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SYSTEMATIC REVIEW

No Clinically Important Difference in Knee Scores or Instability Between Transtibial and Inlay Techniques for PCL Reconstruction: A Systematic Review

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Abstract

Background It is unclear whether the biomechanical superiority of the inlay technique over the transtibial technique, arising from avoidance of the killer turn at the graft-tunnel margin of the proximal tibia during posterior cruciate ligament (PCL) reconstruction, leads to better knee scores or greater knee stability.

Questions/purposes This systematic review was designed to compare Tegner and Lysholm scores, and posterior residual laxity of the knee, between single-bundle PCL reconstruction using transtibial and inlay techniques.

Methods We searched MEDLINE®, Embase®, and the Cochrane Library for studies comparing Tegner and/or Lysholm scores and posterior residual laxity, in patients who underwent PCL single-bundle reconstruction with the transtibial and tibial inlay techniques. There were no restrictions on language or year of publication. Studies were included if they compared clinical outcomes in patients who underwent PCL single-bundle reconstruction with the transtibial and tibial inlay techniques; they simultaneously reported direct comparisons of transtibial and tibial inlay PCL single-bundle reconstruction; and their primary outcomes included comparisons of postoperative scores on knee outcome scales and posterior residual laxity. A total of seven studies (including 149 patients having surgery using a transtibial approach, and 148 with the tibial inlay approach) met the prespecified inclusion criteria and were analyzed in detail.

Results Our systematic review suggested that there are no clinically important differences between the transtibial and the tibial inlay single-bundle PCL reconstruction in terms of Tegner or Lysholm scores. Of the five studies that assessed Lysholm scores, one favored the transtibial approach and four concluded no difference on this endpoint; however, the observed differences in all studies where differences were observed were quite small (< 7 of 100 points on the Lysholm scale), and likely not clinically important. Of the four studies that compared postoperative Tegner scores, three identified no differences between the approaches, while one favored the tibial inlay approach by a small margin (0.5 of 11 points) suggesting that there likely is no clinically important difference between the approaches in Tegner scores, either. Finally, we identified no difference between the approaches in terms of residual laxity, either among the seven studies that presented data using Telos radiographs, or the five that reported on patients with residual laxity greater than Grade 2 on a four-grade scale of posterior drawer testing (28/107 for transtibial and 26/97 for tibial inlay).

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Conclusion We found no clinically important differences between the transtibial and tibial inlay approach for PCL reconstruction. Based on the best evidence now available, it appears that surgeons may select between these approaches based on clinical experience and the specific elements of each patient's presentation, since there do not appear to be important or obvious differences between the approaches with respect to knee scores or joint stability. Future randomized trials are needed to answer this question more definitively.

Level of Evidence Level III, therapeutic study.

Introduction

PCL reconstruction may be performed numerous ways, including single-bundle transtibial and tibial inlay techniques or double-bundle transtibial and tibial inlay techniques [10]. Two of the most-commonly used approaches are the tibial inlay single-bundle approach and the transtibial approach. Despite widespread use of the transtibial technique, this approach may result in graft abrasion caused by the sharp graft angulation at the intraarticular aperture of the tibial tunnel, called the "killer turn", located on the posterior aspect of the proximal tibia [10]. The inlay technique was developed to avoid this sharp graft bending angle [17].

Although studies have shown that the inlay technique is biomechanically superior to the transtibial technique [3, 18], it remains unclear whether this advantage leads to better clinical outcomes. In addition, although some studies have reported clinical outcomes of patients who underwent PCL reconstruction using either technique [2, 27], few have compared clinical outcomes directly in patients who underwent PCL reconstruction using the transtibial and inlay techniques [15, 19].

This systematic review therefore was designed to compare clinical outcomes, including knee scale score and posterior residual laxity of the tibia, of single-bundle PCL reconstruction using transtibial and inlay techniques.

