Original Article

# A Recess Is Observed Between the Posterior Knee Capsule and the Meniscotibial Ligament Complex in Pediatric Specimens

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**Purpose:** To define the surgical anatomy of the meniscotibial ligament complex of the pediatric medial and lateral menisci and their relation to the proximal tibial physis and posterior joint capsule. **Methods:** Fourteen pediatric cadaveric knee specimens (aged 3 months to 11 years) were dissected to clarify the relation of the posterior knee capsule, the meniscus, and the meniscotibial ligament complex. Metallic markers were placed marking the meniscotibial ligament capsular attachment on the proximal tibia. Specimens underwent computed tomography scanning to evaluate pin placement and relation to the physis. A digital measurement tool was used to measure the distances between the proximal tibial physis and the pins (placed at 5 points on both the lateral and medial menisci). **Results:** In each specimen, clear separation was noted between the posterior joint capsule from the meniscus and meniscotibial ligament complex in the medial and lateral compartments. There was an increase in the distance between the proximal tibial physis and the insertion points of the meniscotibial ligament complex with increasing specimen age. For both the medical and lateral menisci in group 1, the median meniscotibial ligament insertion points were often less than 7 mm (interquartile range, 0.00-7.8 mm) away from the physis. The median meniscotibial ligament insertion points in group 2 tended to be farther from the physis but always less than 20 mm (interquartile range, 2.5-17.5 mm)—and as close as less than 5 mm (lateral posterior root). **Conclusions:** In this anatomic study of pediatric knees, we observed a distinct recess/cul-de-sac space between the posterior knee capsule and meniscal attachments in all specimens. This defines a distinct plane between the posterior knee capsule and the meniscotibial ligament complex, with a distance between the physis and meniscotibial ligament capsular attachments that increases with age. **Clinical Relevance:** The anatomic parameters evaluated in our study should be considered as future meniscal repair and transplantation techniques aim to restore the meniscal anatomy, stability, and mobility provided by the meniscotibial ligament complex and capsule structures.

Meniscal injuries are increasingly recognized in pediatric and adolescent athletes.[1] These injuries often occur with concomitant tibial spine fracture, anterior cruciate ligament (ACL) tear,[2] or discoid meniscus.[3-7] Ramp lesions, also known as meniscocapsular separations of the posterior horn of the medial meniscus, specifically, have been increasing in prevalence in the pediatric population owing to increased

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detection and identification.[8,9] The literature on meniscal ramp lesions has focused on the importance of meniscocapsular stability to the overall stability and health of the knee.[8,10-12] These posterior meniscocapsular and meniscotibial ligament complex separations have been identified in younger patients in up to 28% of adolescent ACL tears,[8] and they may be as prevalent in pediatric and adolescent populations as in adult populations.[10] The relation of the ramp lesion and meniscotibial ligament complex structures is still being defined, but a better understanding of the anatomy of the meniscus and meniscotibial ligaments may improve anatomic surgical repair techniques for these injured structures.

Pediatric and adolescent patients have much higher activity levels than older patients,[13-15] which may explain higher rates of meniscal injury in this group. Healing potential in the young, athletic population may be more promising than in older populations[16] owing to greater meniscal vascularity. However, meniscal surgical revision failure rates are still between 13% and 42%,[17] with higher rates of failure for patients with open physes and bucket-handle tears.[18,19]

An improved understanding of the meniscal anatomy, meniscotibial ligament complex, and joint capsule may alter surgical approaches for the treatment of meniscal pathology.[20] Adult meniscotibial (coronary) ligaments and meniscofibular ligaments have been described by DePhillipo et al.[20] Anatomic studies have shown that the meniscocapsular and meniscotibial attachment sites may act in tandem to prevent the anterior shifting of the tibia in an ACL-deficient knee.[20-23] It has been shown that concomitant meniscotibial ligament reconstruction during meniscal allograft transplantation decreases meniscal extrusion.[24] In adolescent patients, surgical techniques have shown safe and effective management of the lateral meniscus after subtotal lateral meniscectomy, using drill tunnels in the anatomic root locations of both the anterior and posterior horns of the lateral meniscus.[24] In the pediatric knee, these ligaments (meniscotibial ligaments) are not well defined but likely play an equally important role in sagittal and rotatory knee stability. Avoiding physeal injury in pediatric patients undergoing ligament reconstructions has proved beneficial to avoid growth disturbances in growing athletes, and similar anatomic studies on the relation of the physis to the meniscus and meniscotibial ligaments may be essential for anatomic and functional restoration. The distance from the insertion site to the tibial physis is important because techniques to repair the meniscotibial ligaments will need to consider the risk to the physis and the risk of secondary growth disturbance.

