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The effect of patient and injury factors on long-term outcome after anterior cruciate ligament reconstruction

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Abstract

Background—Long-term follow-up is required for accurate assessment of results after anterior cruciate ligament (ACL) reconstruction and recent years have witnessed the publication of numerous papers detailing long-term outcomes. The primary aim of this systematic review was to determine which patient factors affect long-term clinical and radiographic outcomes based on the current literature.

Methods—A comprehensive literature review yielded 18 prospective manuscripts with minimum follow-up ranging from 5–12 years after ACL reconstruction.

Results—Longer follow-up was associated with increased radiographic evidence of osteoarthritis. Increased meniscal or articular cartilage pathology at ACL reconstruction were found to be associated with increased prevalence of radiographic evidence of osteoarthritis at long-term follow-up in most studies. There is currently insufficient evidence to correlate these intra-articular findings with decreases in clinical outcome measures. Further research is needed to determine the effect of body mass index (BMI) on long-term outcome after ACL reconstruction.

Conclusions—Intra-articular injuries noted at the time of ACL reconstruction affect long-term results. The effect of BMI and other patient factors is unclear. Long-term follow-up of large multicenter cohorts will provide definitive data on the relative importance of different factors in determining results of ACL reconstruction.

Keywords

Anterior cruciate ligament; long-term follow-up; osteoarthritis; meniscus; articular cartilage

INTRODUCTION

The anterior cruciate ligament (ACL) is frequently injured and its reconstruction is among the most common procedures performed by orthopaedic surgeons. The orthopaedic literature is replete with reports of outcomes of ACL reconstruction and analyses of multiple factors thought to influence outcome. These factors include patient characteristics such as meniscus

or articular cartilage status at the time of reconstruction or body mass index (BMI), mechanism of injury, as well as, surgical factors.

Osteoarthritis is common after injury to the ACL regardless of whether or not reconstruction is performed.¹ Multiple authors have noted an increased rate of osteoarthritis and decreased clinical outcome scores in patients with meniscal²⁻⁷ or articular cartilage^{4,6,7} pathology noted at ACL reconstruction. However, other series have demonstrated no association between clinical outcomes and intra-articular pathology noted at reconstruction.^{8,9} Increased patient BMI also has been associated with poorer outcomes after ACL reconstruction.^{10,11}

The last decade has seen a significant focus on evidence-based medicine, with a subsequent increase in the quality of published studies.¹² Numerous authors have suggested that long-term follow-up is required for accurate assessment of results after ACL reconstruction, and recent years have witnessed the publication of numerous papers detailing long-term outcomes.^{6,7,13} The primary aim of this systematic review was to determine which patient factors affect clinical and radiographic outcomes after ACL reconstruction based on published prospective studies with 5-year minimum follow-up.

MATERIALS AND METHODS

Literature Review

A MEDLINE literature search was performed to identify all publications from January 1, 1966 through May 1, 2009 reporting long-term outcomes of ACL reconstruction. A search for articles containing the terms “reconstruction,” “follow-up,” and either “anterior cruciate” or “ACL” yielded 1381 results. The title, abstract, and full text of these publications were reviewed when necessary, and studies failing to meet inclusion and exclusion criteria outlined in Table 1 were excluded. Full texts of the resulting 42 articles were obtained. Only prospective studies were included. Subsequent review led to the exclusion of 22 studies that were retrospective in nature,^{2,6,8,14-32} two that were repeat publications,^{33,34} and one study that included patients represented at longer follow-up in another included study.³⁵ The literature search is summarized in Figure 1.

A search of the Embase database was then performed using the same search strategy. The title and abstracts of the resulting 974 studies were reviewed and 933 papers were excluded in the same manner as in the MEDLINE search. Thirty-six of the remaining 41 articles had previously been identified in the MEDLINE search. Full text of the remaining five articles was obtained and four were excluded³⁶⁻³⁹ because they were retrospective studies.

Eighteen papers were thus included in this review.^{7,9,11,13,40-53} The references of all 18 studies were reviewed and no additional manuscripts meeting criteria were identified.

