Superior Postoperative Stability and Functional Outcomes With Anteromedial Versus Transtibial Technique of Single-Bundle Autologous Hamstring Anterior Cruciate Ligament Reconstruction: A Meta-analysis of Prospective Randomized Controlled Trials


Purpose: The aim of this meta-analysis was to compare the postoperative stability and functional outcomes of anteromedial (AM)– and transtibial (TT)–based single-bundle hamstring anterior cruciate ligament (ACL) reconstruction techniques.

Methods: A meta-analysis comparing the outcomes of single-bundle hamstring ACL reconstruction using the AM and TT techniques was performed. Prospective randomized controlled trials identified from searches of PubMed, Cochrane, and Embase were included in this review. The outcome measures analyzed included postoperative Lachman test and pivot-shift test results, side-to-side difference, International Knee Documentation Committee (IKDC) score, Lysholm score, and Tegner activity score.

Results: A total of 7 randomized controlled trials (654 patients) were included in this review. The AM technique, compared with the TT technique, resulted in superior postoperative stability based on the negative Lachman test rate (risk ratio [RR], 1.12; 95% confidence interval [CI], 1.01 to 1.24; \(P = .03\); 95% prediction interval [PI], 0.32 to 3.46), negative pivot-shift test rate (RR, 1.16; 95% CI, 1.06 to 1.28; \(P = .002\); 95% PI, 0.40 to 2.88), and side-to-side difference (weighted mean difference [WMD], \(-0.32 \text{ mm}; 95\% \text{ CI, } -0.48 \text{ to } -0.16; P < .0001\); 95% PI, \(-0.55 \text{ to } -0.09\)). Likewise, the AM technique contributed to superior postoperative functional outcomes based on the proportion of IKDC grade A findings (RR, 1.16; 95% CI, 1.02 to 1.32; \(P = .03\); 95% PI, 0.40 to 2.83) and the Lysholm score (WMD, 0.82; 95% CI, 0.23 to 1.41; \(P = .007\); 95% PI, \(-0.22 \text{ to } 1.86\)). However, the AM and TT techniques had comparable subjective IKDC scores (WMD, 0.98; 95% CI, \(-0.91 \text{ to } 2.88\); \(P = .31\); 95% PI, \(-3.18 \text{ to } 5.14\)) and Tegner activity scores (WMD, 0.32; 95% CI, \(-0.23 \text{ to } 0.86\); \(P = .25\); 95% PI, \(-3.84 \text{ to } 4.48\)).

Conclusions: The AM method of single-bundle hamstring ACL reconstruction results in superior postoperative stability and functional outcomes compared with the TT method.

Level of Evidence: Level I, systematic review of Level I studies.

The anterior cruciate ligament (ACL) is the primary anterior stabilizer of the knee joint. Favorable ACL reconstruction outcomes largely depend on both anatomic and biomechanical factors. With anatomic graft positioning allowing for superior rotational stability, there has been a trend toward such anatomic ACL reconstructions. In view of the combined rotational and anteroposterior stability, failure rates of anatomically positioned ACLs have also been reported to be significantly lower than those of non–anatomically positioned grafts.1-6

When surgeons are performing anatomic ACL reconstructions, the landmarks for the femoral and tibial tunnels are their respective native footprints.
Two main techniques have been described for graft placement: the transtibial (TT) technique and the anteromedial (AM) technique. The TT technique, however, has been described to be associated with a higher risk of vertical graft placement, which can predispose patients to rotational instability.\(^7\) This finding has been attributed to the increased technical challenge of achieving a lower femoral tunnel.\(^8,9\) The newer AM technique, also known as the “far medial” or “transportal” drilling technique, has similarly been described for anatomic graft placement. Although it requires the creation of a separate AM portal, this technique allows surgeons greater freedom in positioning the femoral tunnel. This contributes to increased ease in establishing anatomic positioning of the ACL graft.\(^10-13\)

Existing systematic reviews and meta-analyses in this area have been largely based on retrospective cohorts or small sample sizes,\(^14,15\) making it challenging to draw meaningful conclusions to guide clinical practice. The aim of this meta-analysis was to compare the postoperative stability and functional outcomes of AM- and TT-based single-bundle hamstring ACL reconstruction techniques. We hypothesized that the AM method of single-bundle anatomic ACL reconstruction would result in superior postoperative stability and functional outcomes compared with the TT method owing to more anatomic placement of the ACL graft associated with the AM technique.

