been found to be of importance.[18,26,30] Graft tunnel positioning, especially whether anatomic tunnel placement was achieved, is another topic that has been highlighted.[11,22]

As an increasing number of patients are being assessed for revision surgery,[5] there is a continuous need for knowledge on why the primary surgery fails. Such knowledge can help surgical decision-making at repeat surgery and lower the risk of overall failure. The current study, therefore, aimed to investigate the potential risks of failure after

The Orthopaedic Journal of Sports Medicine, 8(10), 2325967120960538
DOI: 10.1177/2325967120960538
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ACLR in a retrospective case-control study that utilized prospectively collected data. A group of patients in need of revision surgery after their primary reconstruction were compared with a matched control group of patients with an uneventful postoperative course. The null hypothesis was that no difference would be found in pre- and peroperative potential risk factors for failure between the groups.

METHODS

Patient Selection

Patients who had undergone ACLR and had later undergone revision surgery from 1999 to 2015 at our clinic were eligible for the study and thus defined the sample size. Patients who had undergone concomitant ligament surgery such as medial collateral ligament, lateral collateral ligament, posterior cruciate ligament, or posterior cruciate ligament reconstruction were excluded. A matched control group of patients who had undergone ACLR without the need for revision immediately following in time to each of the cases that needed revision (and therefore made out the case group) was also included[7] (Figure 1). The ratio of case to control was set as 1:1. Such matching was performed to adjust for changing surgical techniques in the period of inclusion. A minimum of 2-year follow-up was required for patients to be included in the study. All participants included in the control group were contacted to ensure they had not undergone revision surgery at another clinic. If so (n = 1), they were excluded in favor of the next consecutive patient that had been reconstructed after the index case (later undergoing revision). The study was approved by a regional ethical review board.

Data Collection

All data were collected from a prospective institutional quality assessment database. The following preoperative data were extracted: age, side of injury, sex, height, weight, activity at injury, time of injury, time of surgery, and time of any revision surgery. Further, perioperative data such as graft type and size, the surgeon's level of experience (defined by the number of previous ACL surgeries performed: 0-25, under supervision; 26-100, moderate experience; and >100, experienced), and any concomitant lesion of meniscal or articular cartilage were included. Tegner activity score, International Knee Documentation Committee (IKDC) 2000 subjective score, and Knee injury and Osteoarthritis Outcome Score (KOOS) were extracted from

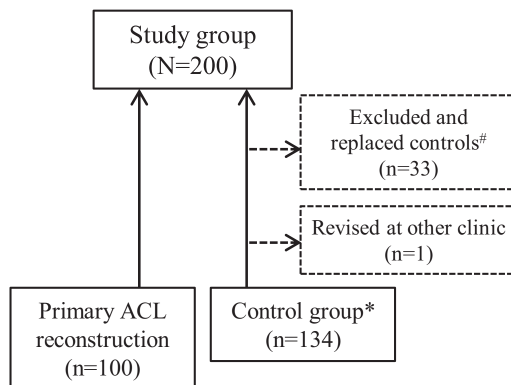

Figure 1. Patient selection for the revision and control groups. *Selected as the next consecutive primary anterior cruciate ligament (ACL) reconstruction leading to revision. #Excluded as controls owing to concomitant ligament surgery, loss to follow-up, or patient deceased.

preoperative assessment. Also, preoperative Lachman test, pivot-shift test,[23] and KT-1000 arthrometer (MEDmetric) measurements were included. For the latter, the maximum manual difference between injured and normal knee (side-to-side difference) was calculated and used for analyses.

Surgical Procedure

The primary reconstruction in both the revision group and the control group was performed from April 1990 to August 2014. Therefore, a certain variety in tunnel placement strategies (transtibial and anteromedial portal techniques), choice of graft source (hamstrings and patellar tendon autograft only), and graft fixation methods were seen. Surgical technique was, however, not individualized based on patient characteristics but rather a reflection of what was seen as the gold standard at all times throughout the period. Meniscal repair was done with one (or combinations) of the following techniques: inside-out, outside-in, or all-inside suture devices—depending on the type, size, and position of the tear. The rehabilitation protocol allowed partial weightbearing for 2-4 weeks and free range of motion. In cases of concomitant meniscal repair, patients were restricted to partial weightbearing for 6 weeks and range of motion from full extension to 90° of flexion. A standardized follow-up regimen included postoperative visits to

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Final revision submitted May 6, 2020; accepted May 19, 2020.
The authors declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the Regional Committee for Medical and Health Research Ethics, Western Norway (REK Helse Vest ID No. 2015/2176).

TABLE 1
Characteristic Data in Revision and Control Groups[a]

	Revision (n = 100)	Control (n = 100)	P
Age at surgery, y	24.2	28.4	.006[b]
Female patients	56	44	ns[c]
Body mass index	24.4 ± 4.0	24.9 ± 4.3	ns[b]
Time from injury to surgery, mo, mean ± SD	11.9 ± 19.0	22.7 ± 43.4	.041[b]
Follow-up time, y, median (range)	11.0 (2.2-26.4)	10.9 (2.1-25.5)	ns[b]
Injured side (left)	46	46	ns[c]
Tegner preinjury, mean ± SD	7.58 ± 1.63	7.44 ± 1.60	ns[b]

[a]ns, not significant.
[b]Nonparametric Mann-Whitney U test.
[c]Chi-square test.

both physical therapist and surgeon at the clinic. All patients were offered functional testing at 9-12 months after surgery, including hop tests and isometric strength testing. Further rehabilitation and potential return to sports were advised according to the results of these tests.

Statistical Analysis

All statistical analyses were performed using the SPSS 23.0 software (IBM Corp). As measures of central location and spread of data, mean and standard deviation or median and range were calculated. Normality of continuous variables was investigated using QQ plots and Shapiro-Wilk test. If normality was found, independent-samples *t* tests were used; if not, the nonparametric Mann-Whitney *U* test was applied. Chi-square test was used for testing distributions of categorical variables such as sex and injured side. An a priori *P* value of .05 was used to denote statistical significance. A group size calculation was performed, aiming to detect a minimally clinical important difference for IKDC subjective score of 9 points.[24] With a statistical significance of .05, a β value of 0.1 (power of 0.9), and a standard deviation of IKDC of 15 (based on earlier data), a group size of 58 was found to be sufficient.

RESULTS

A total of 100 patients who had undergone revision surgery and 100 control patients were included in the study. There was no difference in median follow-up time (11 years) between the revision group and the control group. The median time from surgery to revision was 2.1 years (range, 14 days-21 years). One case was revised after 14 days because of an infection. Characteristic data for the 2 groups are presented in Table 1. The revision group was significantly younger at the time of surgery ($P = .006$) and had a significantly shorter time from injury to surgery ($P = .041$), as compared with the control group. Sex, injured side, body mass index (BMI), and preinjury Tegner score did not differ

TABLE 2
Findings From Preoperative Clinical Examinations and Patient-Reported Outcome Measures[a]

	Revision (n = 100)	Control (n = 100)	P
KT-1000 arthrometer side-to-side difference, mm	6.5 ± 3.0	6.8 ± 2.6	ns[b]
ALRI			ns[c]
0	2	0	
1	3	5	
2	59	61	
Classification not possible because of muscular guarding	14	16	
Lachman grade			ns[c]
0	0	0	
1	13	8	
2	71	75	
3	10	8	
IKDC	57 ± 15	55 ± 15	ns[b]
KOOS, Sports and Recreation	44 ± 27	44 ± 26	ns[b]
KOOS, Knee-Related Quality of Life	32 ± 18	31 ± 16	ns[b]

[a]IKDC, International Knee Documentation Committee; ALRI, anterolateral rotational instability; KOOS, Knee injury and Osteoarthritis Outcome Score; ns, not significant.
[b]Independent-samples *t* test.
[c]Chi-square.

between the groups. Further, type of activity at the time of injury was not significantly different between the 2 groups, with approximately 50% of injuries being related to soccer, 15% from team handball, and 15% from alpine skiing; and 20% of injuries were related to work, traffic accidents, or other activities.

The preoperative clinical examination displayed no differences in mean KT-1000 arthrometer side-to-side difference, distribution of pivot-shift, or Lachman grading. Also, KOOS and IKDC subjective score were not found to differ significantly between those who had undergone revision and controls (Table 2).

There was no significant difference between the groups in the distribution of meniscal injuries, articular cartilage injuries, treatment of cartilage injuries, or meniscal resections concomitant to the primary reconstruction. The control group patients were more frequently treated with meniscal repair compared with the revision group ($P = .024$) (Table 3). Of those who had undergone a meniscal repair, 6 of 8 in the revision group had a later meniscal resection, while only 6 of 21 in the control group had undergone later resection ($P = .038$).

The mean graft size was not found to differ between the 2 groups (8.5 mm in the revision group vs 8.7 mm in controls) (Table 4). A graft size of <8 mm was, however, more frequently used in the revision group than in the control group ($P = .018$). The distribution of graft type (hamstring or patellar tendon autografts) did not differ between groups. No allografts were used. When examining the effect of surgeon experience, no difference in risk of revision was seen

TABLE 3
Concomitant Meniscal and Cartilage Injuries at Time of Surgery[a]

	Revision (n = 100)	Control (n = 100)	*P*
Meniscal tear	46	59	ns[b]
Meniscal resection	23	22	ns[b]
Meniscal repair	8	21	.024[b]
Cartilage injury	13	14	ns[b]
Later failed meniscal repair	6/8	6/21	.038[b]

[a]ns, not significant.
[b]Chi-square test.

TABLE 4
Perioperative Findings: Graft Size, Graft Type, Length of Surgery, and Surgeon Experience[a]

	Revision (n = 100)	Control (n = 100)	*P*
Mean graft size, mm	8.5 ± 0.9	8.7 ± 0.8	ns[b]
Graft size <8 mm	9	1	.018[c]
Patellar/hamstring tendon autograft	18/82	21/79	ns[c]
Length of surgery, min	107 ± 35	107 ± 31	ns[b]
Surgeon experience			ns[c]
0-25	9	7	
25-100	24	26	
100+	67	67	

[a]ns, not statistically significant.
[b]Nonparametric Mann-Whitney U test.
[c]Chi-square test.

when comparing surgeons under supervision, surgeons with moderate experience, and experienced surgeons.

DISCUSSION

The most important finding in the current study is that patients in need of revision ACLR (because of a failed primary ACLR) had a lower survival rate of meniscal repairs when compared with a control group of patients who had not undergone revision surgery. Further, those who were in need of revision ACLR had more frequently received a hamstring tendon autograft of <8 mm diameter. The latter finding adds to the reports from other studies that smaller graft size is an independent risk for failure after ACLR. Differences were also seen between the revision group and the control group regarding time from injury to surgery and age at the time of surgery. Level of surgeon experience was, however, not found to affect the risk of needing later revision ACL surgery.

Proper repair of the meniscus is thought to restore its native function, which includes its role as a secondary stabilizer of the knee along with the reconstructed ACL.[16,17] This was evident in an experimental biomechanical study by Stephen et al,[33] who examined the effect of a posteromedial meniscocapsular lesion on tibiofemoral joint laxity in the ACL-deficient knee. They found normalization of sagittal and rotational stability of the knee only after the meniscal tear was repaired along with the ACLR. Clinical studies have also displayed the synergistic effect of meniscal repair and ACLR. A recent multivariate analysis of a cohort of US military personnel by Pullen et al[30] found concomitant meniscal repair to protect against later revision ACL surgery. Trojani et al[34] also noted the importance of meniscal repair. In their study, better functional results and better knee stability were seen after ACLR where repair rather than resection had been performed.