Search Criteria and Strategy

Data and Literature Sources

This study was based on Cochrane Review Methods [7]. MEDLINE® (January 1, 1976 to June 30, 2015), Embase® (January 1, 1985 to June 30, 2015), and the Cochrane Library (January 1, 1987 to June 30, 2015) were searched for studies that compared clinical outcomes, including scores on knee outcome scales and posterior residual laxity, in patients who underwent PCL single-bundle reconstruction using the transtibial and inlay techniques. There were no restrictions on language or year of publication. Search terms used in the title, abstract, MeSH and keywords fields included "posterior cruciate ligament reconstruction" [tiab] OR "PCL reconstruction" [tiab] AND "knee" [tiab], and "posterior cruciate ligament/surgery" [MeSH] OR "posterior cruciate ligament/injuries" OR "posterior cruciate ligament/anatomy and histology" [MeSH]. After the initial electronic search, relevant articles and their bibliographies were searched manually. Articles identified were assessed individually for inclusion.

Study Selection

Study inclusion was decided independently by two reviewers (Y-SS and H-JK), based on the predefined selection criteria. Titles and abstracts were read; if suitability could not be determined, the full article was evaluated. Studies were included in the systematic review if (1) they compared clinical outcomes in patients who underwent PCL single-bundle reconstruction with the transtibial and tibial inlay techniques; (2) they simultaneously reported direct comparisons of transtibial and tibial inlay PCL single-bundle reconstruction; and (3) their primary outcomes included comparisons of postoperative scores on knee outcome scales and posterior residual laxity. Knee outcome scales included the Lysholm score [28] and Tegner score [24]. Two scores were used because the Lysholm score has been validated for use in the evaluation of symptoms of instability after knee ligament surgery, and the Tegner score may be a more-sensitive measure of a patient's sports activity level [14]. Posterior residual laxity was defined as the difference between posterior tibial translation on the affected and normal sides, measured by a posterior stress radiograph using a Telos stress device (Austin & Associates, Fallston, MD, USA), or the proportion of knees that were Grade 2 or greater on posterior draw tests at the final followup. Studies also were included if (4) they fully reported the number of patients in each group (transtibial and tibial inlay groups), the means and SDs of knee outcome scales and postoperative posterior tibial translation laxity compared with the normal side, and the numbers of knees that were Grade 2 or greater on posterior drawer tests after surgery; and (5) they used adequate statistical methods to compare these variables in the two groups.

We included studies that allowed concomitant injuries in addition to PCL injuries, and some of the included studies did include patients with multiple knee injuries; likewise, various fixation and rehabilitation approaches were used in the studies we included (Table 1).

Table 1. Summary of study characteristics of the included study

Study	Concomitant injuries		Graft type and fixation techniques		Rehabilitation protocols	Number of total failures/number of total evaluated subjects (%)	
	TT	TI	TT	TI		TT	TI
Kim et al. [9] (2009)	LMT MMT CD of LFC	LMT	Ach allo F: bone plug with BAIS T: bone plug with BAIS + suture anchor with washer	Ach allo F: bone plug with BAIS T: bone plug with BAIS + suture washer	Full extension with a splint for 2 weeks/ PWB from Postoperative Day 1/ ROM at 90° from 2 weeks/ PCL brace for 6 weeks after removal of splint/ low-impact sports from 6 months	None	None
Lee et al. [13] (2013)	PLC II	PLC II	STG auto F: Rigid fix T: BAIS + backed up screw and washer	STG auto F: BAIS + staple T: 6.5 mm CS with washer	Full extension with a splint for 2 weeks/ PWB from Postoperative Day 1 to 8 weeks/ passive ROM from 3 to 5 postoperative days, full ROM from 12 to 24 weeks/ PCL brace for 6 weeks after removal of splint	Instability (> 10 mm):1/34 (3)	None
MacGilli-vray et al. [15] (2006)	None	None	BPTB auto + BPTB allo + Ach allo F: bone plug with BAIS + staple T: bone plug with BAIS + backed up screw and washer	BPTB auto + BPTB allo F: bone plug with BAIS T: CS with washer	Full extension with PCL brace for 4 to 6 weeks/ PWB from Postoperative Day 1 to 6 weeks/ full activities from 9 to 12 months	Instability (> 10 mm):1/13 (8) Convert to TKA:1/13 (8)	Instability (> 10 mm):1/7 (14)
Seon & Song [20] (2006)	None	None	STG auto F: anchor screw T: BAIS	BPTB auto F: BAIS T: screw and washer or staple	Full extension with a splint for 4 weeks/ PWB from 9 weeks followed by FWB from 12 weeks/ PCL brace for 12 weeks after removal of splint/ low-impact sports from 6 months	None	None
Seon et al. [21] (2013)	None	None	STG auto F: anchor screw T: BAIS	BPTB auto F: BAIS T: screw and washer or staple	Full extension with a splint for 4 weeks/ PWB from 9 weeks followed by FWB from 12 weeks/ PCL brace for 12 weeks after removal of splint/ low-impact sports from 6 months	None	None
Song et al. [22] (2014)	None	None	STG auto F: anchor screw T: BAIS	BPTB auto F: BAIS T: screw and washer or staple	Full extension with a splint for 4 weeks/ PWB from 9 weeks followed by FWB from 12 weeks/ PCL brace for 12 weeks after removal of splint/ low-impact sports from 6 months	None	None