Data Extraction

A templated EBM literature review form was used to assist in data collection. Extracted data included patient demographics (age, sex, and body mass index), intra-articular pathology (articular cartilage and meniscal status at reconstruction), details of rehabilitation, length of follow-up, clinical outcome measures (International Knee Documentation Committee

[IKDC], Lysholm and Tegner scores; manual and KT-1000™ [MEDmetric Corp., San Diego, CA]; stability measurements; and range of motion), and radiographic findings. Data were extracted by two authors independently and discrepancies were resolved by consensus.^{54,55}

RESULTS

The literature review described above yielded 18 manuscripts. All papers include prospective (level I or II) data with at least 5-year minimum follow-up. These studies included five randomized controlled trials^{43,45,47,51,53} and two prospective cohort studies^{44,49} comparing outcomes of ACL reconstruction with bone-patellar tendon-bone autografts with those from reconstruction with hamstring tendon autografts. Additional randomized controlled trials were identified comparing bone-patellar tendon-bone autografts with bone-hamstring tendon-bone autografts⁴⁶ and comparing outcomes ACL reconstruction with and with use of a ligament augmentation device.⁴¹ The nine remaining studies were prospective cohorts describing outcomes of ACL reconstruction at a minimum of 5 years postoperatively.^{7,9,11,13,40,42,48,50,52}

Demographics

The mean patient age at reconstruction was 24 years. Mean patient age in the 16 studies reporting it ranged from 22 to 31 years. Overall, 67% of patients were male, with the percentage in the 18 studies ranging from 45–100%. The time from injury to ACL reconstruction varied considerably between studies. All studies used autograft for ACL reconstruction, including bone-patellar tendon-bone, hamstring tendons, and bone-hamstring tendon-bone autografts and all were performed using arthroscopic, arthroscopic-assisted, or two-incision mini-arthrotomy techniques. Exclusion criteria among the studies varied, but all excluded knees with multiple ligamentous injuries other than low-grade medial collateral ligament injuries. Demographic information is detailed in Table 2.

Intra-articular findings

Intra-articular findings varied considerably among the studies. Thirteen studies reported the status of the articular cartilage at reconstruction, with the percentage with articular cartilage pathology ranging from 0–46%. Similarly, 13 studies described the percentage of patients with meniscal pathology at the time of ACL reconstruction, which ranged from 0–73%. These findings are detailed in Table 3.

Rehabilitation

Thirteen studies reported details of their rehabilitation protocol. Nine (69%) allowed immediate full weight bearing. One author allowed immediate partial weight bearing and full weight bearing at 2 weeks while one allowed full weight bearing after 2–3 days. Two other authors allowed partial weight bearing at 2 weeks and full weight bearing at 4–6 weeks. Postoperative extension bracing was used by five authors (31%) for time periods ranging from 1–4 weeks. Table 4 details protocols for each study.

Follow-up

All studies had minimum follow-up after reconstruction of 5 years. Mean follow-up ranged from 5–14 years. Clinical follow-up was performed in all 18 studies, with a mean follow-up rate of 76%, with individual papers' follow-up rates ranging from 33–100%. Instruments used for clinical follow-up included KT-1000 (83%), IKDC score (72%), range of motion (72 %), subjective measures of stability (Lachman/anterior drawer) (72%), and Lysholm score (50%) among other measures. Radiographic follow-up was available in 15 studies, with a mean follow-up rate of 54%, with individual papers' follow-up rates ranging from 33–100%. Follow-up details are presented in Table 5.

Radiographic Evaluation

The IKDC rating system was most frequently used to assess joint degeneration radiographically.⁵⁶ The Kellgren and Lawrence,⁵⁷ Ahlback,⁵⁸ Fairbank,⁵⁹ and Rosenberg⁶⁰ rating scales also were used. Radiographic evidence of osteoarthritis was defined as an IKDC score of C or worse, Kellgren and Lawrence score of 3 or worse, Ahlback score of I or worse, or the presence of Fairbanks changes or major Rosenberg changes. Rough correlation of the degree of joint space loss using each classification system is shown in Table 6.

Effect of Meniscal Status at Reconstruction on Outcome

Four studies described the influence that meniscal status at ACL reconstruction has on IKDC score at long-term follow-up. Shelbourne and Gray⁵² found significantly worse IKDC scores in patients with lateral meniscal damage at the time of ACL reconstruction but no association between IKDC score and medial meniscal status.⁵² Wu *et al.*⁷ noted a significant decrease in IKDC score in patients with any meniscal pathology at ACL reconstruction but did not separately report results for medial and lateral meniscal pathology. Lebel *et al.*¹¹ and Spindler *et al.*⁹ found no significant difference in IKDC scores based on meniscal status.