The purpose of this study was to define the surgical anatomy of the meniscotibial ligament complex of the pediatric medial and lateral menisci and their relation to the proximal tibial physis and posterior joint capsule. Our hypotheses were that (1) pediatric knee specimens would show a consistent posterior recess/cul-de-sac space between the posterior capsule and meniscotibial ligament complex and (2) the meniscotibial ligament complex attachment and relation to the physis could be precisely measured.

## Methods

Fourteen skeletally immature cadaveric knee specimens aged between 3 months and 11 years were dissected and analyzed for this study. Tissues were freshly thawed prior to dissection. Dissection was performed by pediatric and sports medicine fellowship-trained orthopaedic surgeons (M.T., T.G., P.W., H.E., P.F., K.S.). During dissection, incisions approached the knee by dividing the capsule of the knee circumferentially, 4 to 6 cm above the joint line. This allowed the dissection to then fold the capsular layer distally, to look at the inside layer of the joint capsule, without disruption of the capsule at the joint line and level of the meniscus. A blunt probe was inserted in the capsular and meniscotibial ligament pouches, respectively, to initially define the tissue attachment point. The center point of tissue insertion to the periosteum was then visually determined, and dissection pins (metallic markers) were placed, marking the meniscotibial ligament insertion (Fig 1). The pins were placed at 5 points on both the lateral and medial menisci (anterior root, 12-o'clock, 3-/9-o'clock position, 6-o'clock position, and posterior root). OsiriX Imaging Software (version 7.5.1; Geneva, Switzerland) was used to reconstruct the computed tomography images (0.625-mm noncontrast slices on GE Litespeed Scanner; Cincinnati, OH) and measure the distances between the proximal tibial physis and each meniscotibial ligament insertion site. Axial images were used to confirm the pin location, and the measurements were performed in either the sagittal or coronal view depending on the pin's placement and specimen alignment in the computed tomography scanner (Fig 2).

As pediatric tissue is limited, there was a non-normal age group distribution among the specimens. Specimens were divided into 2 groups for analysis: Group 1 included ages 3 months to 2 years (10 pediatric knee specimens, comprising 8 male and 2 female specimens), and group 2 included ages 10 to 11 years (4 pediatric knee specimens, comprising 2 male and 2 female specimens). Mann-Whitney tests were run to analyze differences in variables between age groups.

## Results

In all knee specimens, there was clear separation of the posterior joint capsule from the meniscus and/or meniscotibial ligament complex in the medial and lateral compartments (Fig 3). There was an increase in the distance between the proximal tibial physis and the insertion points of the meniscotibial ligament with increasing specimen age. For both the medial and lateral menisci in group 1, the median meniscotibial ligament insertion points were often less than 7 mm (interquartile range, 0.00-7.8 mm) away from the physis. The median meniscotibial ligament insertion points in group 2 tended to be farther from the physis but always less than 20 mm (interquartile range, 2.5-17.5 mm)—and as close as less than 5 mm (lateral posterior root) (Table 1). The distance from the physis to the coronary ligament attachments at the 9-o'clock, 6-o'clock, 12-o'clock, posterior, and anterior positions of the medial and lateral menisci for both age groups is displayed in Figure 4.

The distance of the meniscotibial ligament insertion on the medial meniscus was farther away from the physis at the anterior and posterior roots compared with the distance in the posterior horn, body, or anterior horn in both age groups (Table 1). For all ages, the anterior horn of the medial meniscus appeared to have the narrowest variance in distance from the meniscotibial ligament insertion compared with other medial meniscal locations.

These trends were not the same for the lateral meniscus. The posterior root of the lateral meniscus was closer to the physis compared with the other locations for both age groups. On the lateral meniscus, the distance appeared to be greater the more anterior the pin.

## Discussion

This anatomic study identifies a clear posterior recess/cul-de-sac space between the posterior meniscus and meniscotibial ligament complex and the posterior capsule of the knee joint. The study also describes the anatomic relation of the distal extent of the meniscotibial ligament complex and the proximal tibial physis, defining the distances between these key knee structures. The meniscotibial ligament distance to the physis increases with age and further growth of the knee joint but remains relatively close to the physis in the growing knee. All measurements, medial and lateral, were less than 20 mm, and sometimes even as close as less than 5 mm (lateral posterior root). These anatomic findings may be of value to surgeons who perform meniscal repair and consider separate repair techniques that may anchor the repaired structure to the tibia, the meniscotibial ligament complex, and the joint capsule in different regions of the knee.

