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Does autograft choice determine intermediate term outcome of ACL reconstruction?

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Abstract

Purpose—Many clinical studies and systematic reviews have compared the short-term (2 year) outcomes of ACL reconstruction with hamstring and patellar tendon autograft. Few differences have been observed, with the exception of increased kneeling pain with patellar tendon grafts. The goal of this systematic review is to determine where there are differences in clinical, patient reported, or radiographic outcomes based on graft choice at a minimum of 5 years after ACL reconstruction.

Methods—A systematic review was performed to identify all prospective outcome studies comparing patellar tendon and hamstring autograft ACL reconstruction with minimum follow-up of at least five years. Seven studies were identified and meta-analysis of select data determined to be sufficiently homogenous was performed (failure and laxity).

Results—Five randomized controlled trials and two prospective cohorts comparing hamstring and patellar tendon autografts were identified. Clinical assessment [failure rate, International Knee Documentation Committee (IKDC) class, Lachman, pivot shift, and KT 1000 testing] showed no difference between grafts. Patient-reported outcomes (Lysholm, Cincinnati, and IKDC) showed no difference. Both anterior knee pain (3/3 studies) and kneeling pain (4/4 studies) were more frequent in the patellar tendon group. However, the patient-reported outcomes in these studies were not different. Radiographic evidence of osteoarthritis was inconsistent between autograft choices.

Conclusion—This Level II systematic review demonstrates no difference in major clinical results between graft types with the exception of increased anterior knee and kneeling pain. There exists a potential for increased incidence of osteoarthritis in the patellar tendon group but increased sample size is required. These longer-term outcomes are similar to results of prior systematic reviews with two-year follow-up.

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 papers reporting outcomes of ACL reconstruction and univariate analyses of factors felt to influence outcome. These hypothesized factors include patient characteristics such as meniscus or articular cartilage status at the time of reconstruction, mechanism of

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The authors report no conflict of interest related to this work.

injury, or body mass index (BMI), as well as surgical factors such as graft choice or surgical technique.

Numerous authors have investigated the impact of autograft choice on outcome after ACL reconstruction and several authors have published systematic reviews on the subject with varying results (Table 1).[16, 24] Some favor bone-patellar tendon-bone[26] and some favor hamstring tendon,[17] while the majority note strengths and weaknesses of each graft type without concluding that one is superior.[1, 3–5, 10, 23] While many of these studies focus on prospective data, they all have minimum follow-up requirements of two years or less. A systematic review of minimum five-year follow-up after ACL reconstruction has not been reported.

The last decades have seen a significant focus on evidence based medicine, with a subsequent increase in the quality of published studies.[8] The last ten years have witnessed the publication of numerous papers detailing long-term outcomes following ACL reconstruction. Numerous authors have suggested that longer-term follow-up is required for accurate assessment of results after ACL reconstruction.[7, 21, 25] The aim of this systematic review is to determine whether graft choice affects clinical, patient-reported, and radiographic outcomes after ACL reconstruction based on published prospective comparative studies with 5-year minimum follow-up. We hypothesize that no significant differences will be noted between the two graft types.

Material and Methods

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 where necessary of these publications were reviewed and studies failing to meet inclusion and exclusion criteria outlined in Table 2 except for prospective nature were excluded. Full texts of the resulting 42 articles were obtained. Subsequent review led to the exclusion of 22 studies that were retrospective in nature, two that were duplicate publications, and one study which included patients represented at longer follow-up in another included study.

A search of the Embase database was then performed utilizing 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 5 articles was obtained and 4 were excluded because they were retrospective studies.

The resulting 18 prospective studies were reviewed to identify those evaluating outcome based on autograft choice (hamstring versus bone-patellar tendon-bone) and 7 studies were identified.[11, 12, 14, 15, 18, 20, 27]

Assessment of Quality of Included Studies

A Modified Coleman Methodology Score was utilized to assess the quality of included studies.[2] This scoring system awards points for study design and size, patient selection, length and completeness of follow-up, and outcomes assessment. Points are totaled to yield a maximum of 100 points (Appendix 1).