In a multivariate analysis investigating predictors for ACLR failure, Parkinson et al[27] found meniscal deficiency to be the single most important factor. The results from our study align with their finding, showing a protective effect of meniscal repair on graft survival. The choice to perform meniscal repair, whenever viable, seems to be paramount when performing ligament surgery. In accordance with the latter belief, a changing attitude toward meniscal surgery is shown in the data from the Norwegian ACL registry.[5] The number of ACLRs with concomitant meniscal repair procedures has risen from 7% to 40%, while resections have decreased from 73% to 48%, in the period from 2005 to 2016. In the current study, it is difficult to establish the causality between meniscal repair failure and increased risk of revision ACLR. On one side, one could argue that an injured meniscus can lead to additional strain on the ACL graft, but it might also be that residual laxity in and of itself increases the risk of a repeat meniscal tear. In addition to the favorable effect of meniscal repair on knee kinematics, one could speculate whether the resulting slower rehabilitation after a meniscal repair is also protective for risk of later revision surgery. This could, in particular, be the case for patients receiving hamstring tendon grafts, as they are believed to need a longer time for graft-to-bone healing.[12,25]

The relationship between graft diameter and patient outcomes has been the subject of investigation in several studies. Magnussen et al[18] reported that hamstring tendon autograft diameter of <8 mm was a predictor for early revision after surgery. Park et al[26] demonstrated how graft diameter was dependent on patient BMI, sex, and athletic level. Further, although there was no relation between smaller graft diameters and risk of revision ACL, patients with a graft size of <8 mm displayed inferior clinical outcomes.[26] In a study from the Swedish ACL registry, more than 2000 patients who underwent reconstruction with hamstring tendon autografts were analyzed.[32] The main finding was an increasing likelihood of undergoing revision surgery for each 0.5-mm decrease in graft diameter from 10 to 7 mm. In contrast to the studies mentioned above is a recent report from the Norwegian ACL registry investigating the effect of BMI and graft size on risk of undergoing revision.[10] When graft diameter was related to patient weight and height, no difference in the risk of revision surgery based on hamstring tendon autograft diameter was seen. In the present study, a smaller graft size of <8 mm was seen more frequently in the revision group compared with the control group. This adds to the notion that surgeons should aim to upsize the graft size whenever

encountering a small diameter during surgery. A careful consideration should, however, be made toward this upsizing, since data from a publication by Pennock et al[28] point toward higher graft failure rates when augmentation with allograft is used to achieve this.

The present study found patients who had undergone revision surgery to be younger at the time of surgery compared with the patients who had not undergone revision surgery.[19,29,36] In a prospective cohort by Kamien et al,[13] age below 25 years was found to be an independent risk factor for ACLR failure. Studies by Magnussen et al[18] and Shelbourne et al[31] have displayed the same findings. Further, reports[4,6,19] from the Swedish, Danish, and Kaiser Permanente registries also emphasize age as an independent risk factor for revision. With younger age comes a greater desire to return to high-risk activities that expose patients to repeat injury of their knee. As discussed by Marx et al,[21] participation in high-risk activity is likely the confounding factor making younger-aged patients more prone to undergo ACL revision surgery.

Several studies have reported on early versus delayed reconstruction after ACL rupture. The level of knee instability, concomitant injuries, and patient expectations are among the factors that influence timing of surgery.[9,14] As highlighted by Krutsch et al,[15] there might be a risk of secondary injuries related to delayed surgery. In their study, an increase in irreparable meniscal lesions was seen in those who underwent delayed surgery. A previous study[8] reported that patients returning to lower level sports can be managed well with proper nonoperative treatment and that "watchful waiting" can therefore be an option. Results from the current study indicated a shorter time from injury to surgery in patients who were in need for revision surgery, as compared with the control patients. While this finding could be interpreted as support for "watchful waiting," we believe that time from injury to surgery is also a derived factor, reflecting a population more eager to return to sports—exposing them to further risk of new injuries. It has to be acknowledged that this mean time from injury to surgery of 22.7 months could influence meniscus healing potential and thereby the results of the study.

There are several inherent limitations in the current study. First, defining failure only by the need for revision surgery will likely underestimate the number of failed ACLRs. Crawford et al[3] found that the overall rate of failure increased from 6% to 12% when patient-reported outcome measures and clinical evaluation of laxity were also accounted for. Not all patients who fail choose to undergo repeat surgery. Further, level of osteoarthritis and return to sports are unknown factors that could help define whether the primary surgery was successful or not. Strengths of the current study include the relatively large prospective cohort of ACLRs undergoing later revision surgery and a homogenous group of controls operated on by the same group of surgeons at a single center. Although data were collected through a long period of time, we believe that the design of the study, applying a matched control group, counterbalances the differences caused by the changing surgical techniques over the time span of the study. We acknowledge that the retrospective design is less robust toward confounding factors than if a prospective design had been applied. The study design supports the generalizability of the results, since in the included patients were an unselected group of patients who experienced failure after ACLR.

CONCLUSION

The current study, investigating the risks for failure after ACLR, demonstrated an association between failed meniscal surgery and the need for repeat ACL surgery. Second, the study found that hamstring tendon autografts of <8 mm diameter were more frequent in those who underwent revision ACLR. Finally, younger age at the time of surgery and shorter time from injury to surgery—both believed to reflect the risk of returning to high-risk activities—were also found to affect the risk of undergoing revision ACL surgery. With an increasing number of patients in need of repeat ACL surgery, knowledge of causes for failure is increasingly important. There is also a need for a better definition of what constitutes failure; thus, further studies should focus on this topic.

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II

III

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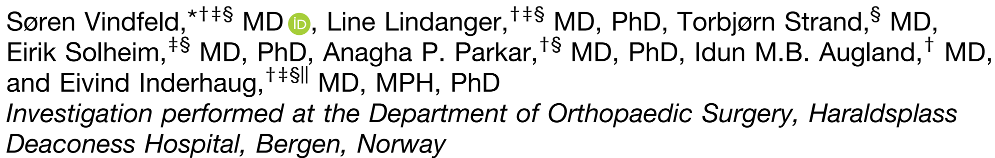
Original Research

Osteoarthritis Development and Clinical Outcomes After Revision Anterior Cruciate Ligament Surgery

A Matched Case-Control Study With 10-Year Follow-up


Søren Vindfeld,[*†‡§] MD, Line Lindanger,[†‡§] MD, PhD, Torbjørn Strand,[§] MD, Eirik Solheim,[‡§] MD, PhD, Anagha P. Parkar,[†§] MD, PhD, Idun M.B. Augland,[†] MD, and Eivind Inderhaug,[†‡§||] MD, MPH, PhD
Investigation performed at the Department of Orthopaedic Surgery, Haraldsplass Deaconess Hospital, Bergen, Norway

Background: Failure after anterior cruciate ligament (ACL) reconstruction occurs in 3% to 30% of all patients. However, not all failures necessitate a revision surgery. Revision ACL reconstruction (ACLR) presents significant challenges for both the surgeon and the patient, and limited research has been conducted regarding long-term functional outcomes and the potential increased risk of osteoarthritis (OA).

Purpose/Hypothesis: This study evaluates the long-term radiographic and clinical outcomes after revision ACLR compared with those of primary ACLR. It was hypothesized that revision ACLR results in a higher incidence of OA and inferior functional and patient-reported outcomes.

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

Methods: A retrospective follow-up compared patients with revision ACLR to a matched group of primary reconstruction (matched by sex, age, and surgery date). After a median of 9.7 years, OA was assessed using the Kellgren-Lawrence (K-L) classification.
Clinical outcome assessment included Patient-Reported Outcome Measures and knee laxity testing.

Results: A total of 273 patients were included, 140 ACL revisions and 133 primary ACLRs. Radiographic evidence of OA (K-L grade $\geq$2) was present in 67% of the revision group versus 33% in the primary ACL group ($P < .001$). A longer time from injury to follow-up, meniscal injury, and a high body mass index (BMI) at the index surgery independently increased the odds of developing OA. Although significant improvements in knee laxity measurement were seen in both groups, these were greater in the primary reconstruction group. Improvements well above the minimal important clinical change were observed for both the International Knee Documentation Committee subjective score and the Knee Injury and Osteoarthritis Outcome scores in both groups, with a higher proportion of patients meeting the patient-acceptable symptom state in the *primary group.*

Conclusion: Patients undergoing revision ACLR exhibit worse long-term functional outcomes and a higher prevalence of OA compared with patients undergoing primary ACLR. A longer time from injury to follow-up, meniscal injury, and a high BMI at the index surgery independently increased the odds of developing OA. Despite the inferior results, patients undergoing revision reconstruction experience significant improvements in both subjective scores and clinical findings, and report a high level of satisfaction.

Keywords: anterior cruciate ligament; knee laxity; long-term outcomes; osteoarthritis; revision anterior cruciate ligament reconstruction

Failure after anterior cruciate ligament (ACL) reconstruction (ACLR) is reported to occur in 3% to 30% of all patients.[7,32,49] ACL failure definitions and revision surgery

The Orthopaedic Journal of Sports Medicine, 13(10), 23259671251383083
DOI: 10.1177/23259671251383083
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indications remain debated. Because not all failures lead to revision or benefit from it, revision rates remain low, ranging from 3% to 10% of primary ACL cases.[18,28,33,48] New trauma, small graft size, errors in surgical technique, younger age, high BMI, and cigarette smoking have all been identified as risk factors for failure after ACLR.[5,22,31,46,48]

Injury to the ACL has been shown to increase the lifetime risk of developing OA of the knee compared with that of patients with an intact ACL,[43] resulting in decreased quality of life.[3] Reconstruction of the ACL may reduce this risk compared with nonoperative treatment, although reports are conflicting[1,26] and little is known about the risk for OA after revision surgery, specifically. In a 5-year follow-up cross-sectional study of patients undergoing revision ACLR, including a control group of primary ACLR, Kievit et al[25] found radiographic OA in 52% and 23% of patients, respectively. In contrast, Gifstad et al[13] only found 27% and 12% radiographic OA when comparing revision with primary reconstruction at an 8-year follow-up.

Research on medium- to long-term outcomes of ACL revision is limited, primarily consisting of small case series, with few studies including control groups for comparison.[15] Noyes et al[36] reported improvements in pain, daily activities, sports participation, and patient satisfaction within their case series of 55 revisions at a mean 33-month follow-up. Similarly, Carson et al[5] found that while revision ACL patients demonstrate improved functional and subjective outcomes, their outcomes remain inferior to those of primary ACL patients. Lind et al[30] demonstrated that while revision ACL patients achieve acceptable knee stability, they report lower outcomes, particularly in the Knee injury and Osteoarthritis Outcome Score (KOOS) subscales for sports and quality of life, compared with primary ACL patients.[27,29] In a recent study from the Multicenter ACL Revision Study cohort, chondral and meniscal pathology at the time of revision was found to decrease patient-reported outcomes 6 years after revision.[16] Gifstad et al[13] based on a retrospective case-control series, concluded that revision ACL reconstructions are associated with lower KOOS, Lysholm, Tegner activity scores, and reduced muscle strength. Finally, Grassi et al,[15] who defined *clinical failure* as a grade C or D on the International Knee Documentation Committee (IKDC) objective score, found such failure rates ranging from 0% to 82% in a review summarizing 16 case series.

The wide range in the reported outcomes after revision ACLR demonstrates the need for more knowledge on the risk of OA development and other objective and subjective outcome measures. Such knowledge is required to conduct the shared decision-making for this large and growing group of young patients. Thus, this study aimed to investigate the long-term outcomes of a case-control study comparing patients undergoing ACL revision with a matched control group of patients who had nonrevised primary reconstructions. Our primary hypothesis was that revision ACLR patients would have a higher rate of radiographic OA compared with a matched control group at 10-year follow-up. Furthermore, we hypothesized that the *revision group* would also exhibit worse knee laxity and patient-reported outcome measures at the follow-up.

