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Morphological Study of the Transverse Ligament of Knee Joint in Embalmed Cadavers

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SUMMARY

Background. The aim was to study the morphological pattern and dimensions of the transverse genicular ligament (TL) in adult embalmed knee joints.
Methods. The present study utilized 50 adult embalmed human cadaveric knee joints.
Results. The TL was observed in 90% of the specimens of this study. It was extending from the medial meniscus (MM) anterior horn to the lateral meniscus (LM) anterior margin in 82% of cases. In 4% cases, the TL was attaching between the anterior margins of the MM and LM. In one specimen (2%), the TL was implanting into the anterior horn of MM and the capsule of the knee joint laterally. The double lateral attachment of the TL was observed in 2% of the cases. The length, width and thickness of the TL were 30.38 ± 2.38 mm, 29.23 ± 3.7 mm, 2.8 ± 0.79 mm, 2.56 ± 0.68 mm, 1.94 ± 0.53 and 2.25 ± 0.56 mm over the right and left sides, respectively. The distance of the TL from the anterior cruciate ligament was 2.4 ± 1.2 mm and 2.24 ± 1.12 mm, and its distance from the tibial tuberosity was 40.24 ± 1.94 mm and 39.11 ± 1.94 mm at the right and left sides respectively.
Conclusions. This anatomical investigation has offered extra details about the attachment patterns and dimensions of TL. These details are essential to the arthroscopic surgeons during the reconstruction procedures of the cruciate ligaments of the knee joint.

KEY WORDS

Anatomic variation; anterior cruciate ligament reconstruction; arthroscopy; knee; meniscus.

BACKGROUND

Transverse ligament (TL) of the knee joint is also known as the transverse inter-meniscal ligament, which runs transversely across the anterior aspect of the knee. Embryologically, the TL is considered as the vestigial part of the mesenchyme, which forms the menisci. Interestingly, the TL was also studied in detail in tetrapods like *Crocodilus* (1), *Eryops megacephalus* (2), domestic fowl and grey squirrel (3). It was also reported that various other primates are found to have the TL, along with the humans. The TL starts developing during the 7th week of intrauterine life and is observed to be cellular, until the completion of the embryonic stage (4). It provides stability to the medial and lateral menisci, and prevents them from the displacement. It plays an instrumental role during the initial phase of flexion of the knee joint, as it reduces the pressure over the ventral region of the medial meniscus (MM) (5). It also has limiting effect over the antero-posterior expedi-

tion of the MM anterior horn during the initial knee flexion (5). The cadaveric studies suggest that, TL inhibits the posterior translation of the MM anterior horn in the first 30° of the knee flexion. However, it was also described that, TL has no influence on the mobility of meniscus at the extension and above 60° flexion (5). It was reported that, this intracapsular band like ligament is often variable in its attachments (6). The TL is among the neglected structures in the ultrasound examinations of the knee as it is not assessed in it (7). This ligament can be misinterpreted as the anterior horn meniscal tear in the magnetic resonance imaging (MRI) film (8). Sintzoff *et al*. (9) reported that, TL is a normal anatomical variant, which can be identified in the lateral view radiographs of the knee. But in the radiograph, it is seen only if there is enough fat around, which creates the contrast, however it is very well visualized in the MRI films.

It was described that the TL coincides with the anterior edge of the anterior cruciate ligament (ACL) at the tibial footprint over the sagittal plane. The TL can be considered as a landmark during the anatomical ACL reconstruction during the tibial tunnel positioning (10). The morphological knowledge of TL is essential for the procedures like arthroscopic surgical repair and allograft meniscal transplantation (11). During the arthroscopic surgery, it is advisable to maintain the attachments of the TL, in order to prevent the degeneration of the articular cartilages of knee joint (12). Because of the close proximity of the TL to the menisci, there are fibre bundles which pass in vertical, horizontal and oblique directions, occupying a larger area over the meniscal anterior margin (4). The variability over the insertion of the MM anterior horn need to be assessed, particularly during the arthroscopic ACL reconstruction, which is done very close to the topography of the TL (11). It was also opined that, there is a higher frequency of MM tears in patients with the TL attaching to the MM, than without the attachment (13). It was opined that the detailed morphology of TL is not clearly studied in the literature (3) and particularly, there are not many cadaveric studies of this subject are available. In this context, the aim of this study was to observe the topographical pattern and dimensions of the TL in adult embalmed knee joints. The objectives were to measure its prevalence, length, width, thickness, topographical relationship with the tibial tuberosity (TT) and the tibial insertion of the anterior cruciate ligament (ACL).

MATERIALS AND METHODS

The present study included 50 adult embalmed cadaveric knee joints, which were available at the department of anatomy. Among them 25 belonged to the right side and 25 were left sided. The age and gender of the specimens were not taken into consideration. The knee joints, which exhibited obvious pathological changes and congenital anomalies were excluded from the present study. The TL was exposed by cutting the patellar ligament, capsular ligament and collateral ligaments of the knee joint. The ACL was cut at its midpoint and this exposed the tibial plateau area, clearly. The intracapsular ligaments of the knee joint, which are present over the tibial plateau are schematically represented in **figure 1**.

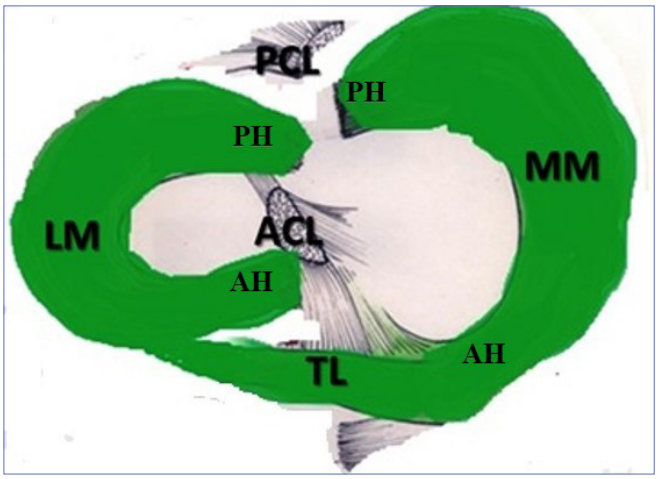

Figure 1. Schematic representation of the intracapsular ligaments of the knee joint.

MM: medial meniscus; LM: lateral meniscus; AH: anterior horn; PH: posterior horn; TL: transverse ligament; ACL: anterior cruciate ligament; PCL: posterior cruciate ligament.

A digital Vernier calliper was used for performing the measurements and they were performed by the same person in order to prevent the inter observer variation. The length of TL was measured between the medial and lateral most parts of its attachment. The width and thickness were measured at the mid-point of the TL. Distance between the TL and the anterior most part of the ACL at its tibial attachment was measured. The mid-point of the tibial tuberosity (TT) was also measured from the midpoint of the TL. The data were represented in millimetre and as mean ± standard deviation. The recent version of SPSS software was utilized for performing the statistical analysis between the right and left sided measurements. The paired t-test was applied and the difference was considered as statistically significant if the P-value is smaller than 0.05. The present study was approved by the institutional Ethics Committee of Kasturba Medical College, Mangalore on November 18, 2021 (protocol number IEC KMC MLR 11/2021/351) and this study was performed as per the guidelines of declaration of Helsinki (14).

RESULTS

The TL was observed in 45 cadaveric knee joints (90%), and it was absent in 5 (10%) of our specimens (**figure 2**). It was extending from MM anterior horn to the LM anterior margin in 82% cases (**figure 3**). In 4% cases, the TL was attaching between the anterior margins of the MM and LM (**figure 4**). In one specimen (2%), the TL was attaching to the MM anterior horn and the capsule of the knee joint laterally. Double lateral attachment of the TL was observed in 2% of the cases (**figure 5**). The morphological variants of the TL, which are observed in this study are represented in **figure 6**. The frequency of presence of TL of this study was compared with other sample population groups and is represented in **table I**.

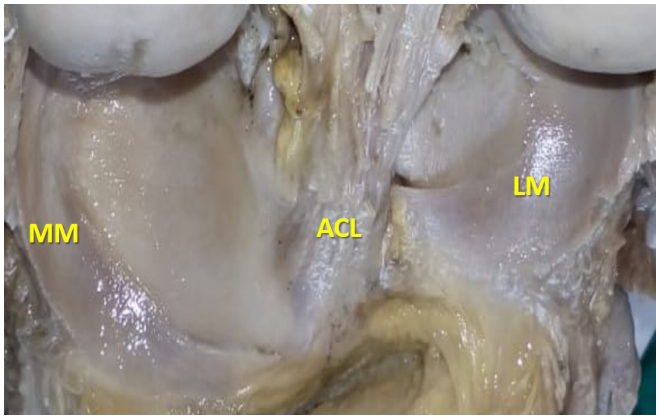

Figure 2. Left cadaveric knee joint showing the absence of transverse ligament (10%).
MM: medial meniscus; LM: lateral meniscus; ACL: anterior cruciate ligament.

Figure 3. Knee joint showing the attachment of the TL from the anterior horn of MM to the anterior margin of LM.
MM: medial meniscus; LM: lateral meniscus; TL: transverse ligament.

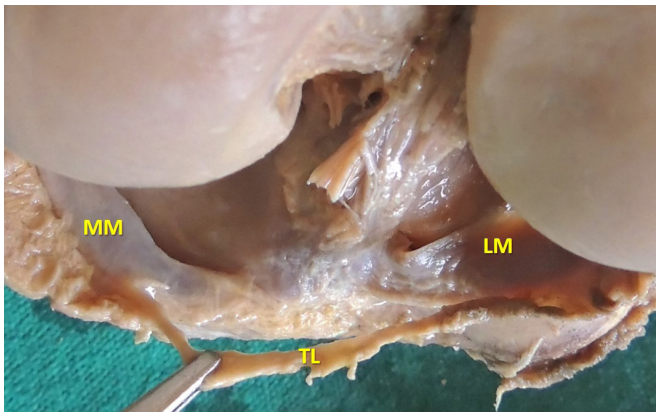

Figure 4. Knee joint showing the attachment of the TL from the anterior margin of MM to anterior margin of LM (4%).
MM: medial meniscus; LM: lateral meniscus; TL: transverse ligament.

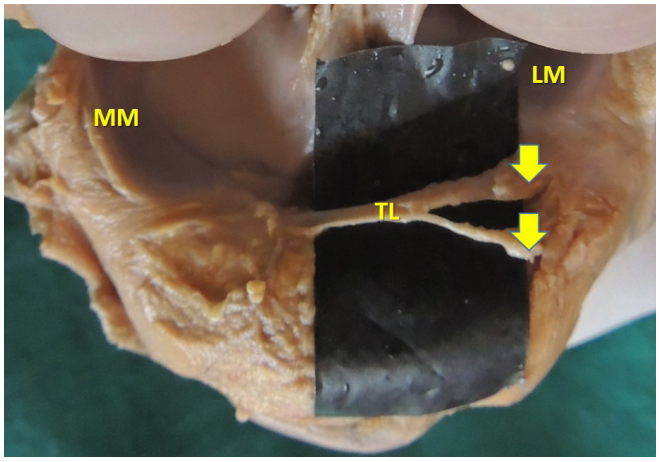

Figure 5. Adult cadaveric left knee joint showing the double lateral attachment (↓↓) of the transverse ligament (2%).
MM: medial meniscus; LM: lateral meniscus; TL: transverse ligament.

The length, width and thickness of the TL were 30.38 ± 2.38 mm, 29.23 ± 3.7 mm, 2.8 ± 0.79 mm, 2.56 ± 0.68 mm, 1.94 ± 0.53 and 2.25 ± 0.56 mm over the right and left sides respectively (**figure 7**). There was no difference, which was observed statistically significant (**table II**), over the comparison between the left and right sides in any of the parameters measured ($p > 0.05$). According to our study, the distance of the TL from the tibial attachment of the ACL was 2.4 ± 1.2 mm and 2.24 ± 1.12 mm over the right and left knee joints. Its distance from the tibial tuberosity (TT) was 40.24 ± 1.94 mm and 39.11 ± 1.94 mm at the right and left sided specimens.

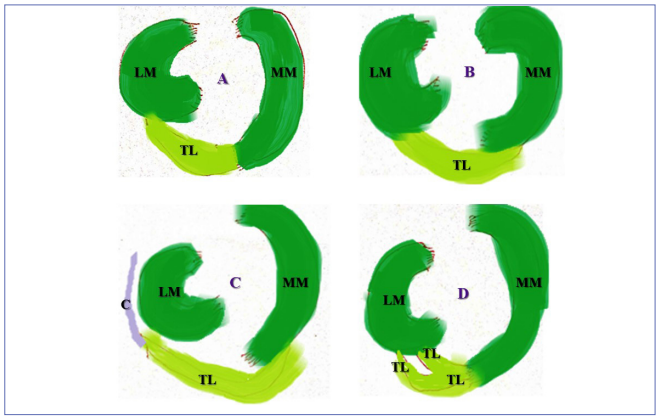

Figure 6. Schematic representation of the variations of TL, observed in this study.

(A) TL extending from anterior horn of MM to the anterior margin of LM; **(B)** TL extending from anterior margin of MM to the anterior margin of LM; **(C)** TL extending from anterior margin of MM to the capsule of the knee joint, laterally; **(D)** Bifid TL at the lateral end.

Table I. Comparison of frequency of TL of this study with other populations.

Authors	Population	Frequency
Nelson and LaPrade	North American	94%
Pauzat	French	100%
Berlet and Fowler	Canadian	71%
Kohn and Moreno	German	69%
Zivanovic	British	58%
Aydingöz *et al.*	Turkish	53%
Sintzoff *et al.*	Belgian	58%
Vaseie *et al.*	Iranian	53.9%
Present study	Indian	90%

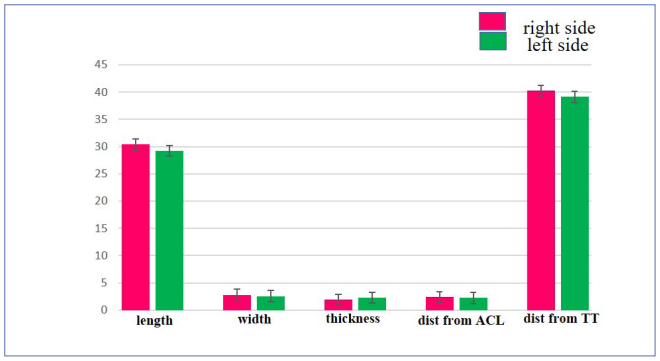

Figure 7. Side based comparison of the morphometric parameters of TL (n = 50).

ACL: anterior cruciate ligament; TT: tibial tuberosity; measurements are in mm ± SD, paired t test, $p > 0.05$.

Table II. Side based comparison of the morphometric parameters of transverse ligament (n = 50).

Parameter	Right side (n = 25)	Left side (n = 25)
Length	30.38 ± 2.38	29.23 ± 3.7
Width	2.8 ± 0.79	2.56 ± 0.68
Thickness	1.94 ± 0.53	2.25 ± 0.56
Distance from ACL	2.4 ± 1.2	2.24 ± 1.12
Distance from TT	40.24 ± 1.94	39.11 ± 1.94

ACL: anterior cruciate ligament; TT: tibial tuberosity; measurements are in mm ± SD; paired t-test; $p > 0.05$.

DISCUSSION

Due to the advanced technology, the knee joint can be accessed precisely with the radiological methods. However, the radiological studies require anatomical data for the comparison and better understanding. The literature search did not reveal many studies about the anatomical findings of the intra and extracapsular knee ligaments. The TL is an extra-capsular ligament, which is found superficial to the capsule of knee joint at the infra-patellar location (15). The present study endorses the opinion of Berlet and Fowler (16) that, the TL was observed within or overhung by the retro patellar fat. It is believed that the anatomical variations of this ligament are quiet common, since it is extracapsular. During the interpretation of MRI of the knee, it is required to know the morphological variants of the intracapsular ligaments. The morphological variations of the meniscus and its associated structures can mimic the meniscal tears to an inexperienced radiologist. The correct radiological reporting is important to avoid the incorrect diagnosis and management.

Higgins (15) reported that the prevalence of TL is extremely variable and in various studies it ranges between 55-100%. In their 4% cases, the TL was membranous, fibrous in 10% cases and in 15% cases, strong bundle of fibres (15). Pauzat (17) described that the TL is present in 100% cases. In contrast, Tubbs *et al.* (3) identified the TL in only 55% of their lower limb specimens. The TL was found in 87.7% cases in our previous study, which involved the human embalmed fetuses (18). This present study from adult cadaveric knee joints, observed the TL in 90% cases. This is a higher frequency in comparison to the prevalence in other population subgroups (**table I**). However, this much higher frequency was previously reported by Pauzat (17) in French population, and by Nelson and LaPrade (11) in North Americans. However, the lesser frequency of 53% was reported by Aydingöz *et al.* (19) in Turkish population.

De Abreu *et al.* (13) reported that, there is a strong association between the attachment of the TL to the MM and the tears of MM. The variant attachment of the TL into the MM can be attributed as an aetiological factor. Ohkoshi *et al.* (20) observed that, 5% of their specimens had attachment of the anterior horn of MM directly into the TL. Nelson and LaPrade (11), previously observed that the TL was attaching to the anterior horn of MM in 24% cases. It is interesting to note that, in these cases, TL was the lonely attachment for the MM anterior horn. Nelson and LaPrade (11) also classified the TL into three varieties, the type 1 pattern which had attachment of TL between the anterior horn of MM and the anterior margin of LM. They could observe this type of morphology in just 46% of their cases. But in our study, this type 1 morphology was higher, and it was observed in majority of our specimens (82% cases). Our study endorses the classical textbook explanation of the TL, which is the type 1 as per Nelson and LaPrade (11). The type 2 variety had attachment between the anterior margin of MM and laterally to the joint capsule, which was observed in 26% of our cases. The type 3 pattern had both sides attachment to the knee capsule. Aydingöz *et al.* (19) classified the TL into type A, type B and type C, which is slightly different from that of Nelson and LaPrade (11). In the specimens of De Abreu *et al.* (13), TL attached to the MM in 83.3% cases, among them 93.3% attached to the middle portion of anterior horn and the outer part of it in the remaining 6.7% cases. It was attaching to the LM in 91.6% of their cases, which included 94% attaching to the exterior of the anterior horn and into the main area of the anterior horn in 6% of cases. In the present study, we did not particularly classify the TL into types, because of the smaller sample size. This can be considered as one of the limitations of this study. In the present study, the splitting morphology of TL was observed in 2% of cases. This is as per the previous reports from the other population groups. De Abreu *et al.* (13) observed bifid TL in 3 of their cases, and Tubbs *et al.* (3) observed it in 2 cases (3.7%). Zivanovic (21) identified double TL in 6% of his cases.

According to Nelson and LaPrade (11), the average length and mid-substance width of TL is 33 mm and 3.3 mm respectively. According to Tubbs *et al.* (3), the mean length and width of TL were 35.4 mm and 2.5 mm, respectively. In the present study, the TL length was 30.38 ± 2.38 mm and 29.23 ± 3.7 mm over the right and left sides. The studies from American population, observed the longer TL, because the Caucasians are usually tall and robust. Relatively, they may have a longer dimension of the TL. Tubbs *et al.* (3) observed that, the average thickness of TL was to be 2.5 mm and according to Muhle (5), it was 2.7 mm. De Abreu *et al.* (13) reported that the thickness of TL ranges between 1 and 4.4 mm (2 ± 0.9 mm). The mean length of the TL in embalmed human foetuses measured 3.7 ± 1.4 mm in male and 3.7 ± 1.6 mm in female (18).

According to Nelson and LaPrade (11), the average distance of the TL from the tibial end of the ACL was 7.8 mm. In the present study, we observed a very short distance between the tibial insertion of ACL and the TL, which was less than 2.5 mm. However, this is similar to the findings of Tubbs *et al.* (3), who observed this distance to be 2.5 mm. The present study endorses the opinion of Nelson and LaPrade (11) that, the TL may be prone to tears during the procedures like tibial tunnel preparation for the ACL reconstruction. Nelson and LaPrade (11) suggested about the prevention of injury to the TL, however the consequences of injury to the TL are yet to be studied. Tubbs *et al.* (3) reported the mean distance of TL to the midpoint of TT, which was 40.5 mm. In the present study, this dimension was 40.24 ± 1.94 mm and 39.11 ± 1.94 mm at the right and left sided specimens. This is almost similar to the findings of Tubbs *et al.* (3). Our study agrees with the findings of Tubbs *et al.* (3) that, there are no statistically significant difference among the dimensions of TL of right and left sided specimens.

The clear knowledge about the attachment patterns and dimensions of the knee ligaments will help in making the accurate radio diagnosis and management. This will also avoid the arthroscopy and subsequent accidental ligament injuries. This information is also necessary to the clinical embryologists, morphological and anthropological researchers. The dimensions of the TL are advantageous to understand the biomechanics concerning the role of the TL (11). The morphological and topographic anatomy of TL is essential to understand the variability in the insertion of anterior horn of the menisci (11). The iatrogenic injury to the TL can be minimized during the arthroscopic surgeries like ACL reconstruction. The differentiation of osteochondral fragments, meniscal tears and pseudo-tears from that of the anatomical variants of the meniscus is important (22). