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Spotlight on Surgical Techniques

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The Anatomic Centers of the Femoral and Tibial Insertions of the Anterior Cruciate Ligament

A Systematic Review of Imaging and Cadaveric Studies Reporting Normal Center Locations

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Background: The anterior cruciate ligament (ACL) is regularly reconstructed if knee joint function is impaired. Anatomic graft tunnel placement, often assessed with varying measurement methods, in the femur and tibia is considered important for an optimal clinical outcome. A consensus on the exact location of the femoral and tibial footprint centers is lacking.

Purpose: To systematically review the literature regarding anatomic centers of the femoral and tibial ACL footprints and assess the mean, median, and percentiles of normal centers.

Study Design: Systematic review.

Methods: A systematic literature search was performed in the PubMed/Medline database in November 2015. Search terms were the following: ACL and insertion anatomy or anatomic footprint or radiographic landmarks or quadrant methods or tunnel placement or cadaveric femoral or cadaveric tibial. English-language articles that reported the location of the ACL footprint according to the Bernard and Hertel grid in the femur and the Stäubli and Rauschning method in the tibia were included. Weighted means, weighted medians, and weighted 5th and 95th percentiles were calculated.

Results: The initial search yielded 1393 articles. After applying the inclusion and exclusion criteria, 16 studies with measurements on cadaveric specimens or a healthy population were reviewed. The weighted mean of the femoral insertion center based on measurements in 218 knees was 29% in the deep-shallow (DS) direction and 35% in the high-low (HL) direction. The weighted median was 26% for DS and 34% for HL. The weighted 5th and 95th percentiles for DS were 24% and 37%, respectively, and for HL were 28% and 43%, respectively. The weighted mean of the tibial insertion center in the anterior-posterior direction based on measurements in 300 knees was 42%, and the weighted median was 44%; the 5th and 95th percentiles were 39% and 46%, respectively.

Conclusion: Our results show slight differences between the weighted means and medians in the femoral and tibial insertion centers. We recommend the use of the 5th and 95th percentiles when considering postoperative placement to be "in or out of the anatomic range."

Keywords: anterior cruciate ligament; anatomy; cadaveric study; systematic review

The predominant technique for anterior cruciate ligament (ACL) reconstruction continues to evolve since the procedure entered common orthopaedic practice more than 3 decades ago.[5] It has changed from open surgery to arthroscopic surgery, with ongoing discussions on relevant topics including the ideal mechanical and biological properties of the graft (ie, graft selection), the ideal isometric placement of graft, and in recent years, single-bundle versus double-bundle and, lately, even triple-bundle reconstruction.[39] There are many surgical considerations, which are taken into account during surgery, such as addressing concomitant ligament and meniscal injuries, proper fixation of inserted grafts, and in recent years, an increasing focus on placement of the femoral and tibial graft tunnels as close as possible to the anatomic ACL insertions (of the native ligament).[32,34] Anatomic reconstruction is preferred to the transtibial technique as studies have shown that the former is better in reducing anterior translation and providing rotational stability/reducing the pivot shift in the ACL-deficient knee.[31] Thus, "anatomic" (single or double bundle) reconstruction of the ACL is increasingly performed.[4,32] This method has induced a rise in imaging used to validate tunnel placement both intraoperatively and postoperatively.[3,8,9,18,20,23,27,42] The practical and clinically efficient use of imaging to validate tunnel placement is hampered by the lack of consensus on where exactly the anatomic centers of the ACL in the femur and tibia are located. There are several works that have measured the femoral ACL insertion location on cadaveric specimens; however, most articles have included only a limited number of knees, varying between 7 to 36 knees, with few measurements.[7,15,22,38,43] In the tibia, a few studies have studied the ACL insertion in vivo cases as well.[11,28] In addition to the small number of cases included, various measurement methods have been used, which makes a comparison difficult.[21,37,40]

The purpose of this study was to systematically review the literature regarding anatomic location centers of the femoral and tibial ACL footprints and to calculate the center means, medians, and percentiles of normal locations of ligament centers (LCs) in humans. We hypothesized that the results would provide a normal range for ligament locations, which will be clinically useful for intraoperative and/or postoperative imaging.