METHODS

Patient Inclusion and Exclusion

Between July 2004 and December 2016, a total of 180 patients underwent ACL revision reconstruction at our clinic. First-time revisions, with or without concomitant meniscal surgery, minor cartilage injuries, and nonsurgically treated grades 1 or 2 medial collateral ligament injuries, were eligible for inclusion (revision group). Patients with concomitant ligament surgeries (of the posterior cruciate ligament, lateral collateral ligament, posterior lateral corner, or medial collateral ligament) at primary or previous revision surgery were excluded, as well as deceased or emigrated patients.

A control group of patients with an "uneventful" primary ACLR, which had not been revised before the inclusion, was selected from an internal quality assessment database (*primary group*). To account for known confounders, the patients in the *primary group* were matched (with the *revision group*) for age, sex, and date of surgery to account for changes in surgical techniques over time. If a patient in the primary group was revised later during the follow-up, they were replaced with the second-best match as a control, maintaining a 1 to 1 ratio (Figure 1).

The follow-up evaluation, which included a clinical examination, a radiological assessment, and the completion of the patient-reported outcome scores, was completed between November 2020 and September 2022. All patients were informed about the study and provided written consent before participation. The study was approved by the regional ethics committee (REK Vest/100644).

Surgical Technique and Rehabilitation

Revision and matched primary ACLRs were performed between June 2004 and December 2016. Therefore,

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Final revision submitted July 5, 2025; accepted July 21, 2025.
The authors have declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the regional ethics committee Regional Etisk Kommitee Vest (REK Vest/100644).

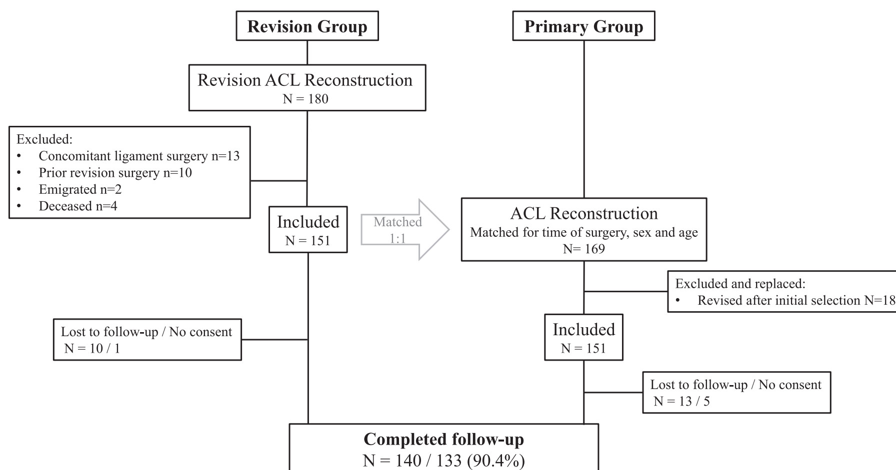

Figure 1. Inclusion and exclusion flowchart. ACL, anterior cruciate ligament.

variations in surgical techniques, including tunnel placement, graft choice, and fixation methods, were seen. Revision surgeries also had to account for previous procedures, taking into consideration graft selection, bone stock, and retained hardware. Surgical techniques were primarily based on what was perceived as the "gold standard" procedure at the time of surgery, and to a lesser degree, individualized based on patient characteristics. All surgeries included in the study were performed or supervised by experienced surgeons specializing in knee ligament surgery. In some cases, the same surgeon was involved in both primary and revision cases.

The rehabilitation protocol recommended crutches for partial weightbearing on the operated leg for the first 2 to 6 weeks, while still allowing free range of motion (ROM) exercises. Patients with concomitant meniscal repair in both groups were recommended partial weightbearing for 6 weeks and ROM restricted to 0° to 90°. Rehabilitation supervised by a physical therapist in an outpatient clinic for the first 6 to 9 months was recommended for all patients. A standardized follow-up included visits with both a physical therapist and a knee surgeon at the surgical clinic. All patients were offered functional testing, including a hop test and an isokinetic strength test, 9 to 12 months after surgery, and were advised accordingly regarding their return to sports based on the results.

Radiographic Assessment

Standardized bilateral weightbearing radiographs, using a Synaflexer positioning frame (BioClinica (formerly Synarc Inc), were obtained at the follow-up evaluation. The patients' knees were placed in 45° of flexion in the frame, with a 15° craniocaudal radiographic beam for a posteroanterior view of the tibiofemoral joint. A lateral view of both knees in maximum extension was also obtained. The radiographs were evaluated by an experienced musculoskeletal radiologist (A.P.P.). Intra- and interrater reliability were established using Cohen's weighted Kappa, with at least a 6-week interval between evaluations. Interrater reliability was established by a second radiologist (I.M.B.A.). Both inter- and intrarater assessments were performed using 50 randomly selected radiographs (100 knees) from the same dataset. Both radiologists were blinded to previous evaluations. Radiographic OA was graded using the Kellgren-Lawrence (K-L) classification,[23] with OA defined as grade ≥2 for analysis.

Clinical Evaluation

At the final follow-up, all patients were examined by an independent, experienced knee surgeon (S.V.). Evaluation of knee laxity included arthrometer measures (KT-1000; MEDmetric), Lachman test, and pivot-shift testing. The maximum manual side-to-side difference between the injured and normal knees was used for the analysis of the arthrometer testing and recorded in millimeters mm).[8] The Lachman test[45] was graded according to the IKDC classification as normal, <3 mm; nearly normal, 3 to 5 mm; abnormal, 6 to 10 mm; and severely abnormal, >10 mm.[17] Anterolateral rotational instability was assessed using the pivot-shift test[11] and graded as 0, negative; 1 + , glide; 2 + , clunk; or 3 + , gross, or as "guarding" if muscular tension prevented proper classification.

Patient-Reported Outcomes

Patient-reported outcome measures were obtained from the patients' medical records immediately before the index surgery and reassessed before the final follow-up. The KOOS[39] was used. A KOOS quality of life subscale <44 is considered indicative of failure after ACLR.[10] A change of 8 to 10 points in the subscale is regarded as the minimal

TABLE 1
Demographic Data in Revision and Primary Groups[a]

Description	Revision Group (n = 140)	Primary Group (n = 133)	*P*
Age, years			
Primary injury	20.3 (16.7-27.9)	25.4 (18.7-33.6)	<.001[b]
Index surgery	25.6 (21-35.6)	27.2 (20.5-34.7)	NS[b]
Time, months			
Injury to the primary surgery	5.9 (3.2-11.7)	7.8 (5.2-16.8)	.006[b]
Injury to follow-up	178.2 (103.1-253.3)	135.1 (63.1-207)	<.001[b]
Female patients	85 (60.7)	79 (59.4)	NS[c]
Injured side, left	66 (47.1)	65 (48.7)	NS[c]
BMI, kg/m^2			
At index surgery	24.2 (22.2-27.1)	24.3 (22.3-27)	NS[b]
At follow-up	25 (22.9-27.8)	25.6 (23.6-28.9)	NS[b]
Tegner preinjury	7 (2-10)	7 (3-10)	NS[d]

[a]Data are presented as median (IQR) or n (%). BMI, body mass index; IQR, interquartile range; NS, not significant.
[b]Independent samples median test.
[c]Chi-square test.
[d]Independent samples Mann-Whitney *U* test.

perceptible clinical improvement.[39] The International Knee Documentation Committee Subjective Knee evaluation Form (IKDC-SKF),[19] was collected before the index surgery for patients included after November 2006 (82%), and for all patients at the final follow-up. A score of ≥76.2 has been suggested as a patient-acceptable symptom state at 10 years after ACLR.[47] The Tegner activity scale[44] was used to assess the ability to perform sport- and work-related activity. Patient satisfaction with the current knee function was graded using a 5-point Likert scale[21] as either Excellent, Good, Satisfactory, Less good, or Poor.

Variables and Statistical Analyses

All statistical analyses were performed using IBM SPSS Statistics Version 29.0 (IBM Corp). An a priori *P* value of .05 was used to denote statistical significance. As measures of central location and spread of data, the mean and standard deviation, or the median and interquartile range, were used. Normality of continuous variables was confirmed using quantile-quantile plots and Shapiro-Wilk tests. If normality was found, independent-samples *t* tests were used; if not, independent samples median tests or the Mann-Whitney *U* test were used. Chi-square statistics were used to test categorical variables. When testing paired categorical data, the McNemar test was used. The Cohen weighted Kappa was used to test the intra- and interrater reliability of the radiographic assessment of the degree of OA. Logistic binomial regression was used for both univariate and multivariate analysis, employing a backward stepwise model to confirm the findings.

RESULTS

A total of 273 patients (90.4%) participated in the follow-up. Eleven completed only an electronic questionnaire and a telephone interview. A total of 29 were unavailable for radiographic evaluation (n = 23), did not consent to radiographs (n = 2), or had undergone knee replacement surgery (n = 4). These patients were evenly distributed between groups; however, all knee replacements occurred in the revision group and were classified as having OA for analysis.

No statistically significant differences were found between the *revision* and *primary groups* in terms of mean *age at index surgery*, *sex* distribution, or *time from index surgery to follow-up* (116.4 months [range, 91.8-163.2 months] vs 117.7 months [range, 90.9-155.7 months]). The overall median *time from surgery to follow-up* was 9.7 years (5.2-17.7). Across the groups, 60% of patients were females. Age at both primary injury and primary surgery was lower in the revision group (20.3 and 20.6 years, respectively) compared with the *primary group* (25.4 and 27.2 years, respectively). The time from injury to primary surgery was shorter in the revision group (5.9 months) than in the primary group (7.8 months). Because of the study design, the time from the primary injury to the follow-up was higher in the *revision* group (Table 1).

Surgical Considerations

A total of 77 (55%) surgeries in the *revision group* were done as a 1-stage procedure. The remaining procedures were 2-stage revisions, with bone grafting of the graft tunnels in the first stage, followed by revision reconstruction with a new graft in the second stage. The recommended interval between the 2 stages was 6 months. Ipsilateral hamstring or patellar tendon autografts were the primary choices for both the primary and revision cases. In the revision group, a contralateral hamstring or patellar tendon autograft was used in 12 cases (8.6%), a quadriceps tendon in 3 cases (2.1%), and an allograft in 2 cases (1.4%). In 5 cases (3.6%), patients opted out of the planned reconstructive surgery after the first-stage bone grafting.

TABLE 2
Surgical Details and Interoperative Findings[a]

Description	Revision Group (n = 140)	Primary Group (n = 133)
Graft choice, index surgery		
Hamstring	47 (33.6)	108 (81.2)
BPTB	83 (59.3)	25 (18.8)
Other	5 (3.6)	0
Bone grafting only[b]	5 (3.6)	NA
Primary surgery		
ACLR + meniscal resection	35 (25)	42 (31.6)
ACLR + meniscal suture	11 (7.9)	19 (14.3)
Cartilage injuries at index surgery		
ICRS grades 1-2	39 (27.9)	20 (15)
ICRS grades 3-4	14 (10)	11 (8.3)
Meniscal injuries, throughout the follow-up period		
Medial	56 (40)	43 (32.3)
Lateral	25 (18.8)	31 (23.3)
Medial + lateral	28 (20)	11 (8.3)
Contralateral ACLR	18 (12.6)	16 (12)

[a]Data are presented as n (%). ACLR, anterior cruciate ligament reconstruction; BPTB, bone-patellar tendon-bone; ICRS, International Cartilage Regeneration & Joint Preservation Society; NA, not applicable.
[b]Patients planned for 2-stage revision reconstruction, but after bone grafting, they chose not to go through with the second stage.

