Optimal Tibial Tunnel Positioning for Posterior Cruciate Ligament Reconstruction: A Systematic Review of Anatomic Landmarks and Biomechanical Evidence

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Abstract: *Purpose:* Arthroscopic Posterior cruciate ligament (PCL) reconstruction is widely used for patients with PCL injury. However, results of PCL reconstruction always tend to be less satisfied than anterior cruciate ligament (ACL) reconstruction when it comes to laxity and stability control. It is crucial for successful PCL reconstruction with arthroscopic tibial tunnel techniques to place tibial tunnel in an accurate position. Current surgical recommendations for tibial tunnel placement only emphasize that tibial tunnel should be placed in the anatomical tibial PCL insertion site, but no specific position suggest is mentioned. The purpose of this review was to identify the optimal placement of the tibial tunnel in PCL reconstruction. *Methods*: A systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. In this systematic review of literature, articles about tibial tunnel for PCL reconstruction was searched via PubMed and Cochrane Library databases from January 2000 to December 2022. All clinical trials, biomechanical studies, anatomical studies and radiological studies were extracted and analyzed. Clinical studies only comparing different tibial tunnel placement techniques were included, and other studies mentioning specific tibial tunnel placement were included. *Results*: There were 2 comparative clinical trials for the entry of tibial tunnel in PCL reconstruction and 0 for the exit. 16 anatomical studies have described the anatomical PCL tibial insertion sites, and 10 biomechanical studies have compared different tibial tunnel placements. Anterolateral entry of the tibial tunnel shows a better outcome in terms of the objective and biomechanical results, while there is no significant difference in clinical results as judged by Lysholm and International Knee Documentation Committee (IKDC) scores. Several anatomical and radiological landmarks were used to analyze the tibial insertion sites of the native PCL. Although some of biomechanical studies have compared the tibial tunnel exit between anterolateral bundle (ALB) center and posteromedial bundle (PMB) center, there was no consensus on the exit position of the tibial tunnel. *Conclusions*: With a detailed cartography of the PCL fovea and reliable anatomical landmarks, more randomized controlled trials are needed for the entry placement of the tibial tunnel to confirm the preference of anterolateral tibial tunnel, while an established map of the PCL fovea and biomechanical studies comparing different pin centers are required for the exit placement of the tibial tunnel for PCL reconstruction. Both the entry and exit placement have the absence of high-quality studies with long-term follow-up.

Keywords: Posterior Cruciate Ligament; Arthroscopic Reconstruction; Tibial Tunnel Placement; Systematic Review; Arthroscopic Techniques

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1 Introduction

With the development of PCL anatomy and biomechanics, many surgical techniques for PCL reconstruction have improved significantly in recent years. Both arthroscopic single-bundle and double-bundle PCL reconstruction with transtibial or inlay techniques have been widely used to restore native knee functions and to control posterior laxity [1]. However, its results still show less satisfying than ACL reconstruction.

It has been certainly confirmed that inlay technique had the advantage of direct visualization of anatomical PCL insertion site and could avoid kill turn of graft. Different from inlay technique, the tibial tunnel technique for arthroscopic surgery could reduce postoperative additional laxity and is able to be performed on a patient in the flexed-knee position [2].

It is vital for successful PCL reconstruction with arthroscopic tibial tunnel techniques to place tibial tunnel in an accurate position. However, although many anatomical studies were conducted to describe accurate position of the tibial PCL insertion site, there was no specific suggestion for tibial tunnel placement. Many surgical techniques showed inconsistent results [3, 4]. For single-bundle reconstruction, there is consensus that the femoral tunnel should be drilled at the anterolateral or at the central of the footprint to obtain a better outcome of laxity control and graft constraint. Concerning about tibial tunnel, it could be divided into the entry and the exit, several studies suggested that the entry of tibial tunnel should be placed at the anterolateral to have a better posterior stability [5-7], but there was a controversy on the exit of the tunnel.

The objective of this review is to identify the optimal position of the tibial tunnel in PCL reconstruction based on clinical and laboratory studies, in order to yield better results in reconstruction and knee laxity as less as possible.