Data Extraction

A templated EBM literature review form was utilized to assist in data collection. Extracted data included study design and follow-up, patient demographics (age, sex, and body mass

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index), surgical and rehabilitation technique, clinical outcome assessment [International Knee Documentation Committee (IKDC) class, Lachman, pivot shift, KT 1000 testing, and range of motion], failure rate, patient reported outcomes (Lysholm, Cincinnati, IKDC, subjective anterior knee and kneeling pain) quadriceps and hamstring strength testing, and radiographic findings (IKDC[9] or Rosenberg[19] rating scales). Radiographic evidence of osteoarthritis was defined as an IKDC score of B or worse or the presence of major Rosenberg changes. Data were extracted by two authors independently and discrepancies were resolved by consensus.[6, 22]

Statistical Analysis

Heterogeneity was qualitatively assessed by comparing the study populations, interventions, and outcomes among the included studies. In addition, statistical tests of homogeneity (chi-square testing for failures and for grouped frequency distribution of instrumented laxity) were employed to determine if any individual study findings refute the null hypothesis that the findings of the individual studies are the same. If the observed variation among studies was inconsistent with this null hypothesis ($P < 0.10$), then heterogeneity was assumed.

A study was withdrawn from meta-analysis of a particular outcome if that outcome was not studied or not reported adequately. A Mantel-Haenszel analysis utilizing a random effects model allowed for pooling of results by graft type, while accounting for number of subjects of individual studies. In order to ensure that the findings were robust, a sensitivity analysis was performed, varying the included studies in the meta-analysis based on study methodology (randomized study design or prospective cohort) as well as on the consistent inclusion or exclusion of clinical failures in the instrumented laxity data.

Results

Study Design and Quality

The literature review described above yielded 7 prospective (level I or II) manuscripts with at least 5-year minimum follow-up. These studies include five randomized controlled trials[11, 14, 15, 20, 27] and two prospective cohort studies[12, 18] comparing outcomes of ACL reconstruction with bone-patellar tendon-bone autografts and hamstring tendon autografts.

All studies had minimum follow-up of 5 years after reconstruction. Mean follow-up ranged from 5 to 8.5 years. Clinical follow-up was performed in all 7 studies, with a mean follow-up rate of 86%, with individual papers' follow-up rates ranging from 67% to 100%. Instruments utilized for clinical follow-up included KT-1000 (100%), range of motion (86%), subjective measures of stability (Lachman/anterior drawer) (71%), overall IKDC score (71%), and validated patient oriented outcome scores (86 %): Lysholm score (57%), subjective IKDC score (14%), and Cincinnati score (14%). Radiographic follow-up was available in 6 studies, with a mean follow-up rate of 83%, with individual papers' follow-up rates ranging from 58% to 100%. Modified Coleman Methodology Scores for the studies ranged from 66 to 78 (Table 3).

Patient Demographics

Mean patient age at reconstruction was 25 years. Mean patient age in the six studies reporting it ranged from 22 to 31 years. Overall, 66% of patients were male, with the percentage in the seven studies ranging from 50% to 100%. The time from injury to ACL reconstruction varied considerably between studies. Exclusion criteria among the studies varied, but all excluded knees with multiple ligament injuries other than low-grade medial collateral ligament injuries. Demographic information is detailed in Table 4.

Surgical and Rehabilitation Technique

All studies utilized autograft for ACL reconstruction performed using all endoscopic, arthroscopic-assisted, or two incision mini-arthrotomy techniques. Fixation of all patellar tendon grafts was with interference screw. Hamstring fixation was variable, with staple, interference screw, and endobutton techniques all utilized (Table 5). Six studies reported details of their rehabilitation protocol. Four (67%) allowed immediate full weight bearing[12, 14, 18, 20]. One author allowed immediate partial weight bearing and full weight bearing at 2 weeks[27] while one allowed full weight bearing after 2–3 days.[11] Postoperative extension bracing was utilized by 2 authors (33%) for time periods ranging from 1–3 weeks.[12, 20]

Clinical Outcome Assessment

Clinical outcomes of the two graft types were compared in each of the seven studies outlined above. No study showed significant differences in overall IKDC score, manual stability, KT-1000 testing, or extension deficit between the patellar tendon and hamstring groups. Data are shown in Table 7.

Graft failure Rate

Graft failure rate was reported in five studies, none of which demonstrated a difference in failure rate between graft types.

Patient-Reported Outcomes

Six studies utilized validated patient-reported outcome scores including Lysholm, Cincinnati, and IKDC in outcome assessment. None demonstrated significant differences between graft types. The three studies reporting anterior knee pain showed a higher incidence in the patellar tendon group (range 25–36%) than the hamstring tendon group (range 7–14%). Similarly, kneeling pain was reported in four studies with three reporting more kneeling pain in the patellar tendon group. The patient-reported outcomes in the studies that reported anterior knee and kneeling pain were not different (Table 8).