**Methods**

**Search Strategy**

The PubMed, Embase, and Cochrane databases were searched from the inception of each database until October 15, 2019, without restriction on publication date or language. Our search term was as follows: (“Randomized Controlled Trials” OR trial OR placebo OR controlled OR Random) AND (TP OR transportal OR Transtibial OR “TT technique” OR AMP OR Anteromedial) AND (“Reconstructive Surgical Procedures” OR Arthroscopy OR Arthroscopic OR Reconstructions OR “ligament integrity”) AND (“intra-articular knee ligament” OR “Anterior Cruciate Ligament” OR ACL).
Eligibility Criteria

After removal of duplicates, 2 investigators (V.M. and A.A.S.) independently reviewed the abstracts and articles to determine their suitability for our study. Any discrepancy in determining an article’s eligibility for inclusion was resolved by consensus and discussion with the senior author (A.H.C.T.).

In evaluating studies to be considered for this study, we defined the selection criteria a priori based on the study population, intervention, outcomes measured, and study design. The inclusion criteria were prospective randomized controlled trials (RCTs) directly comparing AM and TT techniques of single-bundle autologous hamstring ACL reconstruction and reporting stability and/or functional outcomes. The exclusion criteria were animal or cadaveric studies; studies not directly comparing AM and TT techniques; studies not performing single-bundle ACL reconstruction; studies using allograft, bone–patellar tendon–bone, or Achilles tendon; studies with non-RCT study designs; and studies that did not report any stability and/or functional outcomes.

Data Collection

Data were extracted from the included studies by the same 2 researchers independently, and any discrepancy was resolved by consensus subsequently. Basic study characteristics extracted from the included articles were first author, year of publication, study design, level of evidence, average age of patients, sample size, follow-up duration, graft tendon used, and fixation method.

The postoperative outcomes of stability and function extracted from the articles were as follows: proportion of negative Lachman test results, proportion of negative pivot-shift test results, side-to-side difference (SSD) using KT-1000 arthrometer (MEDmetric, San Diego, CA) measurements, International Knee Documentation Committee (IKDC) subjective score and objective score, Lysholm score, and Tegner activity score. When we had any questions about an article, we tried to reach the corresponding author of the article.

Working independently, the same 2 researchers assessed the risk of bias of the included studies using The Cochrane Collaboration’s risk-of-bias tool for RCTs. Seven domains of bias were assessed: random sequence generation and allocation of concealment (both under “selection bias”), performance bias, detection bias, attrition bias, reporting bias, and other bias. For each domain, the risk of bias was assessed as high, low, or unclear.

Statistical Analysis

RevMan (Review Manager, version 5.3 [2014]; The Cochrane Collaboration—The Nordic Cochrane Centre, Copenhagen, Denmark) was used for all statistical analyses in this study. Binary outcomes were analyzed by
determining the risk ratio (RR) and 95% confidence interval (CI) when comparing surgical techniques. For continuous variables, the weighted mean difference (WMD) and 95% CI were determined. Statistical heterogeneity of outcomes of comparison was determined using the $\chi^2$ test and $I^2$ statistic. The $I^2$ statistic describes the proportion of total variation in study estimates that is due to heterogeneity; it is a widely used measure of heterogeneity in meta-analyses. Random-effects models were used for analyses, assuming that the included studies represented a random sample from the larger population of such studies. The random-effects model takes into account interstudy heterogeneity and provides a more conservative evaluation of the significance of the association than an evaluation based on fixed effects. For each analysis, 95% prediction intervals (PIs) were also determined, as described by IntHout et al. In addition, the degree of agreement between the researchers for each domain of the risk-of-bias assessment was quantified with the $k$ statistic.

Results

Search Results

We identified 432 studies via our search strategy; 224 duplicates were subsequently removed. After all titles and abstracts were reviewed, 197 studies were excluded based on our selection criteria. Thereafter, 4 studies were excluded after their full texts were reviewed because 3 did not have a prospective RCT study design and 1 did not directly compare AM and TT techniques of ACL reconstruction. Seven articles were eventually selected for meta-analysis. A summary of the selection process can be found in Figure 1.