Five studies address the influence that meniscal status at ACL reconstruction has on the subsequent development of radiographic evidence of osteoarthritis at follow-up. Shelbourne and Gray⁵² demonstrated that lateral meniscal pathology at reconstruction increases the risk of developing radiographic signs of osteoarthritis. Hart *et al.*⁴² demonstrated a statistically significant increase in the rate of development of osteoarthritis, with radiographic changes noted in 82% of those with meniscal pathology and only 60% of those with normal menisci but did not report medial or lateral meniscal pathology separately. Similarly, Wu *et al.*⁷ noted radiographic signs of osteoarthritis in only 9% of patients with normal menisci while these findings were present in all of those who underwent complete meniscectomy. They did not report the frequency of these signs in patients who underwent partial meniscectomy or report results for lateral or medial meniscectomy separately. Lebel *et al.*¹¹ showed a trend, with 21% of those with meniscal pathology and 14% of those with normal menisci demonstrating signs of osteoarthritis, but this finding was not statistically significant. Spindler *et al.*⁹ showed no correlation between meniscal pathology at reconstruction and subsequent development of radiographic evidence of osteoarthritis.

Influence of Articular Cartilage Status at Reconstruction on Outcome

Four studies evaluated for a correlation between articular cartilage status at the time of reconstruction and IKDC score at follow-up. Shelbourne and Gray⁵² noted a significant correlation between articular cartilage damage noted at reconstruction and lower IKDC score at follow-up. However, three additional studies detected no correlation between articular cartilage pathology at reconstruction and IKDC score at follow-up.^{9,11,13}

Three studies evaluated the influence of articular cartilage injury at the time of reconstruction on the presence of radiographic evidence of osteoarthritis at follow-up. Two studies noted a higher incidence of radiographic signs of osteoarthritis at follow-up in those with articular cartilage injury at reconstruction,^{41,52} while one study noted no correlation between these variables.¹³ Clinical and radiographic outcomes are summarized in Tables 7 and 8.

Influence of BMI on outcome

Only one of the 18 papers above reported patient BMI.¹¹ Lebel *et al.*¹¹ reported a statistically significant association between BMI at the time of reconstruction and the presence of radiographic evidence of osteoarthritis at follow-up. However, they did not find any correlation between BMI and IKDC score at follow-up. Spindler *et al.*⁹ did not report BMI, but they correlated a weight gain of 15 pounds between reconstruction and follow-up with poorer IKDC scores at follow-up.

Influence of length of follow-up on outcome

Fourteen studies reported radiographic data on all patients, allowing the calculation of the percentage of patients who developed radiographic signs of osteoarthritis at follow-up. A significant correlation was noted between length of follow-up and the percentage of patients in each study exhibiting radiographic evidence of osteoarthritis at follow-up ($R^2 = 0.48$, $P < 0.01$) (Figure 2). Ten studies reported Lysholm scores at follow-up on all patients. No correlation was noted between this validated patient oriented outcome and length of follow-up (Figure 3).

DISCUSSION

The strengths of this study are the prospective nature and relatively long-term follow-up of the papers included in the analysis. To our knowledge, no previously published systematic review of outcomes after ACL surgery has had such rigid inclusion and exclusion criteria. The included studies are all level I or II data and thus provide powerful source data for subsequent analysis.

Meniscal pathology at the time of ACL reconstruction has been suggested by many authors to contribute to subsequent development of osteoarthritis and poorer functional outcomes. Although research on stable knees has shown that increased risk of premature development of osteoarthritis is a consequence of complete meniscectomy,^{59,61–63} this relationship is much less clear in the case of partial meniscectomy, as many authors have shown partial meniscectomy to be generally well tolerated.^{64–66}

The studies identified in this review provide mixed results as to the influence of meniscal status at ACL reconstruction on long-term outcome. There appears to be stronger evidence that meniscal status influences development of radiographic signs of osteoarthritis, with a statistically significant correlation or trend noted in four of five studies. A previous systematic review did note a correlation between partial meniscectomy at ACL reconstruction and subsequent development of radiographic evidence of osteoarthritis at medium-term year follow-up, but no clinical follow-up was included.⁶⁷ Only two of the four papers identified in this review were able to correlate worse clinical outcome with meniscal pathology at ACL reconstruction.

One potential limitation of a number of the studies included in this review is the fact that they generally did not treat pathology of the medial, lateral, or both menisci separately. Only Shelbourne and Gray⁵² had sufficient numbers to perform this type of analysis and they noted the correlations outlined above only in patients with lateral meniscal pathology. No correlation was noted when medial meniscal pathology was examined. This finding is not surprising given that multiple authors have noted lateral meniscectomy to be a greater predictor of subsequent degenerative change than medial meniscectomy in patients with stable knees.^{65,68}

It is likely that medial and lateral meniscal pathologies have significantly different etiologies in patients with ACL pathology, with lateral meniscal injury likely occurring at injury and medial meniscal pathology representing subsequent injury from increased stress on the medial meniscus in resisting anterior tibial translation in an ACL-deficient knee.⁶⁹ It is possible that were the other studies to focus on lateral meniscal pathology they would have noted greater correlation of these lesions with outcome.