METHODS

A search of the English-language medical literature was performed to identify all articles that studied the anatomic location of the femoral or tibial ACL insertion centers in nonoperated human knees in cadaveric specimens or living participants using either the Bernard and Hertel[2] (BH) grid or the Stäubli and Rauschning[35] (SR) method. The BH grid is a method to indicate femoral ligament or tunnel placement in 2 directions, perpendicular to one another, along the intercondylar roof direction and across the condylar height. In this method, the arthroscopic terms "deep-shallow" (DS) and "high-low" (HL) are used. The first measurement is the distance from the posterior cortex to the center divided by the distance of the entire depth of the condyle along the intercondylar roof (also called the Blumensaat line). The second measurement is the distance from the intercondylar roof to the center divided by the height of the condyle (Figure 1).[1,2] In this article, DS and HL refer to the locations of the insertions according to the BH grid.

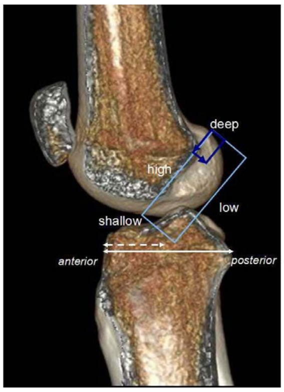


Figure 1.

Measurement according to the Bernard and Hertel[2] grid (light blue rectangle), shown on a 3-dimensional volume-rendered computed tomography scan, where the lateral condyle has been exposed. Measurements are performed in the deep-shallow direction and high-low direction (dark blue rectangle). Tibial tunnel measurement according to Stäubli and Rauschning[35] was performed from the anterior border of the tibia to the center of the ligament or tunnel (dashed arrow) and divided by the depth of the entire tibia (white arrow).

The SR method indicates the LC in the anterior-posterior direction. It is performed by measuring the distance from the anterior cortex to the center and by dividing it by the entire depth of the tibia (Figure 1).[35] In this article, the LC refers to the center point of the whole of the ligament or bundle.

On November 29, 2015, a search was performed in PubMed (http://www.ncbi.nlm.nih.gov/pubmed) for the terms "(acl insertion anatomy) or (acl anatomic footprint) or (acl radiographic landmarks) or (acl quadrant method) or (acl tunnel placement) or (acl cadaveric femoral) or (acl cadaveric tibial)" by a single investigator. The initial search yielded 1393 articles. After 2 investigators reviewed the titles in consensus, the articles that were not relevant, typically either addressing postoperative imaging or not assessing normal knee anatomy, were excluded. A total of 203 abstracts were included for a further examination. After reviewing the abstracts (and excluding irrelevant articles), 49 full-text articles that assessed or studied ACL insertions in the femur or tibia were reviewed in detail. Finally, we excluded articles that did not assess the ACL femoral insertion center with the BH grid and/or the ACL tibial insertion center with the SR method. In the end, 16 English-language articles were included (Figure 2 and Table 1).

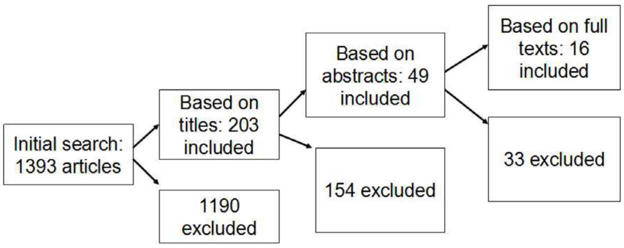


Figure 2.

Selection process of articles and final selection for systematic review.