2 Materials and Methods

A systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8].

Literature search

A systematic search for relevant literature was performed on the PubMed and Cochrane Library databases using the key words “posterior,” “cruciate,” “ligament,” “tibia,” and “adult”. The publication date was from January 2000 to December 2022. The search was limited to studies in adult patients with PCL injury requiring a graft PCL reconstruction. All clinical trials comparing 2 or more different surgical techniques were analyzed and only studies which compared 2 or more different tibial tunnel placements for PCL reconstruction were included. Additional search was conducted to analyze anatomical studies descripting landmarks used for tunnel placement. Biomechanical studies mentioning the tunnel placement and its biomechanical outcomes were also included. The search was restricted to English, Chinese, French, Spanish and German language publications.

The study selection was conducted by 2 authors independently. Abstracts of all publications were reviewed and studies that did not compare different techniques were excluded. In the event of any disagreement between the reviewers, the senior investigator made the final decision. At the end of the process, further studies that might have been missed were manually searched by going through the reference lists of the included studies and relevant systematic reviews. The quality of the selected studies was also evaluated.

Level of evidence

The Oxford Levels of Evidence set by the Oxford Centre for Evidence-Based Medicine were used to categorize the levels of evidence [9].

Statistical analysis

Counts of related articles were tabulated. Reasons for exclusion were documented. Due to insufficient clinical trials, it is impossible to conduct a meta-analysis of surgical outcomes. Instead, a narrative description and analysis of the clinical results were performed.