Meniscal and Cartilage Injuries

No significant difference was found in the distribution of concomitant meniscal procedures at the time of primary surgery between the groups. However, over the entire follow-up period, the revision group had a significantly higher incidence of meniscal injuries (78.8% vs 62.9%; $P = .012$). Additionally, the revision group had a higher incidence and severity of cartilage injuries at index surgery compared with the primary group.

Surgical Burden

The revision group had a significantly higher total mean number of surgeries on the ipsilateral knee over the follow-up period (4.1 ± 1.7) compared with the primary group (1.8 ± 1; $P < .001$). Before primary reconstruction, surgery was performed in 29 patients (20.7%) in the revision group, including 2 patients who had undergone multiple surgeries, and in 31 patients (23.3%) in the primary group, including 4 patients (3%) who had undergone multiple surgeries.

Between primary and revision reconstruction, 81 patients (57.9%) in the revision group underwent additional surgery, with 10 (7.1%) having ≥2 procedures. After the index surgery, 57 patients (40.7%) in the revision group underwent further surgery, with 23 (16.4%) requiring ≥2 procedures, the highest being 8 surgeries. In the primary group, 52 patients (39.1%) underwent additional surgery, with 16 patients requiring ≥2 methods (Table 2).

Additional ACL Reconstructive Surgery

A total of 34 patients (12.5%) underwent contralateral ACLR during the follow-up, including 18 (12.8%) patients in the revision group and 16 (12%) in the primary group. In the revision group, 7 patients (5%) required rerevision (a second ACL revision), and 2 (1.4%) underwent 3≥ modifications. Two patients (1.4%) underwent revision before later undergoing knee replacement, while another 2 (1.4%) patients had total knee replacement without a previous revision.

Development of OA

The intra- and inter-rater reliability tests for radiographic evaluation using the K-L classification showed substantial agreement, with weighted kappa values of 0.72 and 0.64, respectively. For radiographic OA development, the weighted kappa was 0.79 for intra-rater reliability and 0.81 for inter-rater reliability. When defining OA as a K-L grade of ≥2, the revision group had a significantly higher incidence of OA (n = 83 patients, 67%) compared with the primary group (n = 42 patients, 33%; $P < .001$). No significant difference was observed in the contralateral knee (revision: 13 [10%], primary: 18 [15%]), with 8 patients in

TABLE 3
Incidence of Radiological Osteoarthrosis Based on the Kellgren-Lawrence Classification[a]

Grade	Revision Group: Ipsilateral n = 124	Revision Group: Contralateral n = 120	Primary Group: Ipsilateral n = 124	Primary Group: Contralateral n = 124
0	17 (13.7)	93 (77.5)	37 (29.8)	90 (72.6)
1	24 (19.4)	15 (12.5)	45 (36.3)	16 (12.6)
2	35 (28.2)	7 (5.8)	20 (16.1)	10 (8.1)
3	35 (28.2)	3 (2.5)	22 (17.7)	5 (4)
4	9 (7.3)	2 (1.7)	0	3 (2.4)
TKA	4 (3.2)	0	0	0

[a]Values are presented as n (%). TKA, total knee arthroplasty.

TABLE 4
Odds Ratio for Developing Osteoarthrosis (K-L ≥2) at the Follow-up[a]

	K-L ≥2, Median (IQR) or N (%)			
Variable	<2 (n = 123)	≥2 (n = 125)	OR (95% CI)	*P*
Age at injury, years	22.1 (18.1-30.3)	22.6 (17.5-32.1)	1.004 (0.977-1.033)	.755
Sex, female	83 (67.5)	66 (52.8)	1.855 (1.108-3.106)	.019
Time from injury to follow-up, years	11.4 (8.7-14.9)	14.8 (11.2-18)	1.164 (1.095-1.237)	<.001
Meniscal injury, yes	69 (56.1)	106 (84.8)	4.366 (2.386-7.990)	<.001
Cartilage injury at index surgery, yes	25 (20.3)	50 (40)	2.613 (0.217-0.674)	<.001
Smoking, yes	23 (18.7)	37 (29.6)	1.828 (1.009-3.311)	.047
BMI at index surgery, kg/m^2	23.6 (21.7-25.9)	24.8 (23.3-28.2)	1.149 (1.066-1.237)	<.001
Revision surgery	41	83	3.952 (2.332-6.698)	<.001
Total number of surgeries	3 (3-4)	4 (3-6)	1.483 (1.102-1.998)	.009
1-stage/2-stage revision	23/18	42/41	1.247 (0.588-2.646)	.565
Bone grafting only[b]	1	4	2.025 (0.219-18.724)	.534

[a]BMI, body mass index; K-L, Kellgren-Lawrence; OR, odds ratio.
[b]Patients planned for 2-stage revision reconstruction, but after bone grafting, chose not to go through with the second stage.

TABLE 5
Adjusted Multivariate Analysis of Odds Ratio for Developing Osteoarthrosis (K-L ≥2) at the Follow-up[a]

Variable	Adjusted OR (95% CI)	*P*
Age at injury, years	1.016 (0.979-1.054)	.406
Sex, female	1.645 (0.853-3.174)	.138
Time, from injury to follow-up, years	1.136 (1.060-1.217)	<.001
Meniscal injury, yes	3.553 (1.706-7.401)	<.001
Cartilage injury at index surgery, yes	1.453 (0.711-2.967)	.305
Smoking, yes	0.652 (0.306-1.389)	.267
BMI at index surgery, kg/m^2	1.144 (1.046-1.252)	.003
Revision surgery	1.799 (0.788-4.110	.163
Total number of surgeries	1.283 (0.997-1.652)	.053

[a]BMI, body mass index; K-L, Kellgren-Lawrence; OR, odds ratio.

each group having undergone ACLR and developed OA (Table 3).

Patient-Related Factors Associated With OA

The univariate and multivariate analyses of factors associated with the development of OA at the follow-up are presented in Tables 4 and 5. In the unadjusted analysis, *the time from injury to follow-up, meniscal injury, cartilage injury at index surgery, cigarette smoking, BMI at index surgery, revision surgery, and the total number of surgeries* all increased the odds of developing OA at the follow-up. After adjusting for possible confounders, the multivariate analysis demonstrated that the adjusted odds ratio (OR) for *time from injury to follow-up* was 1.14 (95% CI, 1.06-1.22; $P \leq .001$), *meniscal injury* was 3.55 (95% CI, 1.71-7.40; $P \leq .001$), and *BMI at index surgery* was 1.14 (95% CI, 1.05-1.25; $P = .003$). The remaining factors no longer presented significant ORs in the adjusted analysis.

Knee Laxity Evaluation at Clinical Examination

Preoperative knee laxity data were similar between the groups for KT-1000 arthrometer testing, the Lachman test, and the pivot shift test. At the follow-up, both groups showed significant improvement in knee laxity across all 3 measures, with the *primary group* demonstrating a greater improvement (Table 6).

Patient-Reported Outcomes

There was no statistically significant difference between the *revision* and *primary groups in mean preoperative IKDC-SKF scores at the time of the* index surgery. The *primary group*, however, had a significantly higher score at the follow-up (79.7 ± 15.4) compared with the *revision group* (71.7 ± 14.6) (Table 7). Furthermore, the *primary group* more frequently reached the Patient-Acceptable Symptom Score (PASS) value (67.7% vs 43.6%) as defined by Urhausen et al.[47] The KOOS profiles are presented in Figure 2. No differences were found in preoperative scores for the Symptoms, Pain, and Activities of Daily Living subscales; however, the *revision group* scored significantly lower on the Sports and Recreation and Quality of Life subscales. At the follow-up, the *primary group* had significantly higher KOOS scores across all 5 subscales compared with the *revision group*. Additionally, the *primary group* had a higher percentage of patients reporting *satisfied* or better knee function at the follow-up (85%) compared with the *revision group* (72.2%).

DISCUSSION

The main finding of this study was a higher incidence of radiographic OA, defined as a K-L grade of ≥2, among ACL revision reconstructions (67%) compared with "uneventful" primary ACL reconstruction (33%) at

TABLE 6
Clinical Findings Before Index Surgery and at Follow-up[a]

	Preop		Follow-up		
	Normal/Nearly Normal[c]	Abnormal/Severely Abnormal[c]	Normal/Nearly Normal[c]	Abnormal/Severely Abnormal[c]	P
KT-1000 STS difference					
Revision group	26 (24)	84 (76)	91 (76)	28 (24)	<.001
Primary group	30 (27)	81 (73)	110 (88)	15 (12)	<.001
Lachman test					
Revision group	13 (10)	118 (90)	60 (50)	59 (50)	<.001
Primary group	14 (11)	115 (89)	97 (78)	28 (22)	<.001
Pivot-shift test[b]					
Revision group	5 (4)	125 (96)	72 (61)	47 (39)	<.001
Primary group	9 (8)	108 (92)	96 (77)	28 (23)	<.001

[a]Values are presented as n (%). IKDC, International Knee Documentation Committee; Preop, preoperative; STS, side-to-side.
[b]Patients with guarding at examination were excluded from the analysis.
[c]According to the IKDC classification.

TABLE 7
Patient-Reported Outcomes[a]

Description	Revision Group (n = 140)	Primary Group (n = 133)	P
IKDC-SKF			
Presurgery	56.3 (14.3)	58.6 (14.1)	NS[b]
Follow-up	71.7 (14.6)	79.7 (15.4)	<.001[b]
Patient satisfaction			
Excellent	8 (5.7)	24 (18)	0.002[c]
Good	46 (32.9)	52 (39.1)	
Satisfactory	47 (33.6)	39 (27.9	
Less good	29 (20.7)	17 (12.8)	
Poor	8 (5.7)	1 (0.8)	

[a]Data are presented as mean (SD) or n (%). IKDC-SKF, International Knee Documentation Committee Subjective Knee Evaluation Form; NS, not significant.
[b]Independent samples *t* test.
[c]Chi-square test.

a mean of 10 years after surgery. *Meniscal injury, time from injury to follow-up*, and *BMI at index surgery* all independently increased the odds of developing radiographic OA. Both the *revision* and primary groups exhibited clinically significant improvements in knee stability, as measured by the Lachman test, the KT-1000 arthrometer, and the pivot-shift test. Significant improvements, well above minimal clinically important changes, were also observed in IKDC-SKF and KOOS scores for both groups. The relative improvement, both for objective and subjective outcomes, was larger in the *primary group* than in the *revision group*.