TABLE 1

Description of Studies[a]

Author (Year)	N	Cadaveric Study	Age, y	Reliability Tested	Unpaired Knees	Modality
Bernard et al[2] (1997)	10	Yes	Unknown	No	Not stated	Radiographs
Colombet et al[7] (2006)	7	Yes	Mean, 75	Intraobserver error, 0.40-2.50	Yes	Anatomic
de Abreu-e-Silva et al[8] (2014)	8	Yes	22-65	ICC, 0.80-0.91	Yes	3D CT
Forsythe et al[10] (2010)	8	Yes	Mean, 63	ICC > 0.96	Yes	3D CT
Frank et al[11] (2010)	100	No	20-35	ICC, 0.31-0.95	Yes	MRI
Iriuchishima et al[17] (2010)	15	Yes	49-93	No	Yes	Radiographs
Lee et al[19] (2015)	15	Yes	45-87	Kappa, 0.84-0.91	All but 1	Anatomic
Lorenz et al[21] (2009)	12	Yes	Unknown	No	Yes	3D CT
Luites et al[22] (2007)	35	Yes	>60	No	Yes	Anatomic
Musahl et al[26] (2003)	8	Yes	50-79	No	Not stated	3D CT
Parkinson et al[29] (2015)	76	No	18-35	Yes, but no values	Yes	MRI
Pietrini et al[31] (2011)	12	Yes	45-70	ICC > 0.95	Yes	Radiographs
Stäubli and Rauschning[35] (1994)	10	Yes	18-78	No	No	MRI
Takahashi et al[38] (2006)	32	Yes	68-97	No	All but 1	Radiographs
Tsukada et al[40] (2008)	36	Yes	Mean, 78	No	Yes	Anatomic
Zantop et al[43] (2008)	20	Yes	45-87	No	Yes	Radiographs

[a]3D CT, 3-dimensional computed tomography; ICC, intraclass correlation coefficient; MRI, magnetic resonance imaging.

Data Collection, Quality Assessments, Calculations, and Statistical Analyses

Each of the 16 studies was assessed for the measurement methods, number of cases or measurements, cadaveric or radiological studies, age of the population, paired or unpaired knees, and whether interobserver or intraobserver reliability had been reported (Table 1). In some cadaveric studies, the LCs had been marked with metal pins or radio-opaque threads before imaging; in other studies, measurements had been performed directly on the specimen with a caliper. There was no cutoff for studies with a low number of knees as the number of cases in a study is irrelevant in a review of measurements of healthy nonoperated knees. The spread of measurements or SDs in each original study was not considered reasons for exclusion because we wished to capture the breadth of the variations in the population.

All measurements from the studies were given as percentages. The weighted means and medians of the measurements and the weighted percentiles were calculated for the femoral and tibial ACL insertion centers separately. Calculations were performed for the center of the ACL as a whole ligament, reported as the LC. In studies where only 2-bundle centers were reported separately, LC placement was calculated as the average of the 2-bundle centers. As multiple studies reported insertion centers separately for the anteromedial bundle (AMB) and posterolateral bundle (PLB), weighted means, medians, and percentiles were calculated for these separate bundle insertions as well. In the tibia, LCs were also calculated based on imaging, specifically summation images (radiography and 3-dimensional computed tomography [CT]) and tomographic images (magnetic resonance imaging [MRI] and regular CT) separately, as a recent study[28] has indicated that, although not clinically relevant, tibial placement on summation images tend to be 3% smaller than on single-slice images. All calculations and analyses were performed in SPSS Statistics for Windows (v 22.0; IBM Corp).

RESULTS

The reported demographic data, including information about sex-based distribution, were often incomplete. The age of the study population collated from the studies that had reported this information varied from 45 to 97 years for the femur and from 18 to 87 years for the tibia.

Femoral LC Measurements

Thirteen articles were included in the calculations of femoral LCs (Table 2).[¶] Five of these studies[7,8,10,19,31] reported having used tests for reliability. We were able to calculate the LC weighted means on measurements from a total of 218 knees in the femur.