Significant limitations also stem from lumping all patients who underwent partial meniscectomy into one group. Patients undergoing radically different procedures, ranging from trimming out a small portion of meniscus to subtotal meniscectomy could all be described by different authors as undergoing partial meniscectomy. Treating this diverse patient population as a single group for analysis may influence results.

Even if a stronger correlation were noted between meniscal status and poorer outcome, correlation alone does not necessarily indicate that the meniscal injury causes the poorer outcome. It is possible that patients with a concomitant meniscal injury have had higher energy injuries or more chronic ACL injuries. Damage to the articular cartilage at the time of injury or other patient factors, such as increased BMI, could also increase risk of later osteoarthritis.

Similarly, this review identified more evidence of an association between articular cartilage pathology at the time of ACL reconstruction and radiographic evidence of osteoarthritis (noted in two of three studies) than between articular cartilage pathology and clinical outcome (noted in one of four studies).

This review was only able to identify one prospective study with a 5-year minimum follow-up evaluating the influence of BMI on ACL reconstruction outcome. Published reports have shown that patients with increased BMI are at increased risk for additional intra-articular

injury when they the undergo ACL reconstruction.⁷⁰ The association between these injuries and the development of arthritis could be one mechanism by which increased BMI contributes to poor outcome after ACL reconstruction. Increased BMI likely contributes to the development of premature osteoarthritis through other mechanisms as shown by the increased rates of osteoarthritis noted in obese individuals with intact ACL.⁷¹

Finally, we noted a significant correlation between the percentage of patients with radiographic evidence of osteoarthritis and length of follow-up in all studies but did not note a corresponding decrease in the Lysholm score. This finding suggests that radiographs may be more sensitive than the Lysholm score in detecting early osteoarthritis in a post-ACL reconstruction population. It is possible that a score more specifically designed to detect symptoms of osteoarthritis such as the Knee Injury and Osteoarthritis Outcome Score (KOOS) would be more sensitive and thus be a better choice in evaluating these patients at long-term follow-up.

Significant weaknesses exist in this study. Primarily, this study is limited by the available data in the selected papers. The use of different outcome scales as well as incomplete reporting of outcomes in some cases complicated and limited data extraction. Similarly, as each paper had a different primary focus, certain patient characteristics such as BMI were reported in too few papers to draw useful conclusions. Additionally, the papers each represent a different patient population, which influences the prevalence of factors that could influence patient outcomes and makes for heterogeneous data. Selection bias is also possible in that this paper only reflects data from papers we identified in our literature review. Given the huge amount of published outcome data on ACL reconstruction, it is possible that data was missed in spite of our careful review of the literature.

Finally, it should be noted that patient factors represent only a portion of the factors affecting outcome after ACL reconstruction. Numerous other factors may affect patient outcomes, including but not limited to the treatment of meniscal and chondral pathology, ACL reconstruction technique, graft choice, rehabilitation, and subsequent patient behavior. The relative contributions of these factors to patient outcome remain unclear.

Increased meniscal or articular cartilage pathology at ACL reconstruction are associated with increased prevalence of radiographic evidence of osteoarthritis at long-term follow-up in a majority of studies. There is currently insufficient evidence to correlate these intra-articular findings with decreases in clinical outcome measures. Further research is needed to determine the impact of BMI on long-term outcome after ACL reconstruction.

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Figure 1.

The search strategy used to locate the 18 prospective studies in the review included reviews of the MEDLINE and Embase databases followed by exclusion of articles based on exclusion criteria as described.

Figure 2.

Correlation of radiographic evidence of osteoarthritis with time to follow-up. A significant correlation is noted.

Figure 3.

Correlation of Lysholm score with time to follow-up. No significant correlation is noted.

Table 1

Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Published prospective series describing outcomes of primary ACL reconstruction	Case studies
5-year minimum follow-up	Less than 5-year minimum follow-up
Reconstruction with patellar tendon or hamstring tendon autograft	Use of graft tissue other than patellar tendon or hamstring tendon
Use of all-arthroscopic, arthroscopic- assisted, or mini-arthrotomy technique	Open ACL reconstruction
	Multi-ligament knee injury other than low- grade MCL injuries
	Inclusion of skeletally immature patients
	Use of allograft
	Animal studies
	In vitro studies
	Non-English studies
	Reviews without original data
	Inclusion of revision ACL reconstructions
	Use of artificial ligaments
	Retrospective studies

ACL, anterior cruciate ligament; MCL, medial collateral ligament.