Few studies have reported on the development of OA at medium- to long-term after revision ACLR.[2,13,25,35] Previous studies are small and often lack a control group. In the present study, including 140 revision and 133 primary "uneventful" (nonrevised) controls, the incidence of radiographic OA (K-L $\geq$2) at a 10-year follow-up was 67 % in the *revision group* compared with 33% in the *primary*

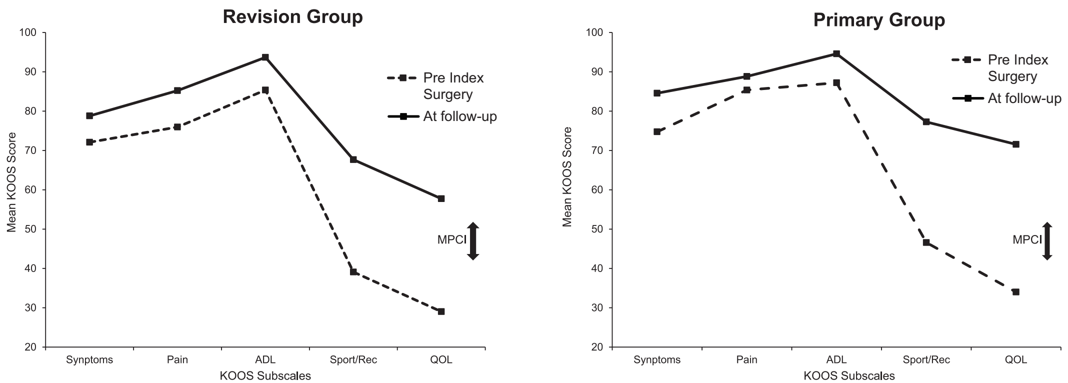

Figure 2. The KOOS scores at the preindex surgery and at the follow-up for the revision and primary groups. Values are presented as means. The MPCI of the KOOS represents a difference of 8 to 10 points.ADL, activities of daily living; KOOS, Knee injury and Osteoarthritis Outcome Score; MPCI, minimal perceptible clinical improvement; QoL, quality of life.

group. This rate is higher than that reported by Gifstad et al,[13] who compared 56 first-time revisions with 52 *uneventful* primary controls at a median follow-up of 7.7 years. They found radiographic OA (K-L $\geq$2) in 27% of revision patients and 12% of controls.[13] Their radiographs were nonweightbearing, which may explain the lower rate of radiological OA, as joint space narrowing is central to the K-L classification.[24] Additionally, their mean follow-up time was shorter (7.5-8 years, range 2.8-13.3 years) compared with a median of 9.7 years (range, 5.2-17.7 years) in the present study.

In a smaller retrospective study, including 20 revision patients and 20 primary controls, Niki et al[35] found a higher incidence of radiographic OA in the revision group at the 3-year follow-up. However, the lesser-used Fairbanks classification cannot be directly compared with the currently applied K-L classification. Secondly, the primary surgeries leading to revision were all failed synthetic ligament reconstructions. In a cross-sectional study evaluating 25 revisions and 27 primaries at a median follow-up of 5 years, Kievit et al[25] found radiographic signs of OA in 52% of revision patients and 23% of primaries, which aligns more closely with the present study. Their shorter follow-up time could explain the lower rate of OA.

Because of the scarcity of studies on medium- to long-term follow-up after revision ACLRs, recent studies on primary reconstructions provide valuable insight. Lindanger et al,[30] in a 25-year follow-up of 235 primary reconstructions, found radiographic OA in 60% of the involved knees and 18% in the contralateral knees using the K-L classification. Similarly, in a 10- to 15-year follow-up of 210 primary reconstructions, Oiestad et al[37] found radiographic OA in 71% of the involved knees and 25% in the contralateral knees.

Overall, a higher incidence of OA appears to be found in revised cases compared with primary, *uneventful* ACLRs and compared with the uninjured contralateral knee. The implication is that the early onset of OA in young patients results in many years with reduced quality of life. Preventing OA development is imperative, yet limited research identifies factors contributing to OA after revision ACLR.[2,40] In this study, logistic regression analysis was used to determine independent factors associated with radiographic OA. The final multivariate analysis identified 3 such factors.

First, the time from injury to follow-up showed an adjusted OR of 1.14 (95% CI, 1.06-1.22; $P < .001$), indicating a 14% increased risk of radiographic OA per year. This aligns with a 2018 systematic review on primary ACLRs, which found a rising incidence of posttraumatic osteoarthritis over time—21% at 10 years and 52% at 20 years after surgery.[6] Battaglia et al[2] demonstrated a correlation between time spent with an unstable knee and OA development, although without quantifying the risk. Because their study relied on retrospective medical record reviews and lacked a control group, the time with instability may not accurately reflect the total follow-up time. Their findings could support more aggressive revision surgery to minimize time with an unstable knee. However, as the present study is adjusted for revision surgery, which was not an independently significant factor for the development of OA, this relationship is less clear. Nonetheless, it underscores the importance of ACL injury prevention.

Patients with a meniscal injury at any point during the follow-up had a more than 3-fold increased risk of developing radiographic OA (adjusted OR, 3.55 [95% CI 1.71-7.40]; $P < .001$). In recent decades, there has been a significant shift in the diagnosis and treatment of meniscal injuries in patients with ACL injuries. Data from the Norwegian Knee Ligament Registry show a shift from 2004 to 2016, with a decrease in partial meniscus resection from 85% to 45%, and an increase in meniscal repair from 5% to 40% reflecting this change in practice.[18] This trend has continued from 2016 until the present, illustrating the communal change in the orthopaedic society embracing meniscal preservation as an important part of knee joint preservation.

In the present study, meniscal injury was diagnosed and treated concurrently with ACLR in 107 of 273 patients (39.2%), with suture repair performed in only 30 cases (11%). The low repair rate may have contributed to the high incidence of radiographic OA observed at the follow-up. This, combined with the fact that the analysis was done with *meniscal injury* and not partial *resection* or *repair*, highlights the importance of the meniscus for joint preservation. Meniscal repair is indisputably important in restoring knee function, together with ACLR.[34,42] The increased attention to meniscal repair over resection, as well as the growing recognition of meniscal ramp lesions and posterior root tear repairs, has emerged primarily over the past decade. In our study, these procedures were only performed during the latter years of the inclusion period, which helps explain the seemingly low rates of meniscal repair. Overall, 194 out of 273 patients (71%) underwent meniscal surgery at some point during the follow-up period. Further research is needed to determine whether this shift in meniscal treatment will influence the long-term development of OA.

Lastly, high BMI at index surgery was independently associated with an increased risk of radiological OA. Each unit increase in BMI raised the risk by 14% (adjusted OR, 1.14 [95% CI 1.05-1.25]; $P = .003$). This aligns with findings from Brophy et al,[4] who reported an OR of 1.08 for medial OA but no significant association with lateral OA. This finding is important given the fact that BMI is a potential modifiable factor, and has been shown to increase risk of OA,[9] whereas a reduction in BMI has been shown to improve pain and function for patients with OA,[38] making it a key consideration for surgeons counseling potential revision ACL patients.

Both the revision and primary groups showed significant improvements in knee laxity from preoperative values to the follow-up. However, a substantial proportion of patients in both groups still had abnormal knee laxity. In the revision group, 52.1% had an IKDC Objective score of C or D, compared with 28% in the primary group, indicating worse outcomes than in other studies. Lind et al[29] reported a 34% rate of C or D scores at a median of 9 years, although without a control group. A meta-analysis by Grassi et al.[14] found lower rates (22% in revision, 5% in

primary) but with a shorter median follow-up (2.1-6.1 years), which raises the possibility that the outcome may worsen over time.

Concomitant lateral extra-articular procedures (LEAP) have been shown in recent decades to decrease graft failure after ACLR.[12] Revision ACLR is considered an indication for this concomitant procedure, with the rationale that secondary instability over time will also affect secondary restraint, yielding a residual laxity. In the present study, anterolateral procedures were only used in the 2 most recent of the 140 revisions, and in none of the primaries. The current increasing use of LEAP may have potential future effects on outcomes after revision ACL. However, a recent study by Sørensen et al[41] was unable to find improved clinical outcomes after adding this procedure.

The present study demonstrates significant improvements in IKDC-SKF scores for both the *revision* and the *primary groups* (15.4 and 21.1), and well above the matrix-induced autologous chondrocyte implantation (MPCI) of the IKDC-SKF of 11.5.[20] However, assessing the MPCI at a group level does not account for individual variability, where some patients experience substantial improvements while others show little to no change or even deterioration. The PASS provides an alternative method for assessing change, based on patient satisfaction. While no studies specifically evaluating PASS in revision patients were identified, a recent 10-year prospective cohort study[47] on ACL tears reported a PASS threshold for the IKDC-SKF of 76.2. In this study, 43.6% of the revision group and 67.7% of the primary group reached the PASS threshold of 76.2 for the IKDC-SKF ($P < .001$). However, 72.2% and 85%, respectively, reported being satisfied or better with their knee function at the follow-up, suggesting that the PASS threshold may not be directly applicable to this cohort. Similar trends were observed for KOOS scores, with both groups exceeding the MCPI threshold of 8 to 10 points. Using the KOOS QoL of <44 as an indicator of ACLR failure, 29.9% of the revision group and 14.3% of the primary group met this criterion at the follow-up.[10]

Satisfaction can indicate surgical success; nonetheless, it is also influenced by patient expectations and whether these expectations are set realistically. While revision patients show improvements, their outcomes are generally less favorable than those undergoing primary ACLR. Still, a large proportion report satisfaction with their knee function despite knee laxity and radiographic OA. However, 28% of the revision group were not satisfied, compared with 15% in the primary group. Future improvements in patient selection, surgical techniques—including meniscal repair and other concomitant procedures (LEAP)—as well as enhanced rehabilitation and guidance on return to sports, may lead to better outcomes.

Strengths and Limitations

A key strength of this study is the inclusion of 140 revision patients, making it one of the largest mid- to long-term evaluations of radiographic OA development after revision ACLR, with a 90% follow-up rate. The study captures a diverse and representative spectrum of revision ACL cases, likely reflecting the general population of revision patients more accurately.

The primary limitation of this study is its retrospective design. Additionally, variations in surgical methods—including graft choice, tunnel placement, meniscal treatment, and concomitant procedures—are challenging to account for in the analysis. The orthopaedic surgeon conducting follow-ups was not blinded due to practical constraints, which may introduce bias. However, because the same experienced knee surgeon (S.V.) performed all evaluations, we believe the clinical results maintain high validity.

The matching process introduced both strengths and limitations to the study. While the matched design of the primary group may create a crossover type error, potentially making the primary group appear better than expected, it also provides a comparable control group for the revision group, which is a key strength. Additionally, data on meniscal injury and treatment were recorded at the treatment level; however, information on resection size and suture type was unavailable, which may have introduced bias. Another limitation was that the radiographic evaluation was performed using only anteroposterior and lateral views—including the Merchant view—which could possibly improve the accuracy of OA assessment.

CONCLUSION

High rates of radiographic OA were present at a median of 10 years after revision ACLR, and significantly higher than in a group of primary *uneventful* controls. Meniscal injury, the time from injury to follow-up, and a higher BMI all increased the odds of OA development. Significant improvements in clinical findings and subjective scores were observed in both groups, with greater improvements in the primary reconstruction group. Despite the superior outcome of primary reconstructions, patients undergoing revision ACLR achieve substantial improvements, and most importantly, report a high level of satisfaction.

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16.2 Forms and questionaires

Bergen 15 May 2007

Norwegian KOOS, version LK1.0

The KOOS form was translated into Norwegian in the following way.

Translation done at The Norwegian Arthroplasty Register (NAR)

- KOOS was translated from the Swedish version by two researchers in orthopedics. The choice of using the Swedish version was based on the assumption that cultural differences between the two neighbour countries would be minimal due to similarities in language and lifestyle.
- The translation was checked by two bilingual orthopedic surgeons (Swedes with permanent address in Norway).
- The form was tested on knee arthroplasty patients to clarify potential misinterpretations.

Translation done by The Norwegian National Knee Ligament Registry (NKLR)

- A translation from the English version was done by an orthopedic researcher.
- Another translation from the Swedish version was done by a former researcher at the Norwegian School of Sport Sciences who is bilingual in Norwegian and Swedish.
- The translations were compared, and due to only minor differences in the use of synonyms, the NKLR chose a wording as close to the Swedish translation as possible. This is due to the fact that the creators of the KOOS form are Swedish, even though the first form was made in English.