TABLE 2

Femoral Ligament Center in Single-Bundle Insertions (n = 218 Knees) and for the 2 Bundles of the ACL (n = 192 Knees)[a]

Author (Year)	Ligament Center, %					
	Single Bundle		Anteromedial Bundle		Posterolateral Bundle	
	DS	HL	DS	HL	DS	HL

Bernard et al[2] (1997)	24.8	28.5	—	—	—	—
Colombet et al[7] (2006)	29.4	36.5	26.4	25.3	32.3	47.6
de Abreu-e-Silva et al[8] (2014)	30.0	35.3	—	—	—	—
Forsythe et al[10] (2010)	28.4	44.3	21.7	33.2	35.1	55.3
Iriuchishima et al[17] (2010)	23.5	39.0	15.0	26.0	32.0	52.0
Lee at al[19] (2015)	37.3	41.0	33.9	25.6	40.6	56.4
Lorenz et al[21] (2009)	24.0	33.5	21.0	22.0	27.0	45.0
Luites et al[22] (2007)	25.5	28.5	23.0	10.0	28.0	47.0
Musahl et al[26] (2003)	26.3	26.6	—	—	—	—
Pietrini et al[31] (2011)	25.3	28.3	21.6	14.2	28.9	42.3
Takahashi et al[38] (2006)	35.9	42.6	31.9	26.9	39.8	53.2
Tsukada et al[40] (2008)	30.4	30.0	25.9	17.8	34.8	41.1
Zantop et al[43] (2008)	23.9	37.8	18.5	22.3	29.3	53.6
Weighted mean	28.6	34.5	24.6	20.6	33.1	48.7
Weighted median	26.3	33.5	23.0	22.3	32.3	47.6
5th and 95th percentiles, respectively	23.5 and 37.3	28.4 and 42.6	15.0 and 33.9	10.0 and 26.9	27.0 and 40.6	41.0 and 56.4

[a]Dash indicates variable not applicable to the study. ACL, anterior cruciate ligament; DS, deep-shallow; HL high-low.

All studies on femoral LC measurements were performed on cadaveric specimens. Takahashi et al[38] and Lee et al[19] included unpaired knees in all but 1 case, and 2 studies did not specify this.[2,26] All remaining studies included only unpaired knees. The weighted mean of the femoral LC was 29% in the DS direction and 35% in the HL direction. The femoral centers from each included study, weighted means across studies, weighted medians, and 5th and 95th percentiles for the LC assessment are given in Table 2.

Tibial LC Measurements

Ten studies were used for the tibial LC calculations (Table 3).[#] Three of these studies[7,10,19] reported reliability. We were able to calculate the LC weighted means on measurements from a total of 300 knees. Eight studies reported on cadaveric specimens,[8,10,17,19,21,35,40,43] and 2 reported MRI measurements on living participants.[11,29] Stäubli and Rauschning[35] included 5 paired knees, and Lee at al[19] included 1 set of paired knees; all other studies included unpaired knees. The weighted mean of the tibial LC was 42% in the anterior-posterior direction. The tibial centers from each included study, weighted means across studies, weighted medians, and 5th and 95th percentiles for the LC assessment are given in Table 3, in addition to tibial centers adjusted for intermodality and differences in imaging.[28] The normal range of centers of the single-bundle ACL is shown in Figure 3.

TABLE 3

Tibial Ligament Center in Single-Bundle Insertions (n = 300 Knees) and for the 2 Bundles of the ACL (n = 118 Knees)[a]

Author (Year)	Ligament Center, %			
	Single Bundle		Anteromedial Bundle[b]	Posterolateral Bundle[b]
	Overall	Corrected for MRI or CT		
de Abreu-e-Silva et al[8] (2014)	40.5	43.5	—	—
Forsythe et al[10] (2010)	35.7	38.7	25.0	46.4
Frank et al[11] (2010)	45.5	45.5	—	—
Iriuchishima et al[17] (2010)	40.5	43.5	31.0	50.0
Lee at al[19] (2015)	40.7	43.7	37.6	43.8
Lorenz et al[21] (2009)	46.5	49.5	41.0	52.0
Parkinson et al[29] (2015)	39.0	39.0	—	—
Stäubli and Rauschning[35] (1994)	44.0	44.0	—	—
Tsukada et al[40] (2008)	43.5	46.5	37.6	49.5
Zantop et al[43] (2008)	38.5	41.5	30.0	44.0
Weighted mean	42.3	43.4	34.7	47.8
Weighted median	43.5	44.0	37.6	49.5
5th and 95th percentiles, respectively	38.5 and 45.5	39.0 and 46.5	25.0 and 41.0	43.8 and 52.0

[a]Dash indicates variable not applicable to the study. ACL, anterior cruciate ligament; CT, computed tomography; MRI, magnetic resonance imaging.