Strength Testing

Isokinetic strength test results were reported in two studies.[12, 15] Keays et al noted nearly full strength of both quadriceps and hamstrings compared to the contralateral side in both groups. O'Neill noted a deficit of at least 10% of quadriceps strength in 34% of patients in the BTB groups and 13% of patients in the hamstring group. A similar deficit in hamstring strength was noted in 10% of patients in the BTB groups and 19% of patients in the hamstring group.

Radiographic Evaluation

Six of the above studies described the rate of development of radiographic evidence of osteoarthritis with a patellar tendon graft versus a hamstring graft. All six compare the rates of tibiofemoral osteoarthritis,[11, 12, 15, 18, 20, 27] four compare the rates of patellofemoral arthritis,[11, 12, 18, 20] and three present sufficient data to allow comparison of the rate of osteoarthritis in either location.[12, 18, 20]

A minority of studies (2/6) showed a significantly increased rate of tibiofemoral osteoarthritis in the patellar tendon group[12, 18] and four showed no difference in tibiofemoral osteoarthritis between groups.[11, 15, 20, 27] All four studies comparing rates of patellofemoral osteoarthritis noted higher rates of osteoarthritis in the patellar tendon group but none demonstrated a statistically significant difference.[11, 12, 18, 20] However, all three studies that allowed calculation of the rate of development of osteoarthritis in either location demonstrated a significantly increased rate in the patellar tendon group.[12, 18, 20, 27] Rates of osteoarthritis in each location by graft type in each study are shown in Table 9.

Assessment of Heterogeneity

Statistical tests of homogeneity supported the null hypothesis that the findings of these seven individual studies were the same with respect to clinical failure rate and instrumented laxity ($P > 0.10$). Remaining outcome measures demonstrated significant heterogeneity and were not subjected to meta-analysis.

Meta-analysis of Graft Failures

Graft failures were reported in five of the seven studies identified for this review.[12, 14, 15, 18, 20] Failure was defined by clinical exam in the five studies without specific criteria reported. The clinical failures from these five studies were pooled by graft type, and the meta-analysis (Figure 1) estimates an odds ratio of 0.63 favoring bone-patellar tendon-bone [95% CI of 0.31 to 1.27, $P = 0.20$].

Meta-analysis of Instrumented Laxity

Six studies reported the grouped frequency distribution of instrumented laxity.[11, 12, 15, 18, 20, 27] The instrumented laxity results of these six studies were pooled by graft type, and the meta-analysis of instrumented laxity more than 5 mm (Figure 2) estimates an odds ratio of 0.87 favoring bone-patellar tendon-bone [95% CI of 0.58 to 1.31, $P = 0.50$]. Of note, when clinical failures are consistently included in the instrumented laxity data, the funnel plot assumes the characteristic funnel shape. In that setting, the meta-analysis of instrumented laxity more than 5 mm estimates an odds ratio of 0.78 favoring bone-patellar tendon-bone [95% CI of 0.53 to 1.16, $P = 0.22$].

Discussion

The most important finding of our study is the absence reproducible differences in clinical assessment, instrumented laxity, or patient-reported outcomes based on autograft choice. Thus we reach a similar conclusion to those of numerous two-year systematic reviews that no reproducible difference exists between autograft choices and confirm that at minimum of five years these results are maintained. Based on this longer-term follow-up, both autografts should be considered equivalent.

Both anterior knee pain and kneeling pain were evaluated in a minority of studies but were consistently worse with bone-patellar tendon-bone grafts. However, anterior knee pain in patients in these studies was not assessed using a validating tool for assessing anterior knee pain such as the Kujala score.[13] It is interesting to note that in each study reporting increased anterior knee pain or kneeling pain in the patellar tendon group, the patient-reported outcomes and clinical assessments did not differ between groups. Further research utilizing validated measures is needed as to the cause of anterior knee pain following ACL reconstruction. Currently available data suggest that patients whose occupation, recreation, or religion requires repetitive kneeling, a hamstring graft should be considered.