Finally the NAR and the NKLR versions were compared, minor adjustments were done, and the translators agreed upon a common translation. The final validated Norwegian version is named KOOS Norwegian version LK1.0

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KOOS SP RRESKJEMA FOR KNEPASIENTER

DATO: _____/_____/_____ FØDELSENR (11 siffer): ___________________

NAVN: ____

Veiledning: Dette spørreskjemaet inneholder spørsmål om hvordan du opplever kneet ditt. Informasjonen vil hjelpe oss til å følge med i hvordan du har det og fungerer i ditt daglige liv. Besvar spørsmålene ved å krysse av for det alternativ du synes passer best for deg (kun ett kryss ved hvert spørsmål). Hvis du er usikker, kryss likevel av for det alternativet som føles mest riktig.

Symptom

Tenk på de **symptomene** du har hatt fra kneet ditt den **siste uken** når du besvarer disse spørsmålene**.**

S1. Har kneet vært hovent?

Aldri	Sjelden	I blant	Ofte	Alltid
☐	☐	☐	☐	☐

S2. Har du følt knirking, hørt klikking eller andre lyder fra kneet?

Aldri	Sjelden	I blant	Ofte	Alltid
☐	☐	☐	☐	☐

S3. Har kneet haket seg opp eller låst seg?

Aldri	Sjelden	I blant	Ofte	Alltid
☐	☐	☐	☐	☐

S4. Har du kunnet rette kneet helt ut?

Alltid	Ofte	Iblant	Sjelden	Aldri
☐	☐	☐	☐	☐

S5. Har du kunnet bøye kneet helt?

Alltid	Ofte	I blant	Sjelden	Aldri
☐	☐	☐	☐	☐

Stivhet

De neste spørsmålene handler om **leddstivhet**. Leddstivhet innebærer vanskeligheter med å komme i gang eller økt motstand når du bøyer eller strekker kneet. Marker graden av leddstivhet du har opplevd i kneet ditt den **siste uken**.

S6. Hvor stivt er kneet ditt når du nettopp har våknet om morgenen?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐	☐	☐	☐	☐

S7. Hvor stivt er kneet ditt **senere på dagen** etter å ha sittet, ligget eller hvilt?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐	☐	☐	☐	☐

Smerte

P1. Hvor ofte har du vondt i kneet?

Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐	☐	☐	☐	☐

Hvilken grad av smerte har du hatt i kneet ditt den **siste uken** ved følgende aktiviteter?

P2. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P3. Rette kneet helt ut

Ingen	Lett	Moderate	Betydelig	Svært stor
☐	☐	☐	☐	☐

P4. Bøye kneet helt

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P5. Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P6. Gå opp eller ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P7. Om natten i sengen (smerter som forstyrrer søvnen)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P8. Sittende eller liggende

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P9. Stående

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Funksjon I hverdagen

De neste spørsmål handler om din fysiske funksjon. **Angi graden av vanskeligheter du har opplevd den siste uken ved f lgende aktiviteter p grunn av dine kneproblemer.**

A1. Gå ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A2. Gå opp trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Angi graden av **vanskeligheter** du har opplevd ved hver aktivitet den **siste uken**.

A3. Reise deg fra sittende stilling

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A4. Stå stille

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A5. Bøye deg, f.eks. for å plukke opp en gjenstand fra gulvet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A6. Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A7. Gå inn/ut av bil

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A8. Handle/gjøre innkjøp

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A9. Ta på sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A10. Stå opp fra sengen

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A11. Ta av sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A12. Ligge i sengen (snu deg, holde kneet i samme stilling i lengre tid)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A13. Gå inn og ut av badekar/dusj

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A14. Sitte

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A15. Sette deg og reise deg fra toalettet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Angi graden av **vanskeligheter** du har opplevd ved hver aktivitet den **siste uken.**

A16. Gjøre tungt husarbeid (måke snø, vaske gulv, støvsuge osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A17. Gjøre lett husarbeid (lage mat, tørke støv osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Funksjon, sport og fritid

De neste spørsmålene handler om din fysiske funksjon. Angi graden av vanskeligheter du har opplevd **den siste uken** ved følgende aktiviteter på grunn av dine kneproblemer.

SP1. Sitte på huk

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP2. Løpe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP3. Hoppe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP4. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP5. Stå på kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Livskvalitet

Q1. Hvor ofte gjør ditt kneproblem seg bemerket?

Aldri	Månedlig	Ukentlig	Daglig	Alltid
☐	☐	☐	☐	☐

Q2. Har du forandret levesett for å unngå å overbelaste kneet?

Ingenting	Noe	Moderat	Betydelig	Fullstendig
☐	☐	☐	☐	☐

Q3. I hvor stor grad kan du stole på kneet ditt?

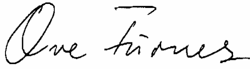
Fullstendigl	I stor grad	Moderat	Til en viss grad	Ikke i det hele tatt
☐	☐	☐	☐	☐

Q4. Generelt sett, hvor store problemer har du med kneet ditt?

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Takk for at du tok deg tid og besvarte samtlige sp rsm l!

Until otherwise is decided it is recommended that future revisions of the Norwegian KOOS form are done by The Norwegian Arthroplasty Register. If someone find that any questions from the questionnaire is difficult to understand or difficult to answer, we will be thankful to receive information on this.



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Haraldsplass
DIAKONALE SYKEHUS
Bergen Diakonissehjem

IKDC 2000 Kneevalueringsskjema

Navn:	Dato:	Skadedato:
Personnummer:		
Mobilnummer:	Email:	Side: ☐ Høyre ☐ Venstre

Symptomer:

Grader symptomene på det høyeste aktivitetsnivå som du tror du kan fungere uten betydelige symptomer, selv om du egentlig ikke driver med aktiviteter på dette nivået. Avhengig av hva som passer, sett kryss eller ring rundt.

1. Hva er det høyeste aktivitetsnivå du tror du kan drive med uten betydelige knesmerter? (kryss av)

- ❑ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball
- ❑ Harde aktiviteter som tungt fysisk arbeid, ski, eller tennis
- ❑ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging
- ❑ Lette aktiviteter som gange, husarbeid eller hagearbeid
- ❑ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av knesmerter

2. I løpet av de siste 4 uker (eller siden kneskaden); hvor ofte har du hatt smerter? (sett ring rundt)

Aldri	0	1	2	3	4	5	6	7	8	9	10	Alltid

3. Hvis du har smerter, hvor intense er de?

Ingen smerte	0	1	2	3	4	5	6	7	8	9	10	Verst tenkelig smerte

4. I løpet av de siste 4 uker (eller siden kneskaden); hvor stivt eller hovent har kneet ditt vært?

- ❑ Ikke i det hele tatt
- ❑ Litt
- ❑ Moderat
- ❑ Veldig
- ❑ Ekstremt

5. Hva er det høyeste aktivitetsnivå du tror du kan drive med uten betydelig hevelse i kneet?

- ❑ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball
- ❑ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis
- ❑ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging
- ❑ Lette aktiviteter som gange, husarbeid eller hagearbeid
- ❑ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av hevelse

6. I løpet av de siste 4 uker, (eller siden kneskaden); har kneet låst seg?

Ja Nei

7. Hva er det høyeste aktivitetsnivå du tror du kan drive med uten betydelig svikt av kneet?

- ❑ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball
- ❑ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis
- ❑ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging
- ❑ Lette aktiviteter som gange, husarbeid eller hagearbeid
- ❑ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av svikt av kneet

Idrettsaktiviteter:

8. Hva er det høyeste aktivitetsnivå du kan delta i (nå)?

- ❑ Veldig hard aktiviteter som hopping og vendinger ved basketball eller fotball
- ❑ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis
- ❑ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging
- ❑ Lette aktiviteter som gange, husarbeid eller hagearbeid
- ❑ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av kneet

9. Hvordan påvirker kneet din evne til å (sett kryss):

	Ikke vanskelig i det hele tatt	**Litt vanskelig**	**Moderat vanskelig**	**Ekstremt vanskelig**	**Kan ikke i det hele tatt**
Gå opp trapper					
Gå ned trapper					
Knele/gå ned på kne					
Gå ned på huk/gjøre knebøy					
Sitte med bøyd kne					
Reise deg opp fra stol					
Løpe rett frem					
Hinke på ditt skadede ben					
Starte og stoppe raskt					

Funksjon:

10. Hvordan vil du gradere din knefunksjon på en skala fra 0 til 10 der 10 er normal, utmerket funksjon og 0 er at du ikke kan gjøre noen av dine daglige aktiviteter, som også kan inkludere idrett?

Funksjon før kneskaden:

Kan ikke gjøre daglige aktiviteter	0	1	2	3	4	5	6	7	8	9	10	Ingen begrensninger i daglige aktiviteter

Nåværende knefunksjon (sett ring rundt):

Kan ikke gjøre daglige aktiviteter	0	1	2	3	4	5	6	7	8	9	10	Ingen begrensninger i daglige aktiviteter

IKDC 2000 ((x-18/87)x100) = ______________

Haraldsplass Diakonale Sykehus, Ortopedisk Senter 2011(Strand/Inderhaug).

Originalartikkel: *Irrgang et al. Development and validation of the International Knee Documentation Committee Subjective Knee Form. The American Journal of Sports Medicine 2001; 29(5): 600-13.* Oversatt av Norsk Senter for Aktiv Rehabilitering, OUS 2005, tom trinn 4 etter retningslinjer urarbeidet av: *Guillemin F, Bombardier C, Beaton D. Cross-cultural adaptation of health-related quality-of-life measures: Literature review and proposed guidelines. J Clin Epidemiol 1993; 46: 1417-32.*

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Haukeland universitetssjukehus
Møllendalsbakken 7, 5021 BERGEN
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F.nr. (11 sifre)..

Navn..

Sykehus...

(Skriv tydelig evt. pasientklistrelapp – **spesifiser sykehus**.)

KORSBÅND

KORSBÅNDSOPERASJONER OG ALLE REOPERASJONER på pasienter som tidligere er korsbåndsoperert.

Alle klistrelapper (med unntak av pasientklistrelapp) settes i merket felt på baksiden av skjemaet.

(Bilateral operasjon = 2 skjema)

AKTUELLE SIDE (ett kryss) ☐^{0} Høyre ☐^{1} Venstre

MOTSATT KNE ☐^{0} Normalt ☐^{1} Tidligere ACL/PCL-skade

TIDLIGERE OPERASJON I SAMME KNE
☐^{0} Nei ☐^{1} Ja

SKADEDATO FOR AKTUELL SKADE (mm.åå) |__|__| |__|__|

AKTIVITET SOM FØRTE TIL AKTUELLE SKADE

☐^{0} Fotball
☐^{1} Håndball
☐^{2} Snowboard
☐^{3} Alpint (inkl. twin tip)
☐^{4} Annen skiaktivitet
☐^{5} Kampsport
☐^{6} Basketball
☐^{98} Annet....................................
☐^{7} Annen lagidrett
☐^{8} Motor- og bilsport
☐^{9} Annen fysisk aktivitet
☐^{10} Arbeid
☐^{11} Trafikk
☐^{12} Fall/hopp/vold/lek

AKTUELLE SKADE (Registrer **alle** skader – også de som ikke opereres)

☐ ACL ☐ MCL ☐ PLC ☐ Med. menisk
☐ PCL ☐ LCL ☐ Brusk ☐ Lat. menisk
☐ Annet...