[b]Measured in the anterior-posterior direction.


Figure 3.

The normal range of centers of the anterior cruciate ligament: in the femur, the range was 24% to 37% in the deep-shallow (DS) direction and 28% to 43% in the high-low (HL) direction, and in the tibia, the range was 39% to 46%.

Femoral 2-Bundle Measurements

Ten included studies reported 2-bundle femoral tunnel placements separately.** We were able to calculate the 2-bundle weighted means on measurements from 192 knees for the femoral insertions (Table 2). All included studies on 2-bundle insertions were performed on cadaveric specimens. Both Takahashi et al[38] and Lee et al[19] included unpaired knees in all but 1 case. All remaining studies only included unpaired knees. The weighted mean of the femoral 2-bundle centers was 25% for the AMB and 33% for the PLB in the DS direction and 21% for the AMB and 49% for the PLB in the HL direction. Weighted means and percentiles are presented in Table 2. The normal ranges of the 2-bundle ACL insertions are shown in Figure 3B. Notably, there was no overlap of the range of the 2 bundles in the HL direction.

Tibial 2-Bundle Measurements

Seven of the included articles reported 2-bundle tibial tunnel placements separately.[10,17,,21,31,40,43] We were able to calculate the 2-bundle weighted means on measurements from 106 knees for the tibial insertions (Table 3). The weighted mean of the tibial 2-bundle centers was 35% for the AMB and 48% for the PLB in the anterior-posterior direction. Weighted means and percentiles are presented in Table 3. There was no overlap between the ranges of the 2 bundles (Figure 4).

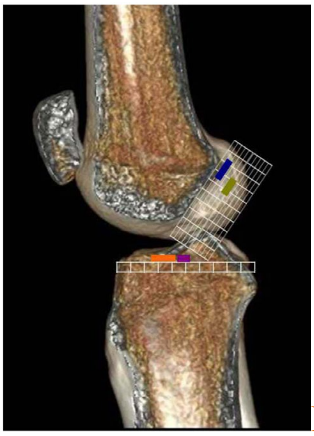


Figure 4.

The normal range of centers of the 2 bundles: in the femoral anteromedial bundle (AMB), the range was 15% to 34% in the DS direction and 10% to 27% in the HL direction (dark blue rectangle), and in the femoral posterolateral bundle (PLB), the range was 27% to 41% in the DS direction and 41% to 56% in the HL direction (green rectangle); in the tibial AMB, the range was 25% to 41% (yellow rectangle), and in the tibial PLB, the range was 44% to 52% (purple rectangle).

DISCUSSION

The major findings of our study were that there were slight differences between the weighted means and medians in both the femoral and tibial insertion centers. The weighted mean and median for the femoral insertion center were 29% and 26%, respectively, in the DS direction and 35% and 34%, respectively, in the HL direction. The normal range between the 5th and 95th percentiles in the DS direction was 24% to 37% (a difference of 13%), and in the HL direction, it was 28% to 43% (a difference of 15%). The weighted mean and median for the tibial insertion center in the anterior-posterior direction were 42% and 44%, respectively, and the normal range between the 5th and 95th percentiles was 39% to 46% (a difference of 7%).