The papers included in this review are inconsistent in regard to the influence of graft choice on the development of osteoarthritis. Two of the six papers strongly link the development of osteoarthritis with the use of patellar tendon grafts while the other four do not. It should be noted that the two studies which demonstrated this effect were not randomized. In both papers, consecutive cohorts are compared. It is possible that other unknown differences in the patient populations, surgical environment, or rehabilitation contributed to the increased osteoarthritis in the patellar tendon group. All papers evaluating the effect of graft choice on the development of patellofemoral osteoarthritis had a p value between 0.05 and 0.20. It is likely that these studies were underpowered to detect a difference. The three studies that allowed for comparison of rates of osteoarthritis in either location showed a statistically and clinically significant increased rate with patellar tendon grafts.

If an increased patellofemoral osteoarthritis rate with patellar tendon grafts is shown in future studies, this may represent the technique of graft harvest and suggest that extreme care be taken during harvest to avoid chondral injury. Reasons for increased tibiofemoral osteoarthritis are less clear, but may be related to the increased rate of postoperative stiffness reported by some authors utilizing patellar tendon grafts. Regardless of the etiology of the effect, it might be advisable to avoid patellar tendon grafts in patients who already exhibit early signs of osteoarthritis. Future studies with multivariable analysis are needed to identify modifiable risk factors for osteoarthritis following ACL reconstruction.

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 the influence of autograft choice on outcome after ACL surgery has had such rigid inclusion and exclusion criteria. The included studies are all level I or II data with at least five-year minimum follow-up and thus provide a high level of evidence for analysis for clinical decision making.

The weaknesses of this study are the heterogeneous outcomes evaluated in each study and lack of validated instruments for anterior knee or kneeling pain. However, these weaknesses do not preclude a systematic review. Further standardization of rehabilitation, utilization of a blinded clinical examiner, and use of additional validated patient-reported outcome measure would improve the strength of conclusions and meta-analysis. Similarly, there remains no universally applied, validated outcome measure for rotational stability following ACL reconstruction, forcing us to rely on the quite subjective pivot-shift examination. Additionally, this study suffers from a weakness inherent to all assessments of relatively long-term outcome data: the data presented above represents surgical instrumentation and techniques that are at least five years old and may not entirely represent current practice. Finally, the strict inclusion criteria for this review have led to the collection of data from a relatively small number of papers selected from numerous studies addressing outcome after ACL reconstruction. The findings of this study thus reflect only this relatively small amount of data.

Conclusion

Data from prospective studies with minimum five-year follow-up indicate that the choice of bone-patellar tendon-bone autograft versus hamstring autograft does not significantly influence clinical outcome at minimum five-year follow-up. Radiographic data is more inconsistent with respect to evidence of osteoarthritis following autograft ACL reconstruction. Both anterior knee pain and kneeling pain occurred more frequently in patellar tendons but the patient-reported outcomes were not different. These findings are consistent with previous two-year systematic reviews and meta-analysis which fail to consistently demonstrate the superiority of one autograft type over the other. Thus, both should be considered the current standard for ACL reconstruction.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Study or Subgroup	BPTB Events	BPTB Total	Hamstring Events	Hamstring Total	Weight	Odds Ratio M–H, Random, 95% CI
Keays 2007	0	29	1	27	4.7%	0.30 [0.01, 7.67]
Liden 2007	2	32	2	36	12.2%	1.13 [0.15, 8.55]
O'Neill 2001	9	150	6	75	43.2%	0.73 [0.25, 2.15]
Roe 2005	4	90	9	90	33.6%	0.42 [0.12, 1.41]
Sajovic 2006	1	30	1	31	6.3%	1.03 [0.06, 17.33]
Total (95% CI)		**331**		**259**	**100.0%**	**0.63 [0.31, 1.27]**
Total events	16		19			

Heterogeneity: Tau² = 0.00; Chi² = 1.16, df = 4 (P = 0.88); I² = 0%
Test for overall effect: Z = 1.30 (P = 0.20)

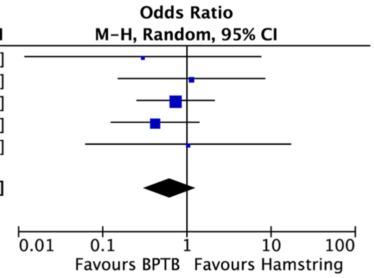

Figure 1.