Table 2

Demographic data.

Author	Journal	Year	Initial cohort	Patient ge mean (range)	Percent male	Chronicity	Method of reconstruction	Graft	Other selection criteria
Deehan	JBJS-Br	2000	90	25 (13 – 42)	53%	74% reconstructed within 3 months of injury	All arthroscopic Femoral tunnel drilled through medial portal	BTB autograft	Multi-ligament, chondral or meniscal pathology, workers compensation, abnormal radiographs at reconstruction excluded
Drogset	AJSM	2002	100	26 (16 – 48)	45%	Mean time from injury to reconstruction 3.5 years	Arthroscopic assisted, two-incision	BTB autograft	Multi-ligament excluded
Hart	JBJS-Br	2005	40	28 (18 – 47)	68%	All reconstructed at least 6 months after injury	All arthroscopic	BTB autograft	Multi-ligament, chondral injury, additional knee surgery or preoperative injury excluded
Hanypsiak	AJSM	2008	54	24	70%	All reconstructed with 3 months of injury	Arthroscopic assisted, two-incision	BTB or hamstring autograft	Multi-ligament except grade I and II MCL injuries excluded; Chronic injuries excluded
Ibrahim	Arthroscopy	2005	110	22 (17 – 34)	100%	NR	All arthroscopic Femoral tunnel drilled through tibia	BTB or hamstring autograft	
Keays	AJSM	2007	62	27 (18 – 38)	71%	Mean time from injury to reconstruction 3 years	All arthroscopic for hamstring, mini-arthrotomy for BTB. Femoral tunnel drilled through tibia	BTB or hamstring autograft	Multi-ligament injuries, patients over 40, acute injuries, and patients with evidence of osteoarthritis at reconstruction excluded
Lebel	AJSM	2008	154	29 (16 – 59)	76 %	Mean time from injury to reconstruction 1.8 years	All arthroscopic Femoral tunnel drilled through medial portal	BTB autograft	Multi-ligament injuries, revisions, and patients reconstructed with graft other than patellar tendon excluded
Liden	AJSM	2007	71	28 (15 – 59)	69 %	Mean time from injury to reconstruction 2.8 years	All arthroscopic Femoral tunnel drilled through tibia	BTB or hamstring autograft	Multi-ligament injuries, bilateral injuries, and revision excluded
Matsumoto	AJSM	2006	80	24	50 %	Mean time from injury to reconstruction 0.9 years	All arthroscopic Femoral tunnel drilled through tibia	BTB or quad tendon autograft	Multi-ligament injuries excluded
O'Neill	JBJS-Am	2001	225	NR	67 %	NR	1/3 all arthroscopic and 2/3 two-incision	BTB or hamstring autograft	Multi-ligament injuries and those under age 18 excluded

Author	Journal	Year	Initial cohort	Patient age mean (range)	Percent male	Chronicity	Method of reconstruction	Graft	Other selection criteria
Panni	KSSTA	2001	141	25 (16 – 44)	67 %	NR	½ all arthroscopic with femoral tunnel drilled through tibia, ½ two- incision	BTB autograft	
Roe	AJSM	2005	180	24 (13 – 52)	53 %	62% reconstructed within 12 weeks of injury	All arthroscopic with femoral tunnel drilled through anteromedial portal	BTB or hamstring autograft	Patients with multi- ligament injuries, chondral injuries, meniscal pathology involving more than 2/3 of the meniscus, contralateral knee injury, or radiographic abnormality excluded
Ruiz	Knee	2002	90	NR	93 %	NR	All arthroscopic	Autograft	NR
Sajovic	AJSM	2006	64	25 (14 – 46)	50 %	Mean time from injury to reconstruction 2.0 years	All arthroscopic	BTB or hamstring autograft	Patients with multi- ligament injuries, abnormal radiographs, previous meniscal surgery, or subsequent contralateral rupture excluded
Shelbourne	AJSM	2009	1276	23 (11 – 53)	72 %	Mean time from injury to reconstruction 1.5 years	Two-incision mini- arthrotomy	BTB autograft	Patients with bilateral injuries, subsequent contralateral ruptures, and those under going revision were excluded
Spindler	JBJS-Am	2005	314	22	55 %	NR	Arthroscopic assisted, two- incision	BTB autograft	Patients with bilateral injuries, those undergoing revision, and those with PCL or PLC injuries were excluded
Wu	AJSM	2002	103	24 (15 – 45)	57 %	27 % reconstructed within 4 weeks of injury	Arthroscopic assisted, two- incision	BTB autograft	Patients undergoing revision ACL reconstruction excluded
Zaffagnini	KSSTA	2006	50 [*]	31 (22 – 49)	62 %	Mean time from injury to reconstruction 0.8 years	All arthroscopic with femoral tunnel drilled through tibia	BTB or hamstring autograft	Patients with PCL injury, meniscal or cartilage injury, non-athletes, prior knee surgery, and age over 50 were excluded