DePhillipo et al.[20] reported on skeletally mature, adult meniscotibial ligament lengths and insertion points. Their study found that the meniscotibial ligament

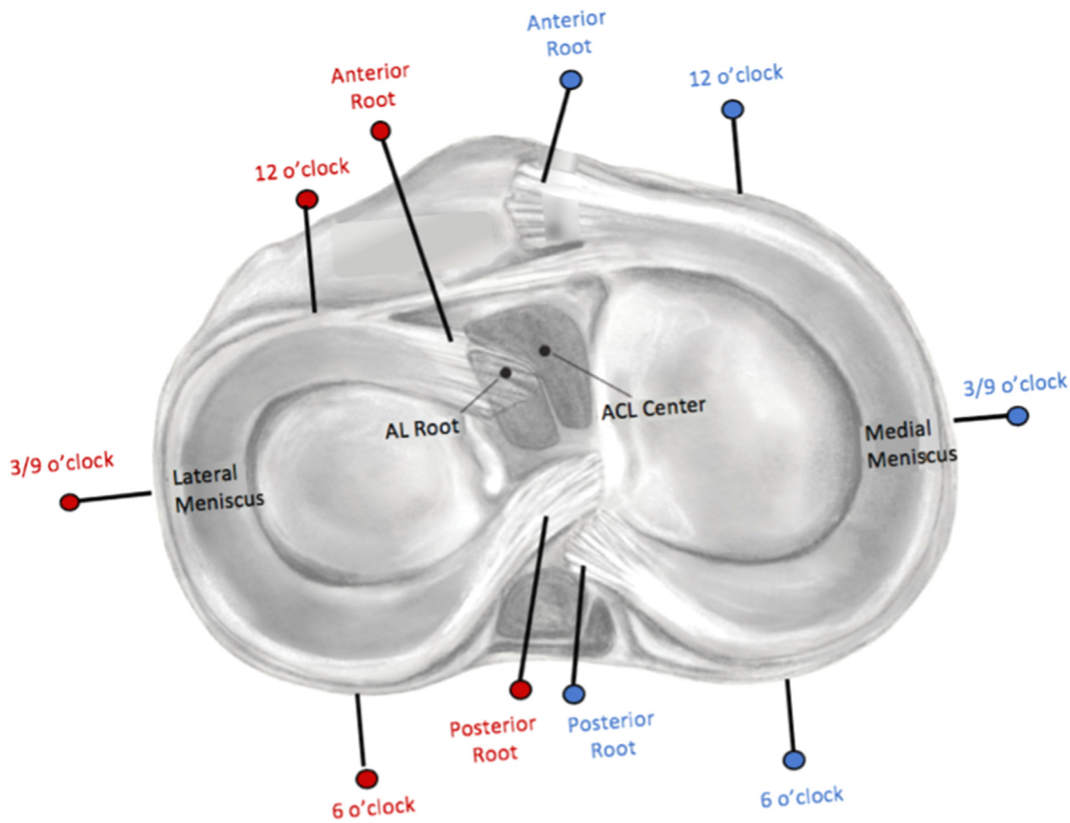


**Fig 1.** Medial (blue) and lateral (red) meniscal pin placement in right knee. (ACL, anterior cruciate ligament; AL, anterior lateral.)