Study or Subgroup	BPTB Events	BPTB Total	Hamstring Events	Hamstring Total	Weight	Odds Ratio M–H, Random, 95% CI
Ibrahim 2005	5	40	7	45	11.0%	0.78 [0.23, 2.67]
Keays 2007	4	27	4	22	7.3%	0.78 [0.17, 3.57]
O'Neill 2001	29	150	19	75	38.8%	0.71 [0.37, 1.37]
Roe 2005	15	59	12	61	22.7%	1.39 [0.59, 3.29]
Sajovic 2006	5	26	4	28	8.1%	1.43 [0.34, 6.03]
Zaffagnini 2006	7	25	10	25	12.0%	0.58 [0.18, 1.91]
Total (95% CI)		**327**		**256**	**100.0%**	**0.87 [0.58, 1.31]**
Total events	65		56			

Heterogeneity: Tau² = 0.00; Chi² = 2.47, df = 5 (P = 0.78); I² = 0%

Test for overall effect: Z = 0.67 (P = 0.50)

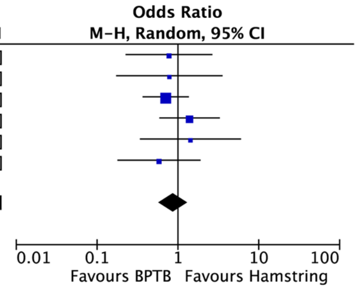

Figure 2.

Table 1

Previous Systematic Reviews

		Level of Evidence	Minimum Follow-up	Included Studies	Conclusions	Direction
Biau	2006	I	1 year	18 Prospective randomized trials	• BTB: minimal evidence for improved stability • Hamstrings: decreased morbidity	Neutral
Forster	2005	I	2 years	6 Prospective randomized trials	• BTB: greater extension loss, trend toward increased patellofemoral pain • Hamstrings: loss of hamstring strength, trend toward increased pivot-shift	Neutral
Freedman	2003	IV	2 years	BTB data from 21 studies Hamstring data from 13 studies	• BTB: decreased failure rate, increased stability and patient satisfaction • Hamstrings: decreased anterior knee pain	Neutral
Goldblatt	2005	I	2 years	11 Prospective controlled trials	• BTB: improved Lachman, pivot-shift, and instrumented stability • Hamstrings: Decreased patellofemoral crepitation and kneeling pain	Neutral
Herrington	2005	I	1 year	13 Prospective controlled trials	• No significant differences	Neutral
Prodromos	2005	IV	2 years	BTB data from 32 studies Hamstring data from 24 studies	• Hamstrings: Increased stability but dependent on fixation method	Favors Hamstrings
Spindler	2004	I	2 years	9 Prospective controlled studies	• BTB: increased kneeling pain • Hamstrings: slight increase in instrumented laxity	Neutral
Yunes	2001	I	2 years	4 Prospective controlled studies	• BTB: improved activity level and decreased laxity	Favors BTB

BTB = Bone-patellar tendon-bone

Table 2

Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Prospective comparative studies comparing outcomes of primary ACL reconstruction with hamstring and patellar tendon grafts (Level I and II evidence)	Retrospective comparative studies and case series (Level III and IV evidence)
Five-year minimum follow-up	Less than 5-year minimum follow-up
Reconstruction with patellar tendon or hamstring tendon autograft	Utilization of graft tissue other than patellar tendon or hamstring tendon
All-arthroscopic, arthroscopic-assisted, or mini-arthrotomy technique	Open ACL reconstruction
Report separate outcomes based on graft type	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

Table 3

Follow-up and Quality Scores

Author	Year	Initial Cohort	Years to Clinical Follow-up Mean (range)	Final Clinical Cohort	Clinical Evaluation	Years to Radiographic Follow-up	Final Radiographic Cohort	Modified Coleman Methodology Score
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%)	66
Keays	2007	62	6	56 (90%)	Cincinnati knee score Lachman/Pivot shift KT-1000 Extension deficit	6	56 (90%)	68
Liden	2007	71	7.2 (5.7–9.5)	68 (96%)	IKDC Grade - overall Lysholm Score Tegner Score Lachman KT-1000 Extension deficit	NA	NA	70
O’Neill	2001	225	8.5 (6–11)	225 (100%)	IKDC Grade - overall KT-1000	8.5 (6–11)	225 (100%)	76
Roe	2005	180	7	120 (67%)	IKDC Grade - overall Lysholm Score Lachman/Pivot shift KT-1000 Extension deficit	7	104 (58%)	78
Sajovic	2006	64	5	54 (85%)	IKDC Grade - overall Lysholm Score KT-1000 Extension deficit Anterior knee pain	5	54 (85%)	71
Zaffagnini	2006	50	5	50 (100%)	IKDC - Subjective IKDC Grade - overall Tegner Score Pivot shift/Lachman KT-1000 Extension deficit Anterior knee pain	5	50 (100%)	75