Table 1. continued

Study	Concomitant injuries		Graft type and fixation techniques		Rehabilitation protocols	Number of total failures/number of total evaluated subjects (%)	
	TT	TI	TT	TI		TT	TI
Suh et al. [23] (2006)	None	None	Ach allo F: metal interference screw T: BAIS+ backed up screw and washer	Ach allo F: BAIS with staple T: 4.5 mm CS	Full extension with a splint for 3 weeks/ PWB from Postoperative Day 1 to 3 months/ ROM at 90° for 6 weeks/ PCL brace for 3 months after removal of splint	Instability (> 10 mm):1/12 (8)	None

TT = transtibial; TI = tibial inlay; LMT = lateral meniscal tear; MMT = medial meniscal tear; CD = chondral defect; LFC = lateral femoral condyle; N/S = not stated; PLC = posterolateral corner; F = femur; T = tibia; Ach = Achilles; allo = allograft; auto = autograft; BAIS = bioabsorbable interference screw; STG = semitendinous gracilis; CS = cannulated screw; BPTB = bone patellar tendon bone; PWB = partial weightbearing; FWB = full weightbearing.

Although the current study involved human participants, institutional review board or informed consent (written/oral) from the participants was not needed because all analyses were based on previously published studies.

Identification of Studies

The details of study identification, inclusion, and exclusion are summarized (Fig. 1). An electronic search yielded 104 studies in PubMed (MEDLINE®), 134 in Embase®, and 20 in the Cochrane Library. Three additional publications were identified through manual searching. After removing 17 duplicates, 244 studies remained; of these, 222 were excluded based on reading of the titles and abstracts. After reading the full texts of the remaining 22 articles, 15 were excluded owing to the absence of usable information regarding clinical and stability outcomes or because they were case series evaluating either the transtibial or tibial inlay technique without direct comparison of the two approaches. After applying these criteria, seven studies [9, 13, 15, 20–23] were finally included in this systematic review.

Study Characteristics and Patient Populations

The seven studies in the systematic review included a total of 149 knees that underwent transtibial and 148 knees that underwent tibial inlay single-bundle PCL reconstruction. All seven studies retrospectively compared Lysholm and Tegner scores, posterior residual laxity on stress radiographs, and the proportion of knees with postoperative Grade 2 or greater laxity on posterior drawer tests after PCL reconstruction using the transtibial and tibial inlay techniques. Four studies measured all four parameters; one study measured three parameters (Lysholm score, posterior residual laxity, and Grade 2 or greater laxity on posterior drawer tests); one measured Lysholm score and posterior tibial translation; and one measured only posterior tibial translation on stress radiographs (Table 2).

Data Extraction

Two reviewers (Y-SS and H-JK) independently recorded data from each study using a predefined data extraction form. Any disagreement unresolved by discussion was reviewed by a third investigator (DHL).