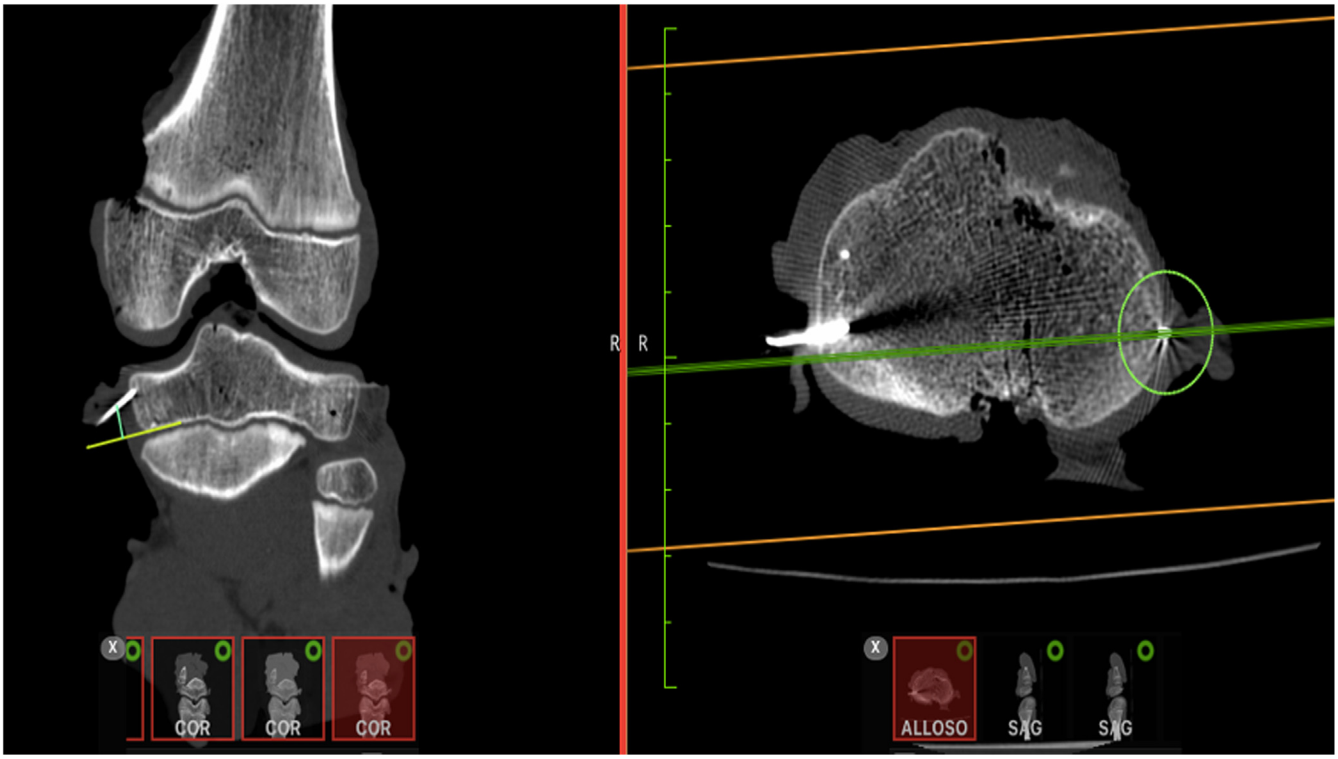


**Fig 2.** Computed tomography scan of 11-year-old male specimen illustrating medial 3-/9-o'clock pin placement (green circle) in axial view (right) and corresponding meniscotibial-to-physis measurement in coronal view (left). (ALLOSO, AlloSource; COR, coronal (view); SAG, sagittal (view).)

attached 5.9 mm inferior to the articular cartilage on the posteromedial tibial plateau. Regarding the posterolateral side, another study found the average meniscotibial attachment to the posteroinferior aspect of the meniscus to be 12.8 mm from the superior surface.[25] It is routine for adult studies to report the meniscotibial ligament insertion from the articular surface because the physeal plate is fully closed and thus not clinically relevant for surgical planning. However, in the skeletally immature population, it is imperative to have awareness of the proximity to the physis to avoid growth plate injury during surgical fixation. This anatomic information about the meniscus and meniscotibial ligament relations will apply to skeletally mature patients as well (Fig 3). Meniscotibial ligament repair has been described for ramp lesions and may be used for meniscal transplant cases.[1,3,6,7,9,10]

Traditional meniscal repair consists of outside-in, inside-out, and all-inside techniques that suture the meniscus and joint capsule tissues together and may be considered the gold standard by some meniscal surgeons.[26-28] These techniques may allow for excellent compression of meniscal tears but may impact the normal meniscal knee anatomy and function by closing the normal space and separation between the posterior capsule and the meniscus and/or meniscotibial ligament complex (Fig 5). Whether this has a negative impact on meniscal healing, biomechanical function, or healing rates is not clear, and additional study is warranted. Sonnery-Cottet et al.[29] have emphasized this relation between the meniscotibial ligament cul-de-sac and the knee capsule in their research. More anatomic approaches to meniscal tear repair and transplantation that consider the meniscotibial ligaments may also influence the biomechanical role of the meniscus in normal knee function.[26,27,29]

Meniscotibial ligament function and anatomy are not well described in the literature, and some of the proposed factors regarding meniscal stability, meniscotibial ligament function, and concerns about "peripheralization" after suture repair to the joint capsule are based on surgical observations after meniscal repair and transplantation. Stabilization of some meniscal regions to the meniscotibial ligament structure may offer more anatomic repair of meniscal tissue by avoiding closing the space between the joint capsule and the peripheral meniscus (Fig 6). Suture-based meniscal repair compression techniques that include the meniscotibial ligaments but avoid tethering of the meniscus to the joint capsule may also allow for more natural meniscal movement with respect to the tibial plateau. In cases in which sutures and/or anchors may be used to duplicate meniscotibial ligament function, the relations of the physis and meniscus will need to be considered in