Characteristics of Included Studies

All 7 articles were prospective RCTs directly comparing single-bundle hamstring ACL reconstruction using AM and TT techniques. The follow-up duration ranged from 6 to 52 months among the included studies. There were a total of 331 and 323 patients in the AM and TT groups, respectively, across the different studies. The basic characteristics of all the included studies are displayed in Table 1. Relevant outcomes of the AM and TT techniques that were extracted from each article are presented in Table 2.

The quality of included studies was assessed. All the included trials were at a low or unclear risk of bias when assessed using The Cochrane Collaboration’s risk-of-bias tool for RCTs (Fig 2). The agreement between the 2 researchers for each domain ranged from moderate to excellent (weighted $k$, 0.59 to 1.00).

Clinical Outcomes of Knee Stability

Postoperative Lachman test findings were reported in 4 studies with a total of 368 patients. The results
suggested that the AM group had a significantly higher rate of negative postoperative Lachman test results than the TT group (RR, 1.12; 95% CI, 1.01 to 1.24; \( P = .03 \); 95% PI, 0.32 to 3.46) (Fig 3A).

Six studies with a total of 591 patients reported postoperative pivot-shift test findings. The overall pooled results suggested that the AM group had a significantly higher rate of negative pivot-shift test results than the TT group (RR, 1.16; 95% CI, 1.06 to 1.28; \( P = .002 \); 95% PI, 0.40 to 2.88) (Fig 3B).

Five studies with a total of 510 patients reported postoperative SSD data. The overall pooled results suggested that the TT group had significantly higher SSDs than the AM group (WMD, \(-0.32\) mm; 95% CI, \(-0.48\) to \(-0.16\); \( P < .0001 \); 95% PI, \(-0.55\) to \(-0.09\)) (Fig 3C). There was no significant heterogeneity between the trials when results were pooled for the postoperative Lachman test (\( P = .81, I^2 = 0\%\)), pivot-shift test (\( P = .35, I^2 = 11\%\)), or SSD (\( P = .50, I^2 = 0\%\)).

**Clinical Outcomes of Functional Recovery**

Four studies with a total of 317 patients reported IKDC grades. The pooled results revealed a higher proportion of IKDC grade A (normal) findings in the AM group (RR, 1.16; 95% CI, 1.02 to 1.32; \( P = .03 \); 95% PI, 0.40 to 2.83) (Fig 4A).

Three studies with a total of 277 patients reported postoperative IKDC scores. However, the postoperative IKDC scores were not significantly different between the AM and TT groups based on the overall pooled results (WMD, 0.98; 95% CI, \(-0.91\) to 2.88; \( P = .31 \); 95% PI, \(-3.18\) to 5.14) (Fig 4B). Five studies with a total of 510 patients reported postoperative Lysholm scores. The pooled results suggested that postoperatively, the AM group had higher Lysholm scores than the TT group (WMD, 0.82; 95% CI, 0.23 to 1.41; \( P = .007 \); 95% PI, \(-0.22\) to 1.86) (Fig 4C).

Two studies with a total of 127 patients reported postoperative Tegner activity scores. However, the postoperative Tegner activity scores were not significantly different between the AM and TT groups (WMD, 0.32; 95% CI, \(-0.23\) to 0.86; \( P = .25 \); 95% PI, \(-3.84\) to 4.48), as identified from the overall pooled results (Fig 4D). Finally, there was no significant heterogeneity between the trials when the results were pooled for IKDC grades (\( P = .60, I^2 = 0\%\)), IKDC scores (\( P = .58, I^2 = 0\%\)), Lysholm scores (\( P = .38, I^2 = 5\%\)), or Tegner activity scores (\( P = .27, I^2 = 19\%\)).
The key finding of our meta-analysis was that single-bundle hamstring ACL reconstruction using the AM technique results in both superior postoperative stability and superior postoperative functional outcomes. Optimal femoral and tibial tunnel positioning is important to prevent anteroposterior and rotational instability and, hence, reduce the risk of graft stretching, loosening, and failure. The most common techniques for graft placement in ACL reconstruction are the TT and AM techniques.