3 Results

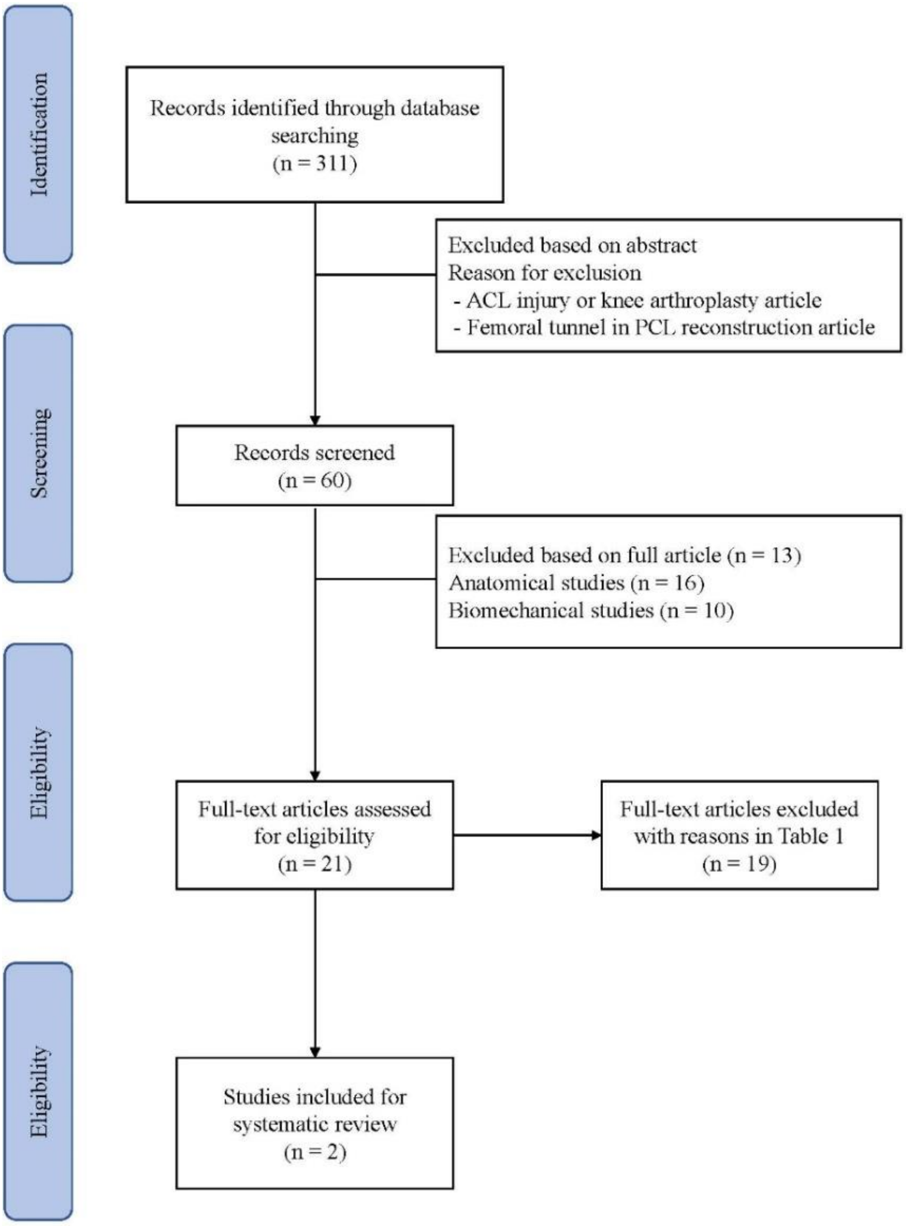

Figure 1 Search strategy and results for systematic review of the literature

Table 1 Clinical trial that compared two or more surgical techniques for PCL reconstruction and reasons for exclusion from final analysis

	Study design	**Technique compared**	**Number of patients**	**Minimum follow-up**	**Tibial tunnel placement**	**Tunnel diameter**	**Reasons for exclusion**
Kim et al. [10]	Retrospective case series	1 versus 2 incision PCL reconstruction	55	2 years	1.5 cm below the articular margin	No description	No variation of tibial tunnel position
Freeman et al. [11]	Retrospective case series	PCL reconstruction with or without posterolateral corner	17	14 months	No description	No description	No variation of tibial tunnel position
Chen et al. [3]	Retrospective case series	Quadriceps tendon autograft versus quadruple hamstring tendon grafts	49	2 years	Distal and lateral of the PCL footprint	8-10 mm	No variation of tibial tunnel position

	Study design	Technique compared	Number of patients	Minimum follow-up	Tibial tunnel placement	Tunnel diameter	Reasons for exclusion
Ohkoshi et al. [12]	Nonrandomized control study	2 incision versus endoscopic PCL reconstruction	51	10 months	Entry: 2 cm distal and lateral to the tibial tubercle Exit: proximal and medial directions of the tibial posterior surface	No description	No variation of tibial tunnel position
Wang et al. [13]	Prospective clinical study	Autogenous versus allogenous graft PCL reconstruction	55	2 years	1.0 cm below the articular surface of the medial tibia plateau slightly lateral to the PCL insertion	No description	No variation of tibial tunnel position
Wang et al. [14]	Prospective clinical study	Single versus double-bundle PCL reconstruction	35	2 years	Entry: 4 cm below the medial joint line and 1-2 cm posterior to the anterior tibia surface Exit: 1.0 cm below the articular surface of the medial tibia plateau slightly lateral to the PCL insertion	No description	No variation of tibial tunnel position
Ahn et al. [4]	Retrospective case-control study	Double-loop hamstring tendon autograft versus Achilles tendon allograft	36	2 years	No description	No description	No variation of tibial tunnel position
MacGillivray et al. [15]	Retrospective case series	Tibial inlay versus transtibial tunnel techniques	20	2 years	No description	11 mm	No variation of tibial tunnel position
Seon et al. [16]	Retrospective case series	Tibial inlay versus transtibial tunnel techniques	43	2 years	No description	8-10 mm	No variation of tibial tunnel position
Jung et al. [17]	Retrospective case series	Fibular head tunnel versus tibial tunnel for posterolateral corner reconstruction	39	2 years	No description	No description	No variation of tibial tunnel position
Kim et al. [18]	Retrospective case series	Tibial tunnel single versus inlay single versus inlay double	29	2 years	No description	No description	No variation of tibial tunnel position
Li et al. [19]	Retrospective case series	4 strand hamstring graft versus LARS artificial ligament	36	2 years	Distal and lateral of the PCL footprint, 8-10 mm from articular joint	No description	No variation of tibial tunnel position
Lee et al. [20]	Retrospective case series	Tibial tunnel single versus inlay single versus inlay double	89	2 years	1.5 cm below the articular surface and distal to the tibial insertion of the PCL	6-8 mm	No variation of tibial tunnel position
Lin et al. [21]	Retrospective case series	autologous patellar tendon versus hamstring tendon grafts	59	3 years	Entry: anteromedial aspect of proximal tibia 1-2 cm distal to tibial tubercle Exit: 13-14 mm distal to medial plateau surface and inferolateral to PCL insertion	No description	No variation of tibial tunnel position
Wang et al. [22]	Retrospective case-control study	Non- versus remnant preservation for PCL reconstruction	45	18 months	1.5 cm below the articular surface and 2 mm lateral to the tibial insertion of the PCL	No description	No variation of tibial tunnel position
Sabat et al.	Retrospective	Open reduction and screw	47	1 year	No description	No de-	No variation