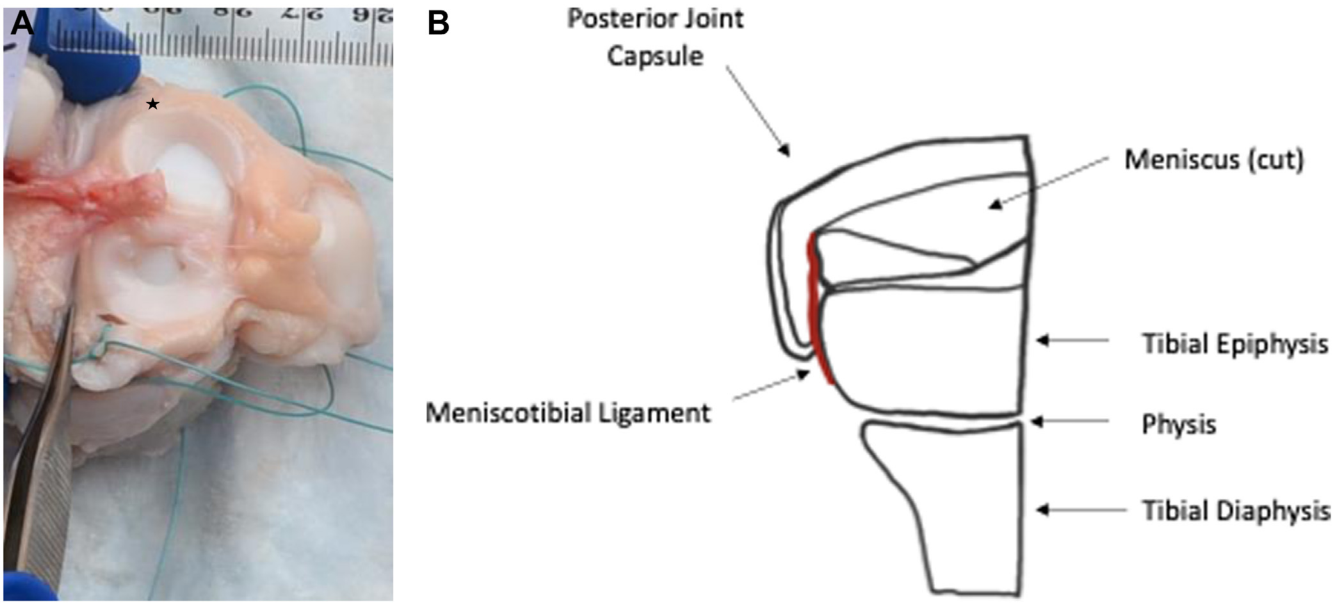


**Fig 3.** (A) One-year-old female cadaveric right knee specimen. It should be noted that the chondral surface of the patella to orient the right side of the images is anterior on the specimen. The axial view depicts the tibial plateau and meniscotibial ligament relation to the meniscus and capsule. The green suture is attached to the popliteus tendon above the lateral meniscus. The tip of the Adson forceps is in the posterior recess/cul-de-sac space between the posterior meniscus/meniscotibial ligament and the posterior joint capsule behind the lateral meniscus. The star denotes the medial meniscal meniscotibial ligaments. (B) Cross section (sagittal-plane anatomy) of tibial plateau showing meniscotibial ligament attachment (red) in relation to tibial physis. One should note the space/recess/cul-de-sac between the meniscotibial ligaments and the capsule in the posterior region of the medial and lateral menisci.

skeletally immature patients, a group increasingly recognized to sustain meniscal injury.[30] The unique anatomy of the pediatric knee may require a different anatomic, surgical approach in which consideration of the location of the physis is relevant to the development of new surgical techniques. Techniques that involve repair of the coronary ligament structures rather than repair of the torn meniscus to the capsule may need to consider physeal proximity in older pediatric and younger adolescent patients with significant growth remaining. Future studies should expand this data set to include specimens in adolescent or young adult age groups as these account for a large proportion of meniscal repair operations.

## Limitations

This study has several limitations. There was a non-normal age group distribution among the specimens. With 10 of the 14 specimens aged younger than 2 years, the tissue specimens represent younger knees when