With the recent focus on anatomic placement of femoral and tibial tunnels during ACL reconstruction, knowledge of the normal location and normal variation of the anatomic insertion centers is directly applicable in clinical practice, that is, for planning ACL reconstruction, for performing intraoperative fluoroscopy, and for assessing the results postoperatively. Intraoperative imaging is recommended to improve the anatomic placement of tunnels.[13,18] Further, this knowledge enables radiologists to report tunnel placement on postoperative imaging as “in or out of the normal range.” This information may assist surgeons in assessing the outcome of their surgical procedure as well as enabling them in fine-tuning correct placement in future patients undergoing ACL reconstruction. A previous study has shown that feedback from postoperative imaging helps surgeons improve their accuracy.[16]

The BH grid for assessing the femoral insertion was chosen over other methods used to indicate femoral insertions or tunnels.[14,40] The main reason was that it is the method recommended by an international group of orthopaedic surgeons.[1] Second, this terminology is not misunderstood by radiologists, while the term “superior” may be misunderstood as proximal and means one thing for orthopaedics but something different on imaging for radiologists and depends on how imaging is performed. The use of the grid is unambiguous (Figure 5).

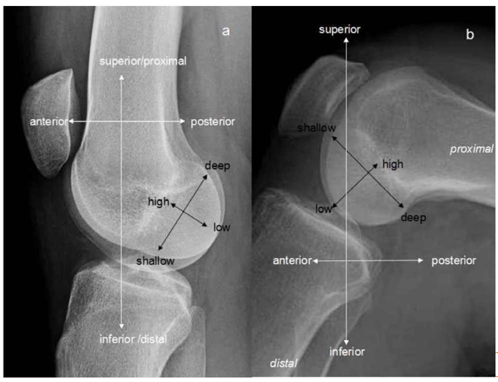


Figure 5.

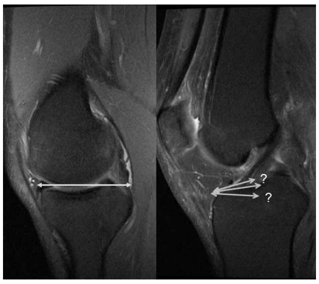
The difference between anatomic terms and radiological terms Lateral radiograph of a knee in full extension, with the directions of deep-shallow and high-low in the anatomic/arthroscopic terminology (in black) The radiographic terminology relates to the image: anterior-posterior and superior-inferior. Proximal and distal relate to the extremity. In flexion, anatomic terminology remains unchanged and unambiguous; however, the radiographic terminology changes.

For the insertion location for both a single bundle and 2 bundles in the femur, we observed that the weighted median was slightly smaller than the weighted mean: 26% for DS and 34% for HL versus 29% for DS and 35% for HL, respectively. We also observed that the weighted median was closer to the lower range than the highest range. A few previous studies have calculated femoral insertion averages, but they included a relatively small total number of cases or mostly radiographic studies. Bird et al[3] examined 6 studies with measurements from a total of 81 knees and presented a mean across studies of 27% for DS and 35% for HL. Piefer et al[30] used 8 studies, mostly radiographic (all but 1, which was a CT study), with measurements from a total of 118 knees and presented a mean across studies of 28% for DS and 35% for HL. We also noted no overlap between the weighted ranges of the femoral 2-bundle insertions in the HL direction. The gap was 14%. It may be partly explained by the fact that the 2 bundles were identified individually by the investigators in each case, thus creating a bias, especially as most studies did not include interrater reliability. Also, there is a difference between the microscopic and macroscopic anatomy of the ACL insertions in both the femur and tibia.[25,33] Further, there is some debate in the literature about whether the ACL actually has 2 bundles.[34]

In the tibia, the weighted medians of single-bundle and 2-bundle insertions were slightly higher compared with the weighted means. The weighted medians were closer to the higher range compared with the lower range. Our results of the tibial insertion are based on studies using the SR method. In the orthopaedic literature, the SR method and the Amis and Jakob[1] (AJ) line are sometimes used interchangeably. Measurements according to the AJ line are performed on radiographs or during fluoroscopy and are the most commonly used.[1,14] Hwang et al[14] stated that measurements performed with the AJ line and SR method yielded similar values. However, there are slight differences between the 2 methods (Figure 5). The SR method is a ratio from the anterior tibia to the center of the insertion and the maximum anterior-posterior diameter of the tibia. The AJ line is a ratio from the anterior tibia to the center of the insertion and the maximum anterior-posterior diameter of the medial tibial plateau. This means that the AJ line cannot be easily measured on normal MRI or CT as the LC and medial tibial plateau are depicted on different images (slices) (Figure 6). Thus, we chose to use the SR method to include larger MRI studies performed in a healthy population.