Table 4

Patient Demographics

Author	Journal	Year	Initial Cohort	Patient Age Mean (range)	Percent male	Chronicity	Method of Reconstruction	Other Selection Criteria
Ibrahim	Arthroscopy	2005	110	22 (17–34)	100%	NR *	All arthroscopic Femoral tunnel drilled through tibia	
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	Multi-ligament injuries, patients over 40, acute injuries, and patients with evidence of osteoarthritis at reconstruction 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	Multi-ligament injuries, bilateral injuries, and revision excluded
O’Neill	JBJS-Am	2001	225	NR	67%	NR	1/3 all arthroscopic and 2/3 2-incision	Multi-ligament injuries and those under age 18 excluded
Roe	AJSM	2005	180	24 (13–52)	53%	62% reconstructed within 12 weeks of injury	All arthroscopic Femoral tunnel drilled through anteromedial portal	Patients with multi-ligament injuries, chondral injuries, meniscal pathology involving more than 2/3 of the meniscus, contralateral knee injury, or radiographic abnormality excluded
Sajovic	AJSM	2006	64	25 (14–46)	50%	Mean time from injury to reconstruction 2.0 years	All arthroscopic	Patients with multi-ligament injuries, abnormal radiographs, previous meniscal surgery, or subsequent contralateral rupture excluded
Zaffagnini	KSSTA	2006	50 **	31 (22–49)	62%	Mean time from injury to reconstruction 0.8 years	All arthroscopic Femoral tunnel drilled through tibia	Patients with PCL injury, meniscal or cartilage injury, non-athletes, prior knee surgery, and age over 50 were excluded

* NR = not reported

** Study also included an extra-articular reconstruction group that was excluded from this analysis

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Table 5

Surgical Technique

Author	Year	Surgical Approach	Method of Drilling Femoral Tunnel	Proximal Fixation	Proximal Fixation	Distal Fixation	Distal Fixation
				BTB*	Hamstring	BTB	Hamstring
Ibrahim	2005	All endoscopic	Transtibial	Interference screw	Endobutton	Interference screw	Screw and washer or staple
Keays	2007	Mini-arthrotomy	Independent	Interference screw	Interference screw	Interference screw	Interference screw
Liden	2007	All endoscopic	Transtibial	Interference screw	Interference screw	Interference screw	Interference screw
O'Neill	2001	2/3 Arthroscopic-assisted 2-incision, 1/3 All endoscopic	2/3 Independent 1/3 Transtibial	Interference screw	2 staples	Interference screw	2 staples
Roe	2005	All endoscopic	Transtibial	Interference screw	Interference screw	Interference screw	Interference screw
Sajovic	2006	All endoscopic	Independent	Interference screw	Interference screw	Interference screw	Interference screw
Zaffagnini	2006	All endoscopic	Transtibial	Interference screw	Endobutton	Interference screw	Interference screw

*BTB = bone-patellar tendon-bone

Table 6

Clinical Outcome Measures

Author Year	Clinical Failure BTB	Clinical Failure Ham	Overall IKDC A or B BTB	Overall IKDC A or B Ham	Normal Lachman BTB	Normal Lachman Ham	Normal Pivot BTB	Normal Pivot Ham	KT-1000 within 2–4 mm of contra- lateral BTB	KT-1000 within 2–4 mm of contra- lateral Ham	No extension deficit BTB	No extension deficit Ham
Ibrahim 2005	NR	NR	35/40 (88 %)	38/45 (84 %)	35/40 (88 %)	39/45 (87 %)	35/40 (88 %)	38/45 (84%)	35/40 (88 %)	38/45 (84 %)	28/40 (70 %)	37/45 (82 %)
Keays 2007	0/29 (0%)	1/27 (3.7%)			29/29* (100 %)	25/25* (100 %)	29/29* (100 %)	25/25* (100 %)	23/27# (85 %)	18/22# (82 %)	29/29* (100 %)	25/25* (100 %)
Liden 2007	2/32 (6.2%)	2/36 (5.6%)	15/31* (48 %)	17/34* (50 %)	30/31* (97 %)	32/34* (94 %)	NR	NR	NR	NR	24/31* (77 %)	27/34* (79 %)
O'Neill 2001	9/150 (6.0%)	6/75 (8.0%)	141/150 (94 %)	67/75 (89 %)	NR	NR	NR	NR	121/150 (81 %)	56/75 (75 %)	NR	NR
Roe 2005	4/90 (4.4%)	9/90 (10%)	50/59# (85 %)	54/61# (89 %)	45/59# (76 %)	50/61# (82 %)	49/59# (83 %)	50/61# (82 %)	44/59# (74 %)	49/61# (80 %)	51/59# (86 %)	55/61# (90 %)
Sajovic 2006	1/30 (3.3%)	1/31 (3.2%)	25/26# (97 %)	27/28# (97 %)	22/26# (85 %)	22/28# (79 %)	21/26# (81 %)	23/28# (83 %)	21/26# (81 %)	24/28# (85 %)	NR	NR
Zaffagnini 2006	NR	NR	19/25 (76 %)	18/25 (72 %)	22/25 (88 %)	16/25 (64 %)	23/25 (92 %)	18/25 (72 %)	18/25 (72 %)	15/25 (60 %)	20/25 (80 %)	18/25 (72 %)