**Table 1.** Distance from Medial and Lateral Meniscal Meniscotibial Ligaments to Tibial Physis

| | Age < 1 yr | | Age 1 yr | | Age 2 yr | | Age 10 yr | | Age 11 yr | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pin Location | Median, mm | IQR, mm | Median, mm | IQR, mm | Median, mm | IQR, mm | Median, mm | IQR, mm | Median, mm | IQR, mm |
| Medial meniscus | | | | | | | | | | |
| Posterior root pin | 7.3 | 5.7 to 7.8 | −1.8 | −1.8 to −1.8 | 1.8 | 1.8 to 1.8 | 11.6 | 8.1 to 15.2 | 8.6 | 7.8 to 9.3 |
| 6-O'Clock pin | 3.5 | 1.9 to 5.4 | | | 3.5 | 3.5 to 3.5 | 4.1 | 3.1 to 5.1 | 9.0 | 7.1 to 10.9 |
| 3-/9-O'Clock pin | 3.6 | 2.5 to 4.4 | 3.4 | 3.4 to 3.4 | 3.8 | 3.8 to 3.8 | 7.0 | 6.2 to 7.7 | 6.9 | 4.5 to 9.2 |
| 12-O'Clock pin | 5.9 | 3.7 to 6.8 | 5.2 | 5.2 to 5.2 | 1.8 | 1.8 to 1.8 | 5.9 | 5.5 to 6.2 | 9.7 | 9.5 to 10.0 |
| Anterior root pin | 5.7 | 4.5 to 6.5 | 5.7 | 5.7 to 5.7 | 5.3 | 5.3 to 5.3 | 9.8 | 9.7 to 9.9 | 10.6 | 10.1 to 11.1 |
| Lateral meniscus | | | | | | | | | | |
| Posterior root pin | 6.4 | 2.1 to 7.5 | 0.7 | 0.7 to 0.7 | 1.8 | 1.8 to 1.8 | 4.2 | 4.0 to 4.4 | 2.0 | 1.5 to 2.5 |
| 6-O'Clock pin | 3.9 | 0 to 6.2 | | | 1.5 | 1.5 to 1.5 | 5.6 | 5.6 to 5.6 | 6.1 | 5.4 to 6.8 |
| 3-/9-O'Clock pin | 4.1 | 2.4 to 5.5 | | | 2.2 | 2.2 to 2.2 | 13.2 | 12.3 to 14.0 | 15.1 | 14.7 to 15.4 |
| 12-O'Clock pin | 4.3 | 2.9 to 5.7 | | | 5.3 | 5.3 to 5.3 | 15.2 | 14.9 to 15.4 | 19.3 | 19.1 to 19.6 |
| Anterior root pin | 6.4 | 5.8 to 7.2 | 4.4 | 4.4 to 4.4 | 5.6 | 5.6 to 5.6 | 13.5 | 13.5 to 13.5 | 17.5 | 16.7 to 18.4 |

IQR, interquartile range.

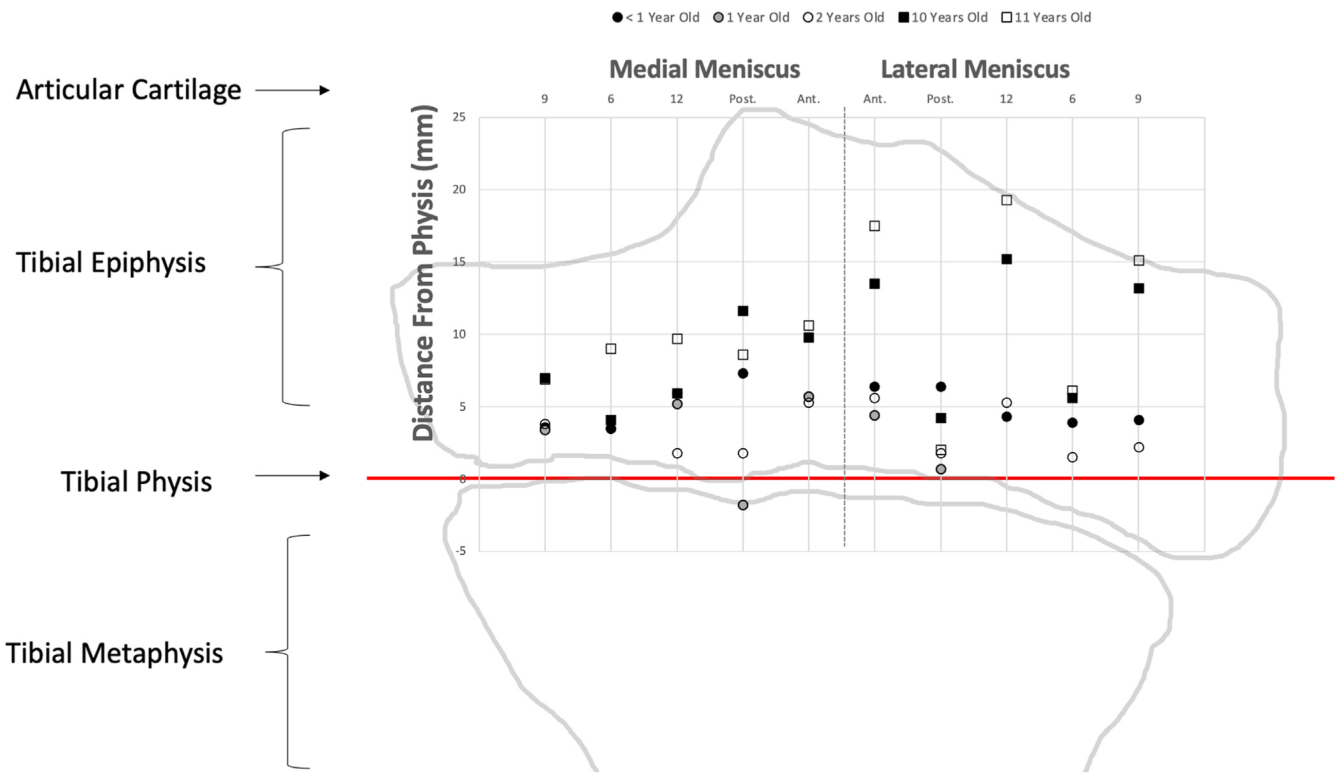


**Fig 4.** Median distance (in millimeters) from physis to meniscotibial ligament pins on medial and lateral menisci. (Ant, anterior; Post, posterior.)