Variables recorded included: (1) means and SDs of postoperative Lysholm and/or Tegner scores, side-to-side differences in posterior tibial translation between the surgically treated and normal sides on posterior stress

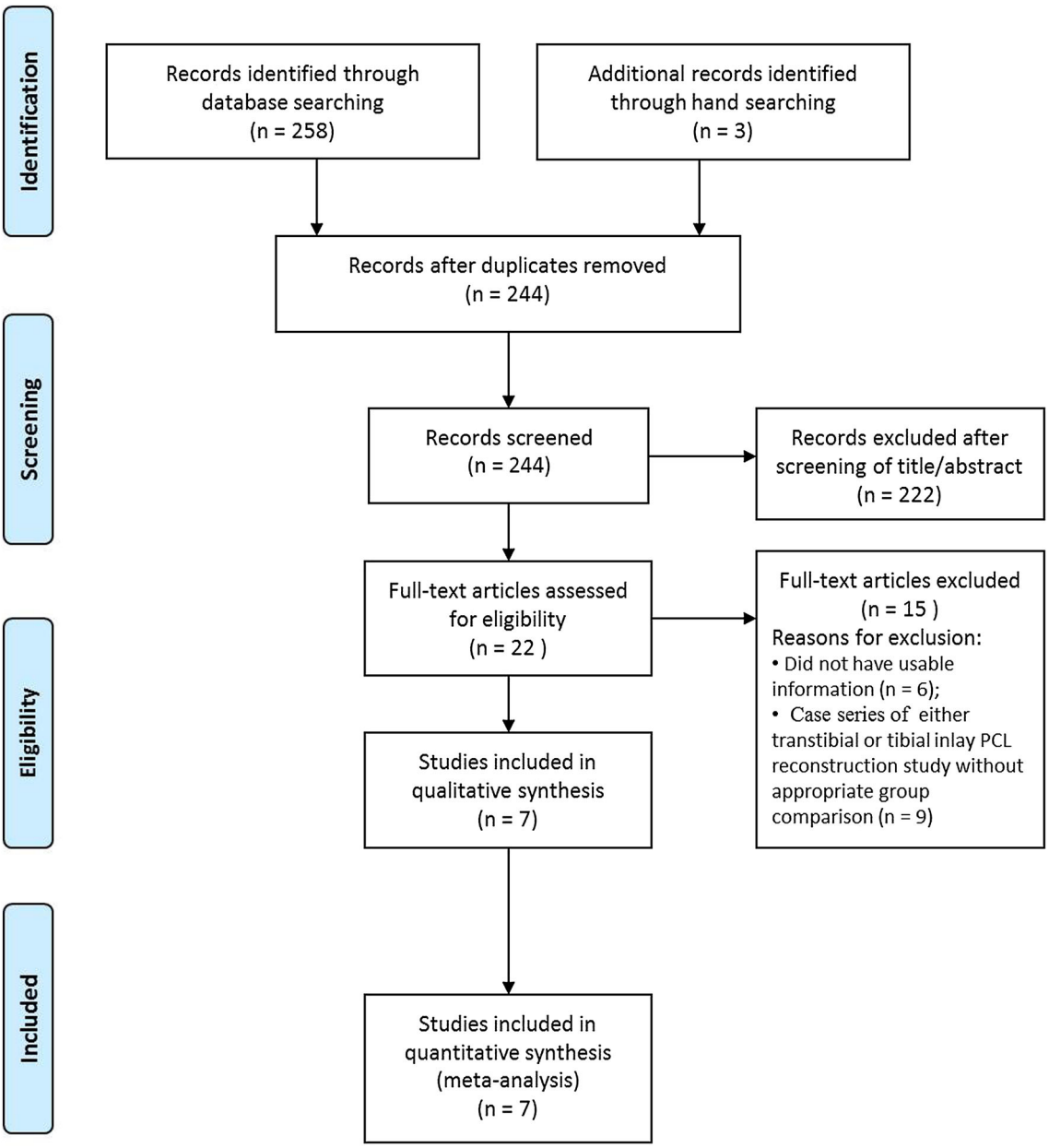

Fig. 1 The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) flow diagram shows identification and selection of the studies included in this meta-analysis.

radiographs after surgery, and numbers of knees with Grade 2 or greater laxity on posterior drawer tests after surgery in the transtibial and tibial inlay PCL reconstruction groups; and (2) the sample size of each group. If these variables were not mentioned in the articles, the authors of the study were contacted by email to request the data.