* Clinical Failures Excluded

\# Clinical Failures and Contralateral Ruptures Excluded

NR = Not Reported

Table 7

Patient-Reported Outcome Measures

Author	Year	Patient Reported Score BTB	Patient Reported Score Ham	Anterior Knee Pain BTB	Anterior Knee Pain Ham	Kneeling Pain BTB	Kneeling Pain Ham
Ibrahim	2005	Lysholm 92	Lysholm 93	10/40 (25%)	3/45 (6.6%)	NR	NR
Keays*	2007	Cincinnati 92	Cincinnati 94	NR	NR	NR	NR
Liden*	2007	Lysholm 91	Lysholm 80	NR	NR	13/31 (42%)	10/34 (29%)
O'Neill	2001	NR	NR	NR	NR	NR	NR
Roe#	2005	Lysholm 93	Lysholm 93	24/63 (38%)	9/64 (14%)	34/63 (54%)	13/64 (20%)
Sajovic	2006	Lysholm 92	Lysholm 92	NR	NR	5/26 (19%)	5/28 (17%)
Zaffagnini	2006	Subjective IKDC 82	Subjective IKDC 76	9/25 (36%)	3/25 (12%)	18/25 (72%)	11/25 (44%)

* Ipsilateral Ruptures Excluded

Ipsilateral and Contralateral Ruptures Excluded

NR = Not Reported

Table 8

Radiographic Outcome Measures

Joint	Author	Year	Follow-up (Years)	Level of Evidence	Radiographic Grading Scale	Radiographic Evidence of OA	Radiographic Evidence of OA	Significance
						BTB Number (Percent)	Ham Number (Percent)	
Tibiofemoral	Ibrahim	2005	6.8	I	NR	6/40 (15%)	8/45 (18%)	p = 0.73
	Keays	2007	6	II	NR	18/29 (62%)	9/27 (33%)	**p = 0.02**
	O'Neill	2001	8.5	I	IKDC	14/150 (9%)	12/75 (16%)	p = 0.2
	Roe	2005	7	II	IKDC	24/53 (45%)	7/51 (14%)	**p = 0.002**
	Sajovic	2006	5	I	IKDC	9/26 (35%)	4/28 (14%)	p = 0.075
	Zaffagnini	2006	5	I	Rosenberg	0/25 (0%)	1/25 (4%)	p = 0.9
Patellofemoral	Ibrahim	2005	6.8	I	NR	8/40 (20%)	3/45 (7%)	p = 0.068
	Keays	2007	6	II	NR	12/29 (41%)	8/27 (30%)	p = 0.2
	Roe	2005	7	II	IKDC	8/53 (15%)	2/51 (4%)	p = 0.053
	Sajovic	2006	5	I	IKDC	7/26 (27 %)	3/28 (11%)	p = 0.12
Any#	Keays	2007	6	II	NR	21/29 (72%)	12/27 (44%)	**p = 0.03**
	Roe	2005	7	II	IKDC	28/53 (53%)	8/51 (16%)	**p < 0.001**
	Sajovic	2006	5	I	IKDC	13/26 (50%)	5/28 (18%)	**p = 0.012**

NR = Not Reported

#Any = Evidence of osteoarthritis noted in either the patellofemoral or tibiofemoral compartments or both