	Study design	**Technique compared**	**Number of patients**	**Minimum follow-up**	**Tibial tunnel placement**	**Tunnel diameter**	**Reasons for exclusion**
[23]	case-control study	fixation versus arthroscopic suture fixation for PCL avulsion fractures				scription	of tibial tunnel position
Wu et al. [24]	Retrospective case-control study	Platelet rich plasma assisted reconstruction of 3-strand peroneal longus tendons versus 4-strand hamstring tendon along	58	3 months	Entry: medial to tibial tubercle Exit: 1.5 cm below the articular surface and lateral to the tibial insertion of the PCL	9-10 mm	No variation of tibial tunnel position
Zhou et al. [25]	Retrospective case series	Minimally invasive open reduction and internal fixation versus arthroscopic double-tunnel suture fixation	31	6 months	No description	No description	No variation of tibial tunnel position
Wu et al. [26]	Retrospective case series	Arthroscopic suture bridge versus double tunnel suture	62	13 months	3.5-4.5 cm distal to the joint line and 1.5-2.0 cm medial to the tibial tubercle.	No description	No variation of tibial tunnel position

The initial search yielded 311 publications. Figure 1 shows a flowchart depicting the process of selection of the studies. After exclusion based on abstracts, 60 studies remained, of which 12 were excluded after reviewing full articles, 16 were anatomical studies and 11 were biomechanical studies, leaving 21 studies which compared a least two different surgical techniques for PCL reconstruction eligible for review. Only two trials compared the entry placement of the tibial tunnel and none compared the exit placement of the tibial tunnel [6, 7]. Reasons for excluding 19 studies is shown in Table 1. 16 anatomical studies evaluating the tibial insertion site of the PCL and 11 biomechanical studies analyzing effects of different tibial tunnel placement were also identified.

The characteristics of two selected clinical trials comparing anteromedial and anterolateral tibial tunnel are shown in Table 2. The patients cohort consisted of 115 participants (92 men [80%] and 23 women [20%]) with a mean age of 30.3 (range: 16-60). The mean minimum follow-up was 52.4 months (range: 24-91 months) and the mean time between injury and surgery was 8.8 months (range: 2-26 months). Achilles allograft, tibial allograft (posterior), patellar autograft and hamstring autograft were used in two studies. The tensioning of the PCL reconstruction was performed at 90 °of knee flexion in one study, while at 70 °of knee flexion in another. The detailed surgical techniques used in each of the selected clinical studies are displayed in Table 3. All selected clinical studies reported objective and subjective outcomes at final follow-up, including IKDC, Lysholm, Posterior tibial translation (PTT), Range of motion losses and return to sports activity. Two studies reported clinically significant improvement at final follow-up compared with preoperative, but no significant difference shown between anterolateral and anteromedial groups in subjective outcomes. One study reported that anterolateral tibial tunnel group showed a significant reduce in PTT. Two studies revealed 0 failures and 3 complications (2.6%), including 2 cases of infection (1.7%) and 1 case of sensory change (0.9%). The detail results are presented in Table 4.