Figure 6.

Tibial tunnel measurement according to Amis and Jakob.[1] The measurement is performed from the anterior border of the tibia to the center of the ligament or tunnel and divided by the depth of the entire tibia, but the lines are placed along the medial tibial plateau (dotted lines). The Stäubli and Rauschning[35] method uses a line placed perpendicular to the shaft of the tibia (white line).



Measurement of the tibial center on magnetic resonance imaging. Illustration of the difference between the angles of the medial tibial plateau (white line). In the midline, it is difficult to judge the medial tibial plateau slope for the Amis and Jakob[1] line, as one has to scroll away from one image to the other for measurement, and it is difficult to know which angle to follow (white lines).

Sullivan et al[36] reported radiographic measurements for the 2-bundle ACL insertions, combining the results of 2 studies (with a total of 35 patients), as 30% and 47% using the SR method. The differences compared with earlier studies may be explained by the present compilation including a much larger sample size as well as using the SR method (whereas most earlier reports used the AJ line for measurements).[1,10-12,21,22,24,28,31] In addition, the intermodality difference of approximately 3% observed in tibial measurements may also influence the average when compared with Sullivan et al.[36]

The quality of included studies in a systematic review marks the quality of the final review. However, there is currently no scoring system for assessing the quality of studies for use in normal measurement studies. Known scoring systems are designed for clinical studies with interventions and for long-term outcomes of knee joint function. For instance, the Coleman Methodology Score was created to assess studies of outcomes after surgery. Quality scores are not advised for use in diagnostic systematic reviews.[6] Also, a meta-analysis could not be performed in this study as there is no intervention and calculating effect sizes serves no purpose; in fact, it would diminish the normal variations that we wished to capture. Therefore, straightforward weighting based on the number of measured knees was used as well as weighted means and medians.

To the best of our knowledge, this systematic review included the highest number of studies and measurements so far. Further, our study also included more CT studies than previous reviews, which strengthens the validity of our calculated weighted measurements as studies have shown higher reliability with CT compared with radiographs.[12,23,24,28]

The conclusions are further strengthened by the reporting of weighted means and weighted medians. The reporting of weighted 5th and 95th percentiles yields a normal range of centers and is valuable in regular clinical practice. We also have compiled tibial insertion locations that are adapted to the variation in imaging types and modalities so that the centers can be used directly in clinical practice, independent of the modality or imaging type used to validate tunnel placement. We recommend the use of weighted medians and percentiles in validation studies.

There are some limitations of the present study. This is a systematic review, and although the results of several studies are combined, resulting in a relatively high total number of cases, the data are based on means from relatively small studies. The demographic data are incomplete, and we were unable to compile sex-specific centers. As most studies in the femoral group are cadaveric studies, the age is much higher than that of the population that normally undergoes ACL reconstruction. However, there are no indications that the ACL undergoes degenerative changes that influence the ligament insertion locations. Very few studies included reliability in their results; thus, there may be a bias due to measurements only being performed by one investigator, especially as former studies have shown poor reliability (as low as 0.5) when using radiographs, and many of the studies assessing especially the femoral tunnel used radiographs.

In conclusion, we calculated the weighted median of the ACL femoral insertion center to be 26% and 34% in the DS and HL directions, respectively. The 5th and 95th percentiles were 24% and 37%, respectively, for DS and 28% and 43%, respectively, for HL. The weighted median of the ACL tibial insertion center was 44% in the anterior-posterior direction, and the 5th and 95th percentiles were 39% and 46%, respectively. Knowledge of the anatomic range of femoral and tibial ACL footprint locations is helpful for surgeons performing ACL reconstruction and for radiologists performing postoperative imaging.

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