YTTERLIGERE SKADER (evt. flere kryss) ☐ Nei, hvis ja spesifiser under

☐ Karskade	Hvilken: ....
☐ Nerveskade	☐ ^{0}N. tibialis ☐ ^{1} N. peroneus
☐ Fraktur	☐ ^{0}Femur ☐ ^{1}Tibia ☐ ^{2}Fibula ☐ ^{3}Patella ☐ ^{4}Usikker
☐ Ruptur i ekstensorapparatet	☐ ^{0}Quadricepssenen ☐ ^{1}Patellarsenen

OPERASJONSDATO (dd.mm.åå) |__|__| |__|__| |__|__|

AKTUELLE OPERASJON (ett kryss)

☐^{0} Primær rekonstruksjon av korsbånd
☐^{1} Revisjonskirurgi, 1. seanse
☐^{2} Revisjonskirurgi, 2. seanse
☐^{3} Annen knekirurgi (Ved kryss her skal andre prosedyrer fylles ut)

ÅRSAK TIL REVISJONSREKONSTRUKSJON (evt. flere kryss)

☐ Infeksjon
☐ Fiksasjonssvikt
☐ Ubehandlede andre ligamentskader
☐ Annet ....
☐ Graftsvikt
☐ Nytt traume
☐ Smerte

ANDRE PROSEDYRER (evt. flere kryss) ☐ Nei, hvis ja spesifiser under

☐ Meniskoperasjon
☐ Synovektomi
☐ Mobilisering i narkose
☐ Fjerning av implantat
☐ Benreseksjon (Notch plastikk)
☐ Osteotomi
☐ Annet ....
☐ Osteosyntese
☐ Bruskoperasjon
☐ Artroskopisk debridement
☐ Operasjon pga infeksjon
☐ Bentransplantasjon
☐ Artrodese

GRAFTVALG

	ACL	PCL	MCL	LCL	PLC
☐ BPTB					
☐ Hamstring					
☐ Allograft					
☐ Direkte sutur					
☐ Annet					

GRAFTDIAMETER (oppgi største diameter på graftet) .. ..mm

Ved bruk av double bundle-teknikk: AM:.........mm PL:.........mm

TILGANG FOR FEMURKANAL
☐^{1} Anteromedial ☐^{2}Transtibial ☐^{3} Annet ....

FIKSASJON
Sett klistrelapp på merket felt på baksiden av skjemaet
Skill mellom femur og tibia

AKTUELL BEHANDLING AV MENISKLESJON

	Partiell reseksjon	Total reseksjon	Sutur	Syntetisk fiksasjon*	Menisk-transpl.	Trepanering	Ingen
Medial	☐	☐	☐	☐	☐	☐	☐
Lateral	☐	☐	☐	☐	☐	☐	☐

* Sett klistrelapp på merket felt på baksiden

BRUSKLESJON (evt. flere kryss)

	Areal (cm²) ≤2	>2	ICRS Grade* 1 2 3 4	Artrose Ja	Nei	Behandlings-kode** 1 2 3 4	Spesifiser annet
Patella MF	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....
Patella LF	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....
Trochlea fem.	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....
Med.fem. cond.	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....
Med. tib. plat.	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....
Lat.fem. cond.	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....
Lat. tib. plat.	☐	☐	☐☐☐☐	☐	☐	☐☐☐☐	....

***ICRS Grade:** 1 Nearly normal: Superficial lesions, soft indentation and/or superficial fissures and cracks; 2 Abnormal: Lesions extending down to <50% of cartilage depth; 3 Severely abnormal: Cartilage defects extending down >50% of cartilage depth as well as down to calcified layer; 4 Severely abnormal: Osteochondral injuries, lesions extending just through the subchondral boneplate or deeper defects down into trabecular bone.
****Behandlingskoder**: 1 Debridement; 2 Mikrofraktur; 3 Ingen behandling; 4 Annet.

DAGKIRURGISK OPERASJON ☐^{0} Nei ☐^{1} Ja

PEROPERATIVE KOMPLIKASJONER ☐^{0} Nei ☐^{1} Ja,
hvilke(n) ....

OPERASJONSTID (hud til hud)......................min

SYSTEMISK ANTIBIOTIKA
☐ ^{0} Nei ☐^{1} Ja ☐^{1} Profylakse ☐^{2} Behandling

Medikament 1 .... Dosering ………..... Varighet ....timer

Eventuelt i kombinasjon med medikament 2 ....

TROMBOSEPROFYLAKSE
☐^{0} Nei ☐^{1} Ja: Første dose ☐^{1} Preoperativt ☐^{2} Postoperativt

Medikament 1 .... Dosering opr.dag…………………………………

Dosering videre .... Varighet ...... døgn

Medikament 2 ....

Anbefalt total varighet av tromboseprofylakse..

NSAIDs
☐^{0} Nei ☐^{1} Ja, hvilken type……………………………………………………….
Anbefalt total varighet av NSAIDs-behandling………………………………………

HØYDE ....cm

VEKT ....kg

RØYK ☐^{0} Nei ☐^{1} Av og til ☐^{2} Daglig

SNUS ☐^{0} Nei ☐^{1} Av og til ☐^{2} Daglig

Lege:...
Legen som har fylt ut skjemaet (navnet registreres ikke i databasen).

202 5007 Byråservice AS - 10.2017

RETTLEDNING

- Registreringen gjelder ALLE fremre og bakre korsbåndsoperasjoner.
- Registreringen gjelder ALLE kneoperasjoner på pasienter som tidligere er korsbåndsoperert.
- Ett skjema fylles ut for hvert kne som blir operert.
- Aktuelle ruter markeres med kryss. Stiplet linje fylles ut der dette er aktuelt.
- Pasienten skal på eget skjema gi samtykke til registrering.

KOMMENTARER TIL DE ENKELTE PUNKTENE

FORKORTELSER SOM ER BRUKT PÅ SKJEMAET

- ACL: Fremre korsbånd
- PCL: Bakre korsbånd
- MCL: Mediale kollateralligament
- LCL: Laterale kollateralligament
- PLC: Popliteus kompleks/bicepssene kompleks
- BPTB; Patellarsene autograft
- AM: Anteromediale bunt av ACL
- PL: Posterolaterale bunt av ACL

SKADEDATO
Skriv inn skadedatoen så eksakt som mulig.
Ved ny skade av tidligere operert korsbånd, skriv inn den nye skadedatoen.

FIKSASJON
Angi hvilken fiksasjonstype som er brukt ved å feste klistrelapp på baksiden.
Husk å skille mellom femur og tibia for graftfiksasjon, og mellom medial og lateral side for meniskfiksasjon.

PEROPERATIVE KOMPLIKASJONER
Ved en ruptur/kontaminering av høstet graft e.l. skal det opprinnelige graftet anføres her.
Andre peroperative komplikasjoner skal også fylles inn her.

SYSTEMISK ANTIBIOTIKA
Her føres det på hvilket antibiotikum som er blitt benyttet i forbindelse med operasjonen. Det anføres dose, antall doser og profylaksens varighet. F.eks. Medikament 1: Keflin 2g x 4, med varighet 12 timer.

TROMBOSEPROFYLAKSE
Type, dose og antatt varighet av profylaksen skal angis separat for operasjonsdagen og senere.

Kopi beholdes i pasientjournalen, originalen sendes til Nasjonalt Korsbåndsregister.

Kontaktpersoner vedrørende registreringsskjema er
Lege Håvard Visnes, Haukeland universitetssjukehus
e-post: haavard.visnes@helse-bergen.no
Sekretær i Nasjonalt Korsbåndsregister, Ortopedisk avd., Helse Bergen
Kate Vadheim, tlf.: 55 97 64 54 e-post: korsband@helse-bergen.no
Internett: http://nrlweb.ihelse.net/

GRAFTFIKSASJON		MENISKFIKSASJON	
FEMUR	TIBIA	MEDIAL	LATERAL

NASJONALT KORSBÅNDSREGISTER
Nasjonalt Register for Leddproteser
Ortopedisk klinikk, Helse Bergen HF
Haukeland universitetssjukehus
Postboks 1400
5021 Bergen

F.nr. (11 sifre)..

Navn:...

Sykehus:...

Skjemaet fylles ut av kirurgen elektronisk. Denne versjonen er tilpasset for visning i papirformat og er ikke ment for utfylling.

KORSBÅNDSOPERASJONER OG ALLE REOPERASJONER på pasienter som tidligere er korsbåndsoperert

Aktuell behandling
☐Primær korsbåndskade (ikke-operativ behandling)
☐Primær rekonstruksjon av korsbånd
☐Annen knekirurgi
☐Revisjonsrekonstruksjon
☐1 seanse Revisjon
☐2 seanse Revisjonsrekonstruksjon

Aktuell side ☐Venstre ☐Høyre

Motsatt kne ☐Normalt ☐Tidligere ACL/PCL-skade

Tidligere operasjon i samme kne
☐MCL ☐LCL
☐Menisksutur ☐Meniskreseksjon
☐Osteosyntese av fraktur ☐Bruskkirurgi
☐Patellastabiliserende kirurgi ☐Osteotomi
☐Ukjent/annet

Hyperekstensjon aktuelt kneledd
☐< 5 grader ☐5 - 10 grader ☐> 10 grader

Skadedato (dd.mm.åå) |__|__| |__|__| |__|__|

Operasjonsdato (dd.mm.åå) |__|__| |__|__| |__|__|

Aktivitet som førte til aktuell skade
Spesifiser: ....

Aktivitetsnivå før skade
☐ Level 1: Pivoterende sport
☐ Level 2: Mindre pivoterende sport
☐ Level 3: Ikke pivoterende aktivitet
☐ Level 4: Ingen/minimal aktivitet

Høyde (cm) |__|__|__| **Vekt (kg)** |__|__|__|

Røyk ☐Ja ☐Nei **Snus** ☐Ja ☐Nei

Har pasienten gjennomført fysioterapi?
☐Ja
☐Usikker
☐Nei. Angi årsak: ☐Akutt skade ☐ Ønsket ikke fysio ☐Økonomi ☐ Annet

Årsak til rekonstruksjon av korsbånd (evt. flere kryss)
☐ Operasjonstrengende meniskskade
☐ Kombinert instabilitet
☐ Residiverende instabilitet i hverdagen
☐ Uakseptabel begrensning i sport/aktivitet
☐ Indikasjon grunnet aktivitetsnivå
☐ Annet (Spesifiser)..

Årsak til revisjon (evt. flere kryss)
☐Nytt traume ☐Graftsvikt
☐Feilplassering av tibiakanal ☐Smerte
☐Feilplassering av femurkanal ☐Infeksjon
☐Ubehandlede andre ligamentskader ☐Fiksasjonsvikt
☐Annet ....

Dagkirurgisk operasjon ☐Ja ☐Nei

Operasjonstid (min) |__|__|__|

Andre prosedyrer
☐ Menisk operasjon ☐ Benreseksjon (Notch plastikk)
☐ Osteosyntese ☐ Osteosyntese patellafraktur
☐ Bentransplantasjon ☐ Operasjon pga infeksjon
☐ Osteotomi ☐ Mobilisering i narkose
☐ Synovektomi ☐ Artroskopisk debridement
☐ Bruskoperasjon ☐ Fjerning av fiksasjonsutstyr
☐ Lateral ekstraartikulær tenodese
☐ Sutur av patellar- eller quadricepssene
☐ Annet (spesifiser) ....

Peroperative komplikasjoner ☐Ja ☐Nei
☐Brudd på sterilitetsrutiner / forurenset graft
☐Relevant intraoperativ nerve- eller karskade
☐Problem med fiksasjon av graft i femur
☐Problem med fiksasjon av graft i tibia
☐Svikt av graft under høsting
☐Ruptur av graft under fiksasjon eller prosedyre
☐Patellafraktur eller seneruptur relatert til høsting
☐Svikt/problemer med utstyr som leder til endret prosedyre
☐Annet (spesifiser) ....
Førte komplikasjonen til endret graftvalg? ☐Nei ☐Ja
Dersom ja, oppgi opprinnelig graftvalg ....