compared with the age of pediatric patients who typically undergo meniscal repair or transplantation. However, access to pediatric tissue is exceptionally rare, making studies of this nature very difficult to complete with a larger number of subjects equally balanced across a wide age range. We included the younger

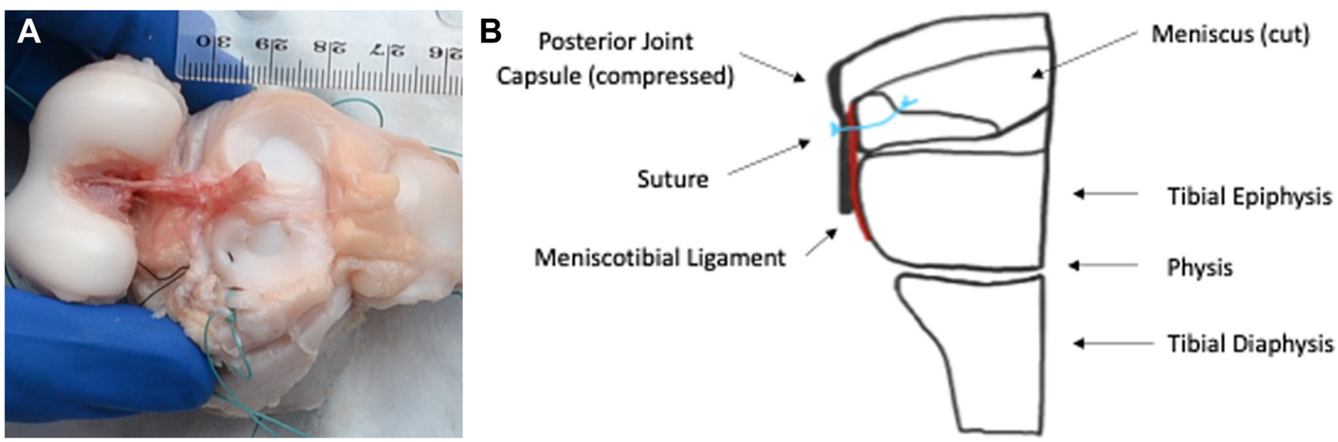


**Fig 5.** (A) One-year old female cadaveric right knee specimen. It should be noted that the chondral surface of the patella to orient the right side of the images is anterior on the specimen. The axial view depicts the tibial plateau and meniscotibial relation to the meniscus and capsule, after a horizontal mattress suture (black suture material) has been placed, simulating an inside-out suture process. The ends of the suture lie posterior, beyond the knot tied on the outer surface of the joint capsule. The suture traverses the meniscus, meniscotibial ligaments, and posterior joint capsule in the lateral compartment. This suture pattern closes the natural recess/cul-de-sac space behind the meniscus that separates the posterior aspect of the meniscus/meniscotibial ligament complex and the more posterior joint capsule. (B) Cross section (sagittal-plane anatomy) of tibial plateau showing meniscal suture (blue) through meniscotibial ligament (red) and capsule, closing the joint space between the posterior meniscus and meniscotibial ligament and the capsule and tethering these normally independently mobile structures.