Several factors may account for the increased biomechanical stability and consequent functional outcomes observed with the AM technique. In a biomechanical study, Bedi et al.27 found that the center of the native femoral ACL footprint could not be captured by use of a TT technique because the tibial tunnel was anatomically restricted. In contrast, the AM technique allowed guidewire positioning at the center of the femoral footprint in all cases, resulting in significantly greater time-zero control of tibial translation with Lachman and pivot-shift testing. Previous studies have also shown the technical impossibility of restoring both the anatomic tibial and femoral origins of the ACL using a TT technique despite any modifications, with tunnels being located in an anterior and vertical position relative to the native footprint.13,28

Moreover, studies have revealed that the AM technique better locates the femoral tunnel within the anatomic footprint.15,29,30 This occurs partly because in the AM technique, femoral tunnel positioning is not restrained by the tibial tunnel. In contrast, in the TT
technique, with the knee flexed at a right angle, it is unlikely for the endpoint of the femoral tunnel, via the tibial tunnel, to entirely correspond with the anatomic endpoint. In the literature, it has been established that the positioning of the femoral tunnel contributes to the ACL graft having similar biomechanical properties to the natural ACL in terms of both rotational stability and anteroposterior stability. Numerous studies have also concluded that minor differences in femoral tunnel positioning will significantly affect graft isometry and consequent knee stability postoperatively.

However, the AM technique has certain limitations. Surgeons have to be careful not to drill cortically short femoral tunnels or compromise the integrity of the posterior wall of the lateral femoral intercondylar notch. Moreover, in a large registry-based study, Rahr-Wagner et al. revealed that after ACL reconstruction, higher revision rates were found when using the AM technique than when using the TT technique, potentially a result of the presence of a learning curve and surgeons being less familiar with the AM technique. Additionally, prior studies have shown that a greater force is carried by

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**Fig 4.** Meta-analysis of postoperative clinical outcomes of functional recovery of knee. (A) International Knee Documentation Committee (IKDC) grade A (normal) findings. (B) IKDC subjective scores. (C) Lysholm scores. (D) Tegner activity scores.
an anatomic ACL reconstruction than by a nonanatomic graft placement. Xu et al.\textsuperscript{32} showed significantly greater force in AM bundles that were reconstructed anatomically than in grafts placed non-anatomically. This greater load, carried by an anatomically reconstructed graft, transfers more load to other structures in the knee, making it more susceptible to graft failure.

Previous systematic reviews and meta-analyses on this topic have been performed, with varying conclusions. In 2013, a meta-analysis by Riboh et al.\textsuperscript{15} revealed no significant clinical differences between the AM and TT techniques. In 2015, another meta-analysis, Chen et al.\textsuperscript{14} concluded that the AM technique resulted in superior knee stability but had similar postoperative functional outcomes when compared with the TT technique. Nevertheless, our results were concordant with the findings of a more recent meta-analysis by Chen et al.\textsuperscript{43} in 2017, which also concluded that in the context of single-bundle hamstring ACL reconstruction, better postoperative knee stability and functional outcomes could be achieved using the AM technique instead of the TT technique. However, the meta-analysis by Chen et al.\textsuperscript{43} included only 5 studies, with limited study sample sizes and outcome data. Only 1 of the 5 studies included by Chen et al. had a follow-up duration greater than 24 months. In contrast, 3 of the 7 studies included in our meta-analysis had follow-up durations greater than 24 months, suggesting that superior stability and functional outcomes of the AM technique exist at least up to 24 months after surgery and not just in the early postoperative period. Furthermore, Chen et al.\textsuperscript{43} did not consider certain key functional outcome scores, such as the Tegner activity score, owing to limited data from only 5 trials. In contrast, our study has provided a more comprehensive and updated analysis of the topic, taking into account 7 prospective RCTs and additional validated functional outcome instruments.

**Limitations**

Nevertheless, there were still several limitations to our meta-analysis: (1) The lengths of follow-up of the 7 studies varied, potentially contributing to some heterogeneity in the outcomes when comparing the AM and TT techniques. (2) Some of the subjective outcome testing, such as the Lachman test and anterior drawer test, may have significant variability in reporting between clinical testers administering the examination across the studies, further contributing to heterogeneity in the outcomes when comparing the 2 techniques. (3) All included studies experienced performance bias as a result of not being able to blind the surgeons within these studies. (4) Only published data were included in this review, resulting in the potential for reporting bias because negative results were less likely to be reported.

**Conclusions**

The AM method of single-bundle hamstring ACL reconstruction results in superior postoperative stability and functional outcomes compared with the TT method.

**References**


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