* Study also included an extra-articular reconstruction group that was excluded from this analysis. BTB, bone-tendon-bone; PCL, posterior cruciate ligament; PLC, posterior lateral corner; ACL, anterior cruciate ligament; NR, not reported.

Table 3

Patients with meniscal pathology at the time of ACL reconstruction.

Author	Year	Articular cartilage status at reconstruction	Meniscal status at reconstruction
Deehan	2000	All normal	All normal or with at least 2/3 of meniscus present
Drogset	2002	Normal = 56% Articular cartilage pathology = 44%	Normal = 31% Meniscal pathology present = 69%
Hart	2005	All normal	Normal = 48% Partial meniscectomy = 52%
Hanypsiak	2008	Normal = 54% Articular cartilage pathology = 46%	Normal = 45% Meniscal pathology present = 55%
Ibrahim	2005	Normal = 84% Articular cartilage pathology = 16%	Normal = 73% Meniscal pathology present = 27%
Keays	2007	NR	Normal = 40% Partial meniscectomy = 60%
Lebel	2008	Normal = 76% Articular cartilage pathology = 24%	Normal = 46% Meniscal pathology present = 54%
Liden	2007	Normal = 89% Articular cartilage pathology = 11%	Normal = 27% Meniscal pathology present = 73%
Matumoto	2006	Normal = 86% Articular cartilage pathology = 14%	Normal = 25% Meniscal pathology present = 75%
O'Neill	2001	NR	NR
Panni	2001	NR	NR
Roe	2005	All normal	Normal = 84% Meniscal pathology present = 16%
Ruiz	2002	NR	NR
Sajovic	2006	NR	Normal = 55% Meniscal pathology present = 45%
Shelbourne	2009	Normal = 78% Articular cartilage pathology = 22%	Normal = 57% Meniscal pathology present = 43%
Spindler	2005	Normal = 78% Articular cartilage pathology = 22%	NR
Wu	2002	Normal = 55% Articular cartilage pathology = 45%	Normal = 39% Meniscal Pathology Present = 61%
Zaffagnini	2006	All normal	All normal

NR, not reported.

Table 4

Protocols for extension brace use.

Author	Year	Time to partial Weight-bearing	Time to full Weight-bearing	Brace use
Deehan	2000	Immediate	Immediate	None
Drogset	2002	Immediate	Immediate	None
Hart	2005	NR	NR	NR
Hanypsiak	2008	NR	NR	None
Ibrahim	2005	2–3 days	2–3 days	None
Keays	2007	Immediate	Immediate	Extension brace × 1–2 weeks
Lebel	2008	Immediate	Immediate	None
Liden	2007	Immediate	Immediate	None
Matsumoto	2006	2 weeks	4 weeks	Extension brace × 1 week
O'Neill	2001	NR	NR	NR
Panni	2001	2 weeks	6 weeks	Extension brace × 2 weeks
Roe	2005	Immediate	Immediate	None
Ruiz	2002	NR	NR	NR
Sajovic	2006	Immediate	Immediate	Extension brace × 3 weeks
Shelbourne	2009	Immediate	Immediate	None
Spindler	2005	NR	NR	NR
Wu	2002	Immediate	Immediate	Extension brace × 4 weeks
Zaffagnini	2006	Immediate	2 weeks	None

NR, not reported.

Table 5

Follow-up details.