Assessment of Methodologic Quality

Two reviewers (Y-SS and H-JK) independently assessed the methodologic quality of each study using the Newcastle-Ottawa Scale [26], as recommended by the Cochrane Non-Randomized Studies Methods Working Group [7]. The star system of the Newcastle-Ottawa Scale [26], which awards stars depending on level of bias, was adjusted to a scale that included only low (one star), high, and unclear bias. Each study was judged on three criteria: the selection of the study groups, the comparability of the groups, and ascertainment of either exposure or outcome of interest for case-control and cohort studies. Any unresolved disagreements between reviewers were resolved by consensus or by consultation with a third investigator. Publication bias was not assessable in these trials. Tests for

Table 2. Summary of patient characteristics of the included studies

Study	Year	Study type	Sample size		Measured parameters	Followup period
			Transtibial	Tibial inlay		
Kim et al. [9]	2009	RCS	8	11	LKS, PTTSR	At least 2 years
Lee et al. [13]	2013	RCS	34	40	PTTSR	At least 2 years
MacGillivray et al. [15]	2006	RCS	13	7	LKS, TAS, PTTSR, PG2,3PDT	Mean 5.7 years
Seon & Song [20]	2006	RCS	21	22	LKS, TAS, PTTSR, PG2,3PDT	Mean 2.8 years
Seon et al. [21]	2013	RCS	44	39	LKS, PTTSR, PG2,3PDT	Mean 3.5 years
Song et al. [22]	2014	RCS	17	10	LKS, TAS, PTTSR, PG2,3PDT	Mean 11.8 years
Suh et al. [23]	2006	RCS	12	19	LKS, TAS, PTTSR, PG2,3PDT	Mean 2.7 years

RCS = retrospective comparison study; LKS = Lysholm knee score; TAS = Tegner activity score; PTTSR = posterior tibial translation on stress radiograph; PG2,3PDT = proportion of Grade 2 or 3 on posterior drawer test.

funnel plot asymmetry typically are conducted only when at least 10 studies are included because that number of studies is required to differentiate an asymmetry identified from chance. As our analysis included only seven studies, tests for asymmetry were not conducted.

Quality of the Included Studies

All seven studies included in this systematic review showed a low risk of selection bias. All compared demographic data in the transtibial and tibial inlay PCL reconstruction groups, whereas none assessed possible confounding factors. A mean postoperative followup greater than 3 years was defined as having a low risk of selection bias. Based on this cutoff, three studies were low risk and two were high risk. The other two studies had unclear risk of selection bias because they did not report mean followup, although their minimum followup was 2 years. None of the included studies reported the percentage of patients evaluated, relative to all patients who underwent PCL reconstruction at that institution. Therefore, all studies included in this systematic review were deemed to have a high risk of bias with respect to adequacy of followup (Table 3).

Results

Knee Scores

Our systematic review suggested that there are no clinically important differences between the transtibial and the tibial inlay single-bundle PCL reconstruction in terms of Tegner or Lysholm scores. Of the seven studies, five compared postoperative Lysholm scores in 71 knees that underwent transtibial and 69 that underwent tibial inlay single-bundle PCL reconstructions. Of these, one favored the transtibial approach and four concluded no difference on this endpoint; however, the observed differences in all cases were quite small (< 7 of 100 points on the Lysholm scale), likely small enough not to be clinically important (no minimum clinically important difference [MCID] has been calculated for this scale in this patient population; however, another study on autologous chondrocyte implantation [5] suggested that the MCID is larger than the differences in the studies we identified here) (Table 4). Four studies compared postoperative Tegner scores in 63 knees that underwent transtibial and 58 that underwent tibial inlay techniques. Three of the four studies identified no differences between the approaches in terms of Tegner scores at followup, while one favored the tibial inlay approach by a very small margin (0.5 of 11 points) (Table 4); in aggregate, the observed differences here, likewise were small enough to probably be below the MCID for that outcomes tool [5].

Residual Posterior Laxity

Similarly, this systematic review identified no important differences between the approaches in terms of residual laxity. All seven included studies compared posterior residual laxity on Telos radiographs in 149 knees that underwent transtibial and 148 that underwent tibial inlay techniques. Residual posterior laxity did not differ in these two groups (Table 5). Analysis of the five studies that presented data regarding the proportion of knees with Grade 2 or greater laxity on a four-grade assessment of posterior drawer testing showed similar findings for the two groups (28/107 versus 26/97) (Table 5).