Table 2 Characteristics of the selected studies

	Level of evidence	**Number of patients**	**M: F (n)**	**Age means (Range)**	**Minimum follow-up (months)**	**Time between injury and surgery**	**Type of injury**
Kim et al [6].	III	A-M: 23 A-L: 37	A-M: 17: 6 A-L: 34: 3	A-M: 32.4 (21-45) A-L: 30.2 (21-48)	A-M: 58.6 (24-89) A-L: 56.9 (24-91)	A-M: 9.5 (2-26) months A-L: 8.4 (2-26) months	16 sports 30 traffic accident 14 fall
Wong et al [7].	III	A-M: 28 A-L: 27	A-M: 20: 8 A-L: 21: 6	A-M: 31 (16-60) A-L: 28 (16-54)	A-M: 48.4 (36-82) A-L: 45.0 (37-85)	n. a	39 motorcycle 12 motor vehicles 4 sports

Table 3 Surgical and rehabilitation protocol

	Graft type	Bundle	Surgical technique	Femoral tunnel	Tibial tunnel	Tension protocol	Tibial tunnel placement		Tunnel diameter	Rehabilitation protocol
							A-M tunnel	A-L tunnel		
Kim et al. [6]	15 allograft, Achilles tendon bone 17 allograft, tibialis posterior tendon 28 autograft, patellar tendon bone	SB	Transtibial	1	1	90 °of flexion	Entry: 2.5 cm posterior to the anterior tibia spine and 4.0 cm below the medial joint line Exit: 1.0 cm below the articular surface of the medial tibia plateau	Entry: 2.5 cm posterior to the anterior tibia spine and 4.0 cm below the lateral joint line Exit-1.0 cm below the articular surface of the medial tibia plateau	n. a	4-6 weeks protection Full flexion at 6th week Exercise on day 1
Wong et al. [7]	Hamstring autograft	SB	Transtibial	1	1	70 °of flexion	45 °to the longitudinal axis of the tibia and 1.5 cm below the articular margin lateral to the midline	through the anterolateral tibial cortex, 2 cm posterolateral to the tibial tuberosity	n. a	n. a

Table 4 Clinical and functional outcomes, complications, and return to sports activity

	PTT (mm)		Range of motion		IKDC		Lysholm		Radiographic evaluation	Complications	Failures	Return to sport
	A-M	A-L	A-M	A-L	A-M	A-L	A-M	A-L				
Kim et al. [6]	3.98±1.27	2.87±1.25	4.7 °±2.38 ° losses	4.0 °±1.73 ° losses	A (30.4%) B (60.9%) C (8.7%)	A (24.3%) B (73.0%) C (2.7%)	88±10	91±8	n. a	2 infection 1 sensory change	0	n. a
Wong et al. [7]	5.1±10.5	6.1±8.6	3.8 °±3.0 ° losses	3.2 °±3.3 ° losses	73.3±11.2	74.1±11.7	88.6±7.10	88.4±6.45	A-M: 6.4±12.9 femoral and 14.2±19.2 tibial tunnel enlargement A-L: 8.8±17.8 femoral and 9.6±12.9 tibial tunnel enlargement	n. a	0	n. a

Sixteen anatomical studies utilized various methods and different landmarks to describe the tibial insertion site of the PCL. Eight studies only described the PCL center location [27-34], while ten studies reported both ALB and PMB center respectively [35-40] and two of these described all [41, 42]. Landmarks such as anterior margin of the tibia, the medial border of the tibial plateau and the tibial plane, were used by Takahashi et al. [36] and Tajima et al. [37] to described the insertion site of both ALB and PMB based on 33 tibiae and 21 tibiae respectively. Using the same anatomical landmarks, Osti et al. [39] documented the PCL tibial insertion of both bundles on 15 tibiae. Two studies conducted by Greiner et al. [30] and Lee et al. [31] used the same anatomical reference and computed tomography to determine the insertion. In recent studies conducted by Johannsen et al. [42] and Feng et al. [34], an additional anatomical landmark, the champagne glass drop-off, was utilized to determine the PCL insertion based on 20 tibiae respectively. The champagne glass drop-off was identified as the lowest point of the tibial plateau. Salim et al. [32] determined the insertion using the length ratio of the PCL facet on 20 tibiae, while Vielgut et al. [33] used the coordinate system to describe it based on 64 tibiae. The detailed results are shown in Table 5.