Aktuell skade (Registrer alle skader – også de som ikke opereres)
☐ACL ☐PCL ☐ MCL ☐PLC ☐LCL

Gradering av skade ved primær korsbåndskade
Grad I ☐ Grad II ☐ Grad III

Konservativ behandling ved primær korsbåndskade
☐ Ortosebehandling
☐ Ortosebehandling ved risikoaktivitet

Graftvalg ved rekonstruksjon	ACL	PCL	MC	LCL	PLC
☐ Hamstring					
☐ BPTB					
☐ QT					
☐ Allograft					
☐ Autograft					
☐ Tractus illotibialis					
☐ Direkte sutur					
☐ Syntetisk graft					
☐ Ikke rekonstruert					

Graftdiameter .... mm.
Graftdiameter ved double bundle-teknikk:
AM .... mm. PL .... mm.

Tilgang for Femurkanal
Anteromedial ☐ Transtibial ☐ Anterolateral ☐

Meniskskade ☐Nei ☐Ja: ☐Lateralt ☐Medialt

Medial beskrivelse

☐Radiær	☐Longitudinell
☐Horisontalt	☐Bøttehank
☐Fremre rotskade	☐Bakre rotskade
☐Komplekse rupturer	☐Rampe lesjon

Degenerativ ☐Ja ☐Nei

Lateral beskrivelse

☐Radiær	☐Longitudinell
☐Horisontalt	☐Bøttehank
☐Fremre rotskade	☐Bakre rotskade
☐Komplekse rupturer	☐Rampe lesjon

Degenerativ ☐Ja ☐Nei

Aktuell behandling av menisklesjon

☐ Partiell reseksjon	☐ Medial	☐ Lateral
☐ Total reseksjon	☐ Medial	☐ Lateral
☐ Sutur - all inside	☐ Medial	☐ Lateral
☐ Annen sutur	☐ Medial	☐ Lateral
☐ Sutur med cortical fiksasjon	☐ Medial	☐ Lateral
☐ Transplantasjon	☐ Medial	☐ Lateral

Brusklesjon (evt. flere kryss)	Areal (cm^2) ≤2 >2	ICRS Grade* 1 2 3 4	Artrose Ja Nei	Behandlings-kode** 1 2 3 4 Spesifiser annet
Patella MF	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....
Patella LF	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....
Trochlea fem.	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....
Med.fem.cond.	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....
Med.tib.plat.	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....
Lat.fem.cond.	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....
Lat. tib. plat.	☐ ☐	☐☐☐☐	☐ ☐	☐☐☐☐ ....

Ytterligere skader

☐ Karskade	☐ Arteria politea
☐ Nerveskade	☐ N. peroneus ☐ N. peroneus
☐ Ruptur i eks.	☐ Quadricepssenen ☐ Patellarsenen
☐ Fraktur	☐ Segondfraktur ☐ Tibia ☐ Femur ☐ Fibula ☐ Patella

Antibiotika profylakse Ja ☐ Nei ☐

Medikament 1 ....

Medikament 2 ....

Lokal antibiotikabehandling av graft

☐Nei ☐ Ja

Tromboseprofylakse - over 7 dager

☐Nei ☐ Ja

Medikament 1 ....

Medikament 2 ....

Lege...

Legen som har fylt ut skjemaet

Fest produktklistrelapp i neste kolonne, eller produkt som er satt inn ved primær- eller reoperasjon:

Graftfiksasjon	
Femur	**Tibia**

Meniskfiksasjon	
Medial	**Lateral**

RETTLEDNING

Årsak til rekonstruksjon av korsbånd

1. Operasjonstrengende meniskskade som fordrer rekonstruksjon av korsbånd samtidig.
2. Inkluderer f.eks ACL+MCL gr 3 skader og multiligament/kneluksasjoner.
3. Instabilitet i dagligliv/hverdagsaktiviteter.
4. Stabil i daglige aktiviteter men uakseptabel begrensning i sport/aktivitet.
5. Operert uavhengig av tilleggsskader grunnet høyt aktivitetsnivå/eliteidrett.

Skadedato

Skriv inn skadedatoen så eksakt som mulig. Hvis dag er ukjent benytt '01' i aktuell måned, f eks 01.06.2018.

Ved revisjon: Skriv dato når du tror korsbåndsgraftet ble skadet etter primærrekonstruksjon. Dersom ingen ny kjent skade før revisjon, la skadedato stå tom.

Dagkirurgisk operasjon

Dagkirurgisk operasjon innebærer at pasienter møter frem, opereres og reiser hjem samme dag.

Peroperative komplikasjoner

Ved en ruptur/kontaminering av høstet graft e.l. skal det opprinnelige graftet anføres her. Andre peroperative komplikasjoner skal også fylles inn her

Hyperekstensjon aktuelt kneledd

Eventuell hyperekstensjon kan med fordel måles liggende på benk. Justere en pøll eller pute under foten i nøytral stilling slik at kneleddet henger fritt og avslappet noen cm over benken. Mål med goniometer (helst lang) akse mellom femur (fra sentral punkt i trochanter til sentral punkt laterale femurkondyl) og tibia (fra den mest laterale punktet i kneets leddlinje til laterale malleol). Du kan også bruke app til smarttelefon, f eks «Protractor™», til å regne ut vinkelen. Dersom bøttehankruptur eller annen skade/hevelse innskrenker bevegelse kan ispilateralt kne brukes.

Aktivitet som førte til aktuell skade
Velg aktivitet ved skadetidspunkt.
Dersom aktuell behandling er «Annen knekirurgi» eller revisjon og det ikke har vært en ny skade som fører til aktuell operasjon (f eks fjerning av cyclops – annen knekirurgi) la denne stå tom.

Aktivitetsnivå før skade
Beskriv hvilken aktivitetskategori pasienten regelmessig vil falle innenfor. Trenger ikke å være samme som skadeaktivitet.
Level 1: Pivoterende sport (fotball, håndball, innebandy, basketball).
Level 2: Mindre pivoterende sport (f eks racketsport, alpint, snowboarding, gymnastikk, aerobics).
Level 3: Ikke pivoterende aktivitet (f eks løping, langrenn, vektløfting).
Level 4: Lite fysisk aktivitet / vanlig ADL.

Aktuell skade og graftvalg
Skader ved inklusjonstidspunkt, påvist på MR OG ved klinisk undersøkelse. F.eks hos en pasient med MR-svar «MCL skade grad 1», uten tegn til laksisitet eller smerte ved klinisk undersøkelse, skal MCL-skade ikke registreres. Dersom ligament/leddbånd fra opprinnelig skade er tilhelt med normale kliniske funn ved inklusjonstidspunkt skal de heller ikke registreres. Ved revisjon 1 seanse – dersom ACL/PCL er skadet skal skade registreres, og graftvalg «ikke rekonstruert» velges.

Graftstørrelse
BPTB: minste bredde av senegraft
Hamstring: minste diamenter på senegraft
QTB/QT: minste bredde av senegraft
Allograft: samme måling som respektive autograft.
Akilles allograft: måles som hamstring

Tilgang for Femurkanal
Angi dersom femurkanalen ble borret ved hjelp av Transtibial (TT), anteriomedial (AM) eller anterolateral (AL) tilgang. Dersom både ACL og PCL rekonstrueres, angi tilgang for ACL.

Brusklesjon
Størrelse, ICRS-klassifisering, evt artrose og behandling av lesjon registreres. For primær korbåndskade registreres størrelse og evt artrose.

*__ICRS Grade:__ 1 Nearly normal: Superficial lesions, soft indentation and/or superficial fissures and cracks; 2 Abnormal: Lesions extending down to <50% of cartilage depth; 3 Severely abnormal: Cartilage defects extending down >50% of cartilage depth as well as down to calcified layer; 4 Severely abnormal: Osteochondral injuries, lesions extending just through the subchondral boneplate or deeper defects down into trabecular bone.
****Behandlingskoder**: 1 Debridement; 2 Mikrofraktur; 3 Ingen behandling; 4 Annet.

Antibiotikaprofylakse
Her føres det på hvilket antibiotikum som er blitt benyttet i forbindelse med operasjonen.

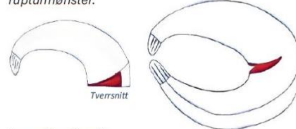
Tromboseprofylakse
Her føres tromboseprofylakse som er gitt med lengde over 7 dager.

Meniskskade
Klassifiser hovedrupturen. Med rotskade menes enten direkte løsning av roten eller signifikant radiær rift inntil 10 mm fra roten som blir behandlet som en rotskade.

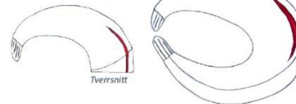
Aktuell behandling av menisklesjon
Ved registrering av all-inside suturer kan produkt registreres enten ved skanning eller ved å velge produkt i nedtrekksmeny. Dersom du f eks har brukt 3 all-inside suturer trenger du ikke registrere 3 implantat, men registrere én og fylle ut totalt antall i «Antall suturer».
Inside-out/Outside-in registreres som «Annen sutur». Dersom du kombinerer «All-inside» med «Annen sutur», registreres totalt antall suturer i «Antall suturer». Rotsutur gjennom borekanal registreres som «Sutur med cortical fiksasjon».
Du trenger ikke å registrere implantat/suturtråd ved «Annen sutur» eller «Sutur med cortical fiksasjon»

Beskrivelse meniskruptur

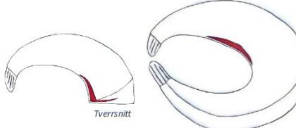
Radiær
Ruptur som starter fra sentrale del av menisken og strekker seg inn mot kapselen i et vertikalt rupturmønster.



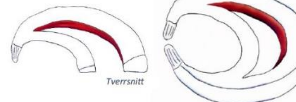
Longitudinell
En langsgående vertikal ruptur som følger meniskens kurve, men hvor fragmentet ikke kan disloseres nok til å låse kneet.



Horisontal
En langsgående ruptur som går horisontalt gjennom menisken, og deler den i en øvre og nedre del.

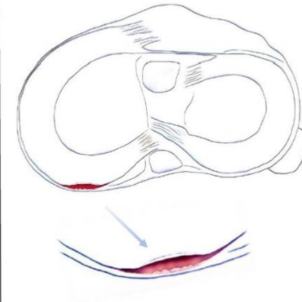


Bøttehank
En longitudinell vertikal ruptur som følger meniskens kurve og gir opphav til et disloserbart fragment

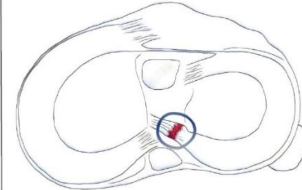


Komplekse rupturer
Ruptur som inkluderer flere mønstre av skader i samme menisk, for eksempel både langsgående og radial ruptur. Ofte degenerative, eller ved større skader.

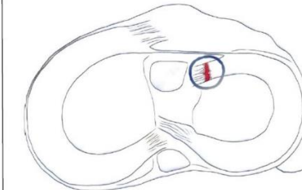
Ramp lesion
Ruptur av mediale menisks forbindelse med leddkapselen i bakhornet.



Bakre rotskade (posteriort)
Med rotskade menes enten avulsjon av roten eller signifikant radiær rift inntil 10 mm fra roten.



Fremre rotskade (anteriort)
Med rotskade menes enten avulsjon av roten eller signifikant radiær rift inntil 10 mm fra roten.



Kontaktpersoner vedrørende registreringsskjema
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Sekretær: Ruth Wasmuth
Telefon: 55 97 64 50 (08:00-14:00)
E-post: NRL@helse-bergen.no
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Besøksadresse: Møllendalsbakken 7, Bergen
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Graphic design: Communication Division, UIB / Print: Skipnes AS

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ISBN: 9788230875308 (print)
9788230877425 (PDF)