Discussion

Two of the most-commonly used approaches of single-bundle PCL reconstruction are the transtibial and the tibial

Table 3. Risk of bias summary: review of authors' judgments regarding each risk of bias item for each included study

Study	Representativeness of patients treated with PCL reconstruction	Selection of control	Ascertainment of exposure to safe records (operative records)	Knee scores and stability not present at start of study	Comparability of cohorts	Control for any additional factor	Assessment of outcome	Sufficient followup	Adequacy of followup
Kim et al. [9] (2009)	–	–	–	–	+	+	+	?	+
Lee et al. [13] (2013)	–	–	–	–	+	+	+	?	+
MacGillivray et al. [15] (2006)	–	–	–	–	+	+	+	–	+
Seon & Song [20] (2006)	–	–	–	–	+	+	+	+	+
Seon et al. [21] (2013)	–	–	–	–	+	+	+	–	+
Song et al. [22] (2014)	–	–	–	–	–	+	+	–	+
Suh et al. [23] (2006)	–	–	–	–	–	+	+	+	+

– = low risk of bias; + = high risk of bias; ? = unclear risk of bias.

inlay approaches. However, there is no consensus regarding which is superior between these two techniques in terms of clinical outcome. Therefore, we believed it worthwhile to systematically review studies comparing studies between transtibial and tibial inlay PCL reconstructions. In this systematic review, we found no important differences in knee scores or residual posterior knee laxity when comparing the tibial inlay technique with the transtibial technique. However, both groups had a substantial proportion of knees with Grade 2 or greater laxity on posterior drawer tests after single-bundle PCL reconstruction (28/107 for transtibial technique and 26/97 for tibial inlay technique).

This study had several limitations. Although we performed comprehensive and sensitive searches through electronic databases to gather all available published evidence, the available population was too small for us to perform a formal (statistical) assessment of publication bias with a funnel plot. Tests for funnel-plot asymmetry typically are conducted when at least 10 studies are included, since at least that many studies are needed to differentiate an asymmetry identified by chance. In addition, study quality was an issue here; all of the studies included in this systematic review were Level III retrospective comparison studies, and the number of included studies was relatively small, resulting in some inherent heterogeneity owing to uncontrolled bias. For this reason, we did not pool (meta-analyze) our data. In addition, heterogeneity among studies may have been attributable to differences in other factors that could affect clinical outcome after PCL reconstruction, including the use of a wide variety of autografts and allografts as graft sources, and variability in the use of fixation devices, which have been associated with differences in residual laxity in other studies [4, 6]. Finally, not every included study rated every patient based on Tegner and Lysholm scores or the degree of posterior translation by stress radiographs and posterior drawer tests; the missing data may have affected the direction or robustness of our findings.

There were few differences observed between the surgical approaches in terms of knee scores, and those that were observed seemed small, and likely were clinically unimportant [5].

Regardless of graft choice or surgical technique, some residual posterior laxity remained in comparable proportions of patients who underwent PCL reconstruction [11, 12]. However, the functional results of PCL reconstruction are not always proportional to posterior laxity and often are better than when compared with objective findings of residual laxity [15]. Residual posterior laxity after PCL reconstruction may affect only high-demand activities, such as participation in sports, not routine daily activities [25]. Lysholm scores, which are more related to

Table 4. Knee scale score of the included study

Study	Transtibial		Tibial inlay		p Value
	Mean	SD	Mean	SD	
Lysholm score					
Kim et al. [9] (2009)	86.8	7.53	79.7	11.67	0.137
MacGillivray et al. [15] (2006)	81	12.2	76	14.5	0.540
Seon & Song [20] (2006)	91.3	6.5	92.8	5	0.259
Song et al. [22] (2014)	89.9	9.7	92.1	10.4	0.467
Suh et al. [23] (2006)	86.8	8.7	88.2	5.3	N/S
Tegner score					
MacGillivray et al. [15] (2006)	6	1.25	6	1.5	0.960
Seon & Song [20] (2006)	5.6	0.5	6.1	0.75	0.264
Song et al. [22] (2014)	5.9	0.75	6	1.25	0.796
Suh et al. [23] (2006)	5.83	0.94	5.84	0.69	N/S

N/S = not stated.