Author	Year	Initial cohort	Years to clinical follow-up Mean (range)	Final clinical cohort	Clinical evaluation	Years to radiographic follow-up	Final radiographic cohort
Deehan	2000	90	5	80 (89%)	IKDC grade Lysholm score Lachman/Pivot shift KT-1000 Extension deficit Pain on kneeling (VAS)	5	65 (72%)
Drogset	2002	100	8	68 (68%)	Subjective patient assessment Lysholm score Lachman KT-1000 Extension deficit	8	68 (68%)
Hart	2005	40	10 (9 – 13)	31 (78%)	Lysholm score Tegner score	10 (9 – 13)	31 (78%)
Hanypsiak	2008	54	12	44 (82%)	IKDC grade Lachman/Pivot shift KT-1000	12	44 (82%)
Ibrahim	2005	110	6.8 (5 – 8)	85 (77%)	Subjective patient satisfaction Lysholm score Tegner score Lachman/Pivot shift KT-1000 Extension deficit	6.8 (5 – 8)	85 (77%)
Keays	2007	62	6	56 (90%)	Cincinnati knee score Lachman/Pivot shift KT-1000 Extension deficit	6	56 (90%)
Lebel	2008	154	11.6 (10 – 13)	101 (66%)	IKDC grade Lachman/Pivot shift Extension deficit	11.6 (10–13)	101 (66%)
Liden	2007	71	7.2 (5.7 – 9.5)	68 (96%)	IKDC grade Lysholm score Tegner score Lachman KT-1000 Extension deficit	NA	NA
Matsumoto	2006	80	7 (5 – 8.5)	72 (90%)	IKDC grade KT-1000 Extension deficit	7 (5 – 8.5)	72 (90%)
O'Neill	2001	225	8.5 (6 – 11)	225 (100%)	IKDC grade KT-1000	8.5 (6 – 11)	225 (100%)

Author	Year	Initial cohort	Years to clinical follow-up Mean (range)	Final clinical cohort	Clinical evaluation	Years to radiographic follow-up	Final radiographic cohort
Panni	2001	141	6.7 (5.3 – 7.5)	141 (100%)	IKDC grade Lachman KT-1000 Extension deficit	NA	NA
Roe	2005	180	7	120 (67%)	IKDC grade Lysholm score Lachman/Pivot shift KT-1000 Extension deficit	7	104 (58%)
Ruiz	2002	90	7 (5.4 – 9.5)	30 (33%)	Lysholm score Tegner score Lachman/Pivot shift KT-1000	7 (5.4 – 9.5)	30 (33%)
Sajovic	2006	64	5	54 (85%)	IKDC grade Lysholm score KT-1000 Extension deficit Anterior knee pain	5	54 (85%)
Shelbourne	2009	1276	14 (10–24)	920 (72%)	IKDC grade Cincinnati knee score Pivot shift KT-1000 Extension deficit	14 (10 – 24)	502 (39%)
Spindler	2005	314	5.4 (5–7.1)	217 (69%)	IKDC grade KOOS Lysholm score WOMAC SF-36	NA	NA
Wu	2002	103	10.4 (9–13)	64 (62%)	IKDC grade Lysholm score Tegner score Pivot shift/Lachman KT-1000 Extension deficit	10.4 (9–13)	64 (62%)
Zaffagnini	2006	50	5	50 (100%)	IKDC grade Tegner score Pivot shift/Lachman KT-1000 Extension deficit Anterior knee pain	5	50 (100%)

IKDC, International Knee Documentation Committee; VAS, visual analog scale; KOOS, knee osteoarthritis outcomes score; WOMAC, Western Ontario and McMaster Universities.

Table 6

Correlation of joint space narrowing across radiographic staging systems.

Joint space	International Knee Documentation Committee (IKDC)	Kellgren and Lawrence	Ahlback	Rosenberg	Fairbank
Normal	A	1 [*]		Normal	Absent
Minimal narrowing	B [†]	2 [‡]			
Moderate narrowing	C [§]	3/	I [¶]	Major [#]	Present
Severe narrowing	D [#]	4 ^{**}	II – V ^{††}		

^{*} Defined as doubtful narrowing

[†] Defined as joint space greater than 4 mm

[‡] Defined as possible narrowing

[§] Defined as joint space 2 – 4 mm

[/] Defined as definite joint space narrowing

[¶] Defined as joint space < 3 mm

[#] Defined as joint space 2 mm less than the contralateral side

^{**} Defined as marked joint space narrowing

^{††} Defined as complete loss of joint space

Table 7

Clinical findings in all patients.