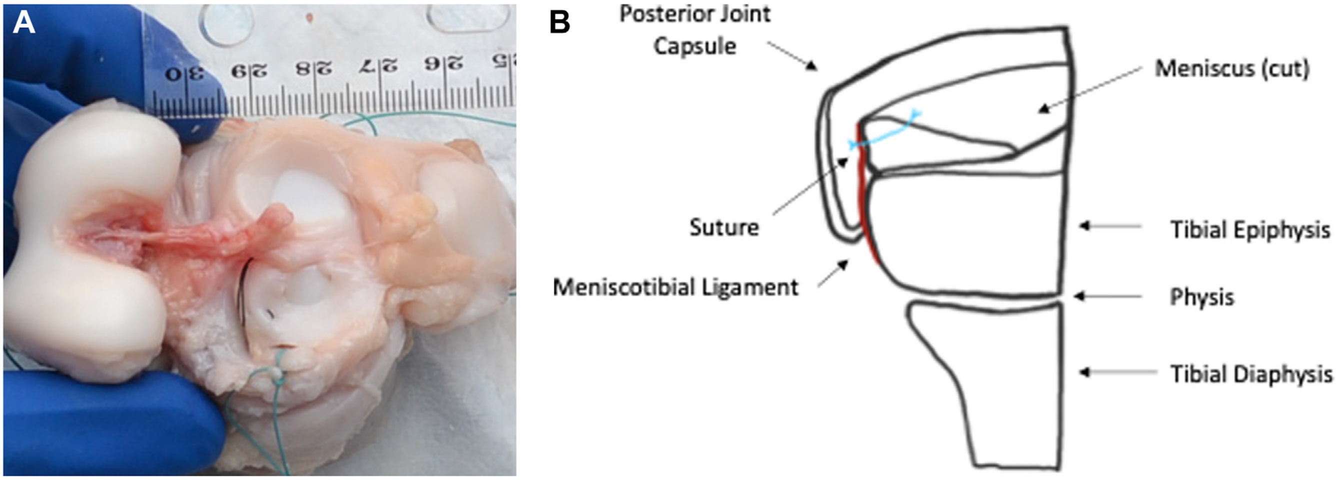


**Fig 6.** (A) One-year old female cadaveric specimen. The axial view depicts the tibial plateau and meniscotibial relation to the meniscus and capsule (suture from meniscus to meniscotibial ligament only). The suture does not traverse the cul-de-sac space, and it is not attached to the posterior knee capsule, preserving the posterior recess/cul-de-sac space and the motion planes between the posterior joint capsule and the posterior meniscotibial ligaments and meniscus. (B) Cross section (sagittal-plane anatomy) of tibial plateau showing tibial plateau and meniscotibial relation to meniscus and capsule (suture from meniscus to meniscotibial ligament only). One should note that the suture does not traverse the cul-de-sac space, and it is not attached to the posterior knee capsule, preserving the posterior recess/cul-de-sac space and the motion planes between these structures. (ALLOSO, AlloSource; COR, coronal (view); SAG, sagittal (view); red, meniscotibial ligament; blue, suture.)

specimens to provide perspective on growth of the knee and development of the meniscotibial ligaments and meniscus. The general trend of increasing distance (with variability) and overlap of distances between ages (particularly posteriorly) could be due to dissection difficulty in the posterior region or could be an indication of true variability and an indication that age-related distance correlation could decrease with a larger sample size.

## Conclusions

In this anatomic study of pediatric knees, we observed a distinct recess/cul-de-sac space between the posterior knee capsule and meniscal attachments in all specimens. This defines a distinct plane between the posterior knee capsule and the meniscotibial ligament complex, with a distance between the physis and meniscotibial ligament capsular attachments that increases with age.

## Disclosures

The authors report the following potential conflicts of interest or sources of funding: Y-M.Y. is a consultant for Smith & Nephew, outside the submitted work. M.C. is a consultant for Wishbone Orthopedics and owns stock or stock options in OssoVR, outside the submitted work. T.J.G. reports a Pediatric Orthopedic Society of North America (POSNA) Arthur Heune Award grant for multicenter study of tibial spine fractures ($30,000, Children's Hospital of Philadelphia, Data Coordinating Center), outside the submitted work; and is co-principal investigator on a patent for an anterior cruciate ligament fixation device that was developed by Orthopediatrics 10 years ago (the author received travel reimbursement and some nominal fees to provide advice but does not receive funds from that device), outside the submitted work. H.B.E. is a board member of Pediatric Research in Sports Medicine and Texas Orthopedic Alliance, outside the submitted work; is an unpaid consultant for Smith & Nephew, outside the submitted work; provides expert testimony for Kershaw Anderson, outside the submitted work; receives grants or has grants pending from POSNA and American Academy of Orthopaedic Surgeons, outside the submitted work; is a paid speaker for Orthopediatrics, outside the submitted work; and receives educational support from Arthrex, outside the submitted work. D.G. reports board membership with Pediatric Research in Sports Medicine, POSNA, American Academy of Orthopaedic Surgeons, *Current Opinion in Pediatrics*, NY County Medical Society, New York State Society of Orthopaedic Surgeons, and Patellofemoral Foundation, outside the submitted work; is a consultant for Arthrex, outside the submitted work; reports patents with Arthrex and Pega Medical, outside the submitted work; receives payment for development of educational presentations from AO Trauma International and Arthrex, outside the submitted work; and reports other support from *Current Opinion in Pediatrics* and Wolters Kluwer Health—Lippincott Williams & Wilkins, outside the submitted work. P.D.F. is a consultant for Wishbone Orthopedics and owns stock or stock options in OssoVR,

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