Table 5 Placement of the PCL tibial insertion according to anatomical studies

	Study Methodology	**Number of knees**	**PCL tibial insertion site**		
			PCL centre	**Anterolateral bundle centre**	**Posteromedial bundle centre**
Sheps et al. [27]	Cadaveric dissection	10	Distal to cartilage tidemark and posterior horns of menisci		
Edwards et al. [35]	Cadaveric dissection	39		From the posterior edge of the root of the posterior horn of the medial meniscus to within 2 mm of the posterior edge of the plateau; 37 mm from medial tibial edge	7 mm under the articular surface of the tibia 38 mm from the medial edge of the plateau
Liu et al. [41]	Cadaveric dissection	30	Posterior intercondylar fossa; from the posterior edge of the root of the posterior horn of the medial meniscus to the posterior bone ridge of upper tibia	5.9 mm from medial tibial plateau 11 mm from upper edge of medial meniscus	11 mm from medial tibial plateau 16.1 mm from upper edge of medial meniscus 6mm from the posterior bone ridge of upper tibia
Moorman et al. [28]	Radiographic analysis of cadaveric knees	14	7 mm anterior to the tibial posterior cortex		
Takahashi et al. [36]	Cadaveric dissection	33		The same level as the articular surface of the tibia 48.2 mm from the medial edge of the plateau 51% of the width of the plateau	4.6 mm distal to the articular surface of the tibia 47.4 mm from the medial edge of the plateau 50% of the width of the plateau.
Ramos et al. [29]	Cadaveric dissection	30	10.3 mm in front of the insertion of the posterior capsule 1.7 mm between the posterior margin of the PCL and the capsule		
Tajima et al. [37]	Cadaveric dissection	21		1.5 mm under the articular surface of the tibia 41.3 mm from the anterior margin of the plateau 34.3 mm from the medial margin of the plateau 47.1% of the width of the plateau	6 mm under the articular surface of the tibia 47.1 mm from the anterior margin of the plateau 31.8 mm from the medial margin of the plateau 43.8% of the width of the plateau
Greiner et al. [30]	Radiographic analysis of cadaveric knees	10	1.6 mm under the plane of the tibial plateau 46.1 mm from the anterior edge of the tibial plateau 36.6 from medial border of the tibial plateau 49% of the total width of the tibial plateau		
Lee et al. [31]	Radiographic analysis of cadaveric knees	10	Posterior 48% of the area of the posterior intercondylar fossa.		
Luo et al. [38]	Cadaveric dissection	22			
Osti et al. [39]	Descriptive laboratory study	15		3.25 mm under the tibial articular surface 39.3 mm lateral from the medial edge of the tibial plateau 40.52 mm posterior from the anterior edge of the tibial plateau 49.27% lateral from the medial border of the tibial plateau 85.15% posterior from the anterior edge of the tibial plateau	6.91 mm under the tibial articular surface 41.15 mm lateral from the medial edge of the tibial plateau 44.06 mm posterior from the anterior edge of the tibial plateau 51.57% lateral from the medial border of the tibial plateau 92.54% posterior from the anterior edge of the tibial