Author	Year	Re-ruptures	Overall IKDC Score	Lysholm (mean)	Tegner (mean)	Normal Lachman/Pivot	KT-1000 within 2-4 mm of contralateral	No extension deficit	Other outcome
Deehan	2000	3 (3%)*	A = 74% B = 25% C = 0% D = 1%	96	NR#	90%/98%	93%	69%	No pain with kneeling – 56%
Drogset	2002	5 (10%)*	NR	87	5.2	78% /NR	72%	87%	Subjective patient assessment Excellent = 17% Good = 78% Fair = 5% Poor = 0%
Hart	2005	0	NR	96	6.5	NR/NR	NR	NR	
Hanypsiak	2008	3 (7%)*	NR	NR	NR	62%/50%	mean: 2 mm more than nl side	NR	Mean Subjective IKDC score 70.3
Ibrahim	2005	NR	A = 62% B = 24% C = 14% D = 0%	92	7.8	85%/85%	85%	70%	Patients satisfied with outcome = 85%
Keays	2007	2 (4%)*	NR	NR	NR	100%/100%	84%	100%	Cincinnati score = 93.2
Lebel	2008	9 (9%)	A = 51% B = 40% C = 9% D = 0%	NR	NR	91%/68%	NR	98%	
Liden	2007	3 (4%)*	A or B = 51% C or D = 49%	85	5.5	95%/NR	mean: 2.1 mm more than nl side	78%	
Matsumoto	2006	0	A = 28% B = 51% C = 17% D = 4%	NR	NR	NR/NR	88%	89%	
O'Neill	2001	15 (7%)	A = 69% B = 23% C = 4% D = 4%	NR	NR	NR/NR	72%	NR	
Panni	2001	NR	A = 21% B = 56% C = 20% D = 3%	NR	NR	83%/NR	mean: 2.6 mm more than nl side	88%	
Roe	2005	13 (8%)*	A or B = 98%	96	NR	79%/83%	77%	79%	

Author	Year	Re-ruptures	Overall IKDC Score	Lysholm (mean)	Tegner (mean)	Normal Lachman/Pivot	KT-1000 within 2-4 mm of contralateral	No extension deficit	Other outcome
			C or D = 2%						
Ruiz	2002	NR	A = 50% B = 40% C = 10% D = 0%	87	7	87%/94%	73%	NR	mean thigh atrophy compared to contra = 1 cm
Sajovic	2006	2 (4%)*	A = 44% B = 53% C = 3% D = 0%	92	NR	92%/92%	84%	95%	anterior knee pain = 18%
Shelbourne	2008	90 (6%)*	A = 48% B = 42% C = 9% D = 0.5%	NR	NR	NR/94%	95%	NR	Cincinnati score = 88.0
Spindler	2005	9 (3%)*	NR	85	NR	NR/NR	NR	NR	Mean subjective IKDC score 70.3
Wu	2002	3 (5%)	NR	88	6.4	95%/97%	mean: 2.3 mm more than nl side	97%	Mean subjective IKDC score 80
Zaffagnini	2006	NR	A = 28% B = 46% C = 20% D = 6%	NR	7.4	82%/76%	66%	78%	Anterior knee pain = 24%

* Re-ruptures excluded from analysis

NR = not reported; IKDC, International Knee Documentation Committee.

Table 8

Radiographic findings in all patients.

Author	Year	Radiographic grading scale	Normal	Minimal narrowing	Moderate narrowing	Severe narrowing
Deehan	2000	IKDC	63 (97%)	2 (3%)	0	0
Drogset	2002	Ahlback	21 (58%)		9 (25%)	6 (17%)
Hart	2005	Ahlback	9 (29%)		13 (42%)	9 (29%)
Hanypsiak	2008	Rosenberg	30 (68%)		14 (32%)	
Ibrahim	2005	NR*	71 (84%)	0	14 (16%)	0
Keays	2007	NR	29 (52%)	20 (36%)	7 (12%)	0
Lebel	2008	IKDC	58 (57%)	25 (25%)	16 (16%)	2 (2%)
Liden	2007	NA [#]				
Matsumoto	2006	IKDC	44 (61%)	22 (30%)	6 (9%)	0
O'Neill	2001	IKDC	199 (88%)	21 (9.3%)	4 (1.7%)	1 (0.4%)
Panni	2001	NA				
Roe	2005	IKDC	73 (70%)	28 (27%)	3 (3%)	0
Ruiz	2002	IKDC	15 (50%)	12 (40%)	3 (10%)	0
Sajovic	2006	IKDC	41 (76%)	12 (22%)	1 (2%)	0
Shelbourne	2008	IKDC	300 (60%)			
Spindler	2005	NA				
Wu ^{\$}	2002	Fairbanks				
Zaffagnini	2006	Rosenberg	49 (98%)		1 (2%)	

* NR = Not reported

[#] NA = Not applicable—no radiographs were obtained^{\$} Wu *et al.* did not report radiographic findings on all patients in their study.

IKDC, International Knee Documentation Committee.