Table 5. Posterior residual laxity of the included study

Study	Transtibial		Tibial inlay		p Value
	Mean	SD	Mean	SD	
Telos radiographs					
Kim et al. [9] (2009)	5.6	2	4.7	1.62	0.374
Lee et al. [13] (2013)	2.3	1.4	2.3	1.5	N/S
MacGillivray et al. [15] (2006)	5.9	2.13	5.5	2.3	0.970
Seon & Song [20] (2006)	3.7	2.1	3.3	1.6	0.607
Seon et al. [21] (2013)	4.1	2	5.2	2	N/S
Song et al. [22] (2014)	4.1	2	4.2	1.75	0.825
Suh et al. [23] (2006)	4	2.3	2.9	0.9	0.101
Posterior drawer tests	Proportion of knees with Grade $\geq$ 2 (%)				
MacGillivray et al. [15] (2006)	10/13 (77)		4/7 (57)		0.480
Seon & Song [20] (2006)	2/21 (10)		4/22 (18)		0.732
Seon et al. [21] (2013)	4/44 (9)		7/39 (18)		N/S
Song et al. [22] (2014)	7/17 (41)		6/10 (60)		0.506
Suh et al. [23] (2006)	5/12 (42)		5/19 (26)		0.236
Total	28/107 (26)		26/97 (27)		

N/S = not stated.

activities of daily living than to sports, are higher than scores on other scales [16, 28] such as the Tegner scale, which is more related to sports activities [24]. Tegner scores better reflect high-demand activities and allow for a more-reasonable characterization of patient activity levels than Lysholm scores [14].

Although biomechanical studies favored the inlay technique over the transtibial technique [3, 18], clinical results we found with respect to residual posterior laxity suggested that the differences observed in the laboratory seem not to translate to differences in measurable levels of persistent instability between the approaches. A cadaveric study showed that the mean laxity measurements after PCL reconstruction were lower with the inlay than with the transtibial technique [3]. A similar cadaveric study found that the inlay technique required lower graft pretension to restore normal laxity than the transtibial technique [18]. However, inferring from these findings that the inlay technique is biomechanically superior is not necessarily accurate because aperture fixation of grafts in transtibial single-bundle PCL reconstruction can mirror the biomechanics achieved with inlay techniques [6]. Despite the biomechanical advantages of the inlay technique, our systematic review showed that the inlay technique may not result in improved knee stability. The magnitude of posterior laxity and proportion of knees with Grade 2 or

greater laxity on postoperative posterior drawer tests were similar using the two approaches. The discrepancy between the results of this systematic review and cadaveric studies may be attributable in part to the excessive loads (150–200 N) applied during cyclic testing in cadavers, loads higher than those applied during in vivo physiologic loading. Therefore, the biomechanical advantages of the inlay technique may be present only under these cyclic test conditions. This was supported by the results of a biomechanical study, in that application of a posterior load of 100 N during 1000 cycles did not result in graft rupture at the killer turn when using the transtibial technique, with no difference in posterior tibial translation between the transtibial and inlay techniques [8]. In addition, an in vivo mid-term followup study of 40 knees that underwent transtibial single-bundle PCL reconstruction found no evidence of graft loosening or tearing owing to the killer turn effect on postoperative MRI and second-look arthroscopy [1]. These findings also showed that the abrasion, attenuation, and graft failure of the transtibial technique reported in previous biomechanical studies [6, 8] seldom occur clinically in vivo.

Although Tegner scores were higher using the tibial inlay than the transtibial technique for single-bundle PCL reconstruction, the magnitude of the observed difference was so small that it seems unlikely to be clinically important to patients. Likewise, Lysholm scores seemed comparable for the two approaches. In addition, there were no apparent between-group differences in posterior tibial translation and the proportion of knees with Grade 2 or greater laxity on posterior drawer tests, even though both groups had a substantial proportion of knees with Grade 2 or greater laxity on posterior drawer tests after single-bundle PCL reconstruction (26% by the transtibial technique and 27% by the tibial inlay technique). Based on the best evidence now available, it appears that surgeons may select between these approaches based on clinical experience and the specific elements of each patient's presentation, as there do not appear to be important or obvious differences between the approaches with respect to knee scores or joint stability. Future randomized trials are needed to answer this question more definitively.

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