	Study Methodology	Number of knees	PCL tibial insertion site		
			PCL centre	Anterolateral bundle centre	Posteromedial bundle centre
					plateau
Johannsen et al. [42]	Controlled laboratory study	20	Anteroposterior view: 1.6 mm distal to the proximal joint line Lateral view: 5.5 mm superior to the champagne glass drop-off	Anteroposterior view: 0.2 mm proximal to the proximal joint line Lateral view: 8.4 mm superior to the champagne glass drop-off	Anteroposterior view: 4.9 mm distal to the proximal joint line Lateral view: 2.5 mm superior to the champagne glass drop-off
Van Hoof et al. [40]	Controlled laboratory study	9		Superolateral aspect of the posterior intercondylar area	In the inferomedial aspect of the fossa
Salim et al. [32]	Descriptive laboratory study	20	Radiographic: 69.7% of the facet length of the PCL; 3D bone model: 71.7% along the PCL facet		
Vielgut et al. [33]	Descriptive laboratory study	64	4.73/1.3 in the coordinate system		
Feng et al. [34]	Radiographic analysis	20	8.4 mm from the medial groove 9.2 mm from the champagne glass drop-off 15.3 mm from the apex of the medial intercondylar		

Ten biomechanical studies compared different tunnel placement were identified. The entry placement of the tibial tunnel was analyzed by five studies using cadaveric experiment and finite element analysis [5, 43-46], shown in Table 6. Anterolateral and anteromedial tunnel were tested by three studies [43, 44, 46], which showed that anteromedial tunnel had a sharp graft angulation and high graft force, indicating it would be more possible to have the "kill turn" effect. Kim et al. [5] also mentioned the central tunnel and reported a same result. In addition, Ahn et al. [45] reported that anterolateral tunnel seemed to show a significant increase in postoperative tunnel enlargement, questioning the security of the anterolateral tibial tunnel. Another five biomechanical studies compared different graft placements in the PCL fovea (that is the exit of the tibial tunnel) and analyzed the impact on biomechanical effect, using different position methods. Markolf et al. [47] measured changes in knee laxity and graft forces resulting from position of the tibial tunnel medial and lateral to the center of the PCL's tibial insertion with the use of ten fresh-frozen human knees. Later study conducted by Tsukada et al. [48] compared the tibial tunnel placed on the center of ALB and PMB with the use of eight fresh-frozen human knees. Kernkamp et al. [49] evaluated the length change patterns of the PCL between the ALB or PMB and the central placements. In additional, two studies conducted by Wang et al. [50, 51] reported a modified tibial tunnel in Fanelli area (that is inferior and lateral to the PCL anatomical insertion), showing it could reduce the peak stress concentration and the "kill turn" effect.

Table 6 Biomechanical studies that compared two or more entry placements of the tibial tunnel

	Study design	Tunnel placement compared	Number of knees	Graft angulation	Graft force	PTT	Tunnel enlargement
Huang et al. [43]	Biomechanical study	Anterolateral versus anteromedial tunnel	12	A-L > A-M	n. a	No difference	n. a
Dunlop et al. [44]	Biomechanical study	Anterolateral versus anteromedial tunnel	3	A-L > A-M	A-L < A-M	n. a	n. a
Kim et al. [5]	Biomechanical study	Anterolateral versus anteromedial versus central tunnel	6	n. a	A-L < central < A-M	n. a	n. a
Ahn et al. [45]	Controlled laboratory study	Anterolateral versus anteromedial tunnel	20	n. a	No difference	n. a	A-L > A-M
Teng et al. [46]	Biomechanical study	Anterior 1/3 anteromedial versus medial 1/2 anteromedial versus tibial crest versus anterior 1/3 anterolateral versus medial 1/2 tunnel	90	Lateral > medial	n. a	n. a	n. a

4 Discussion

Unfortunately, this systematic review finds that it is the lack of clinical research-based evidence for an optimal tibial tunnel placement, both the entry and the exit of the tunnel in PCL reconstruction using the transtibial technique. Several biomechanical studies evaluated the entry of the tibial tunnel placement, especially anterolateral and anteromedial tunnel, which recommend that the anterolateral tunnel was preferred to anteromedial tunnel in biomechanical outcomes such as PTT, graft force and the “kill turn” effect. Various anatomical and radiologic landmarks were used to determine the insertion site of the PCL two bundles, but no clinical trial and biomechanical studies compared different exit placement of tibial tunnels.

Cadaveric and radiological studies utilized various anatomical landmarks to try to accurately describe the PCL insertion site. Initial studies always used a single reference point and did not distinguish between the anterolateral and posteromedial bundles, but it was difficult to define a point accurately and to realize the three-dimensional mapping proposed by Tajima et al. [37] and Takahashi et al. [36]. Following studies added several landmarks such as the champagne glass drop-off and the shiny white fiber point and calculated the length ratio of the PCL facet to locate the insertion site. The coordinate system was used by Vielgut et al. [33] in the radiological analysis. Detailed descriptions of the PCL insertion site were provided by these studies, but it seemed that these landmarks were not suitable for all patients in supine position in the arthroscopic surgery.

Radiological studies also tried to identify some radiological landmarks with accurate PCL orientation, although radiological landmarks would not be seen with the use of arthroscopic techniques. Osti et al. [39] combined radiological outcomes with descriptive anatomical outcomes and Johannsen et al. [42] utilized two different views, anteroposterior view and lateral view, to pursue a more practical method that could be applied in arthroscopic PCL reconstruction surgery, but its effectiveness was still under estimate. As a result of population differences of the PCL insertion site, conventional measurements using just distance showed less reproducibility. To solve this problem, Salim et al. [32] utilized the length ratio of the PCL facet to assist the intraoperative determination of PCL tibial tunnel placement and Vielgut et al. [33] conducted the measurement by the use of an objective coordinate system to assess the placement preoperatively.

For the entry placement of the tibial tunnel, the biomechanical studies reviewed [5, 43-46] suggested that the anterolateral tunnel was preferred to the anteromedial tunnel, while it also existed the risk of postoperative tunnel enlargement that could lead to the failure. For the exit placement of the tibial tunnel, several biomechanical studies demonstrated considerable variation in suggestions for the exit placement of the tibial tunnel. Markolf et al. [47] found that drilling the tibial tunnel 5 mm medial or lateral to the center of the PCL's tibial footprint had no significant effect on knee laxities, but medial tunnel had a slightly higher graft force. Tsukada et al. [48] found that a significant difference of the PTT only occurred under 100-N posterior tibial load at 90° of knee flexion between the tibial tunnel placed on the center of ALB and PMB. Both suggested that placing the tunnel in the PCL fovea was enough, but no clinical evidence could inform their chosen placement. Besides, Fanelli [52] suggested that the distal and lateral tunnel placement out of the PCL fovea could avoid the “kill turn”, and it was tested by Wang et al. [50]. However, it was also reported that the Fanelli tunnel would affect the posterior laxity.

Considering all mentioned suggestions, it will put surgeons in a dilemma. On the one hand, anatomical results show less repeatability and it is difficult for surgeons to match these results with anatomical data, due to limited imaging quality within the surgical setting and use of simple two-dimensional images. On the other hand, it seems that the effort to control laxity and to reduce the “kill turn” go oppositely, which indicates that a balance point should be identified to achieve this goal. More studies should be conducted to support the hypothesis. All in all, a principle that could guide surgeons to have an accurate intraoperative determination in the view of arthroscopic surgery.

Knee flexion is also important to assess the laxity. Biomechanical studies showed that a significant difference in laxity between different tunnel placements was usually found from 30° to 90° of knee flexion under normal tibial load but not at low degree knee flexion.

5 Conclusions

With the currently limited available data, this systematic review did not identify an optimal tibial tunnel placement for arthroscopic PCL reconstruction using a transtibial technique. For the entry of the tibial tunnel, anterolateral tunnel has better clinical and biomechanical outcomes based on exist studies. Although a detailed cartography of the PCL fovea has been descripted by anatomical studies, the exit of the tibial tunnel is not identified in the absence of clinical and biomechanical evidence. More studies, especially randomized clinical trials comparing at least two tibial tunnel exit placement, are needed to confirm where the best position is and result in stable knee joint which has less laxity and complication rates.

Ethical Approval

Not needed.

Conflict of Interest

Authors certifies no commercial association that pose a conflict of interest in connection with the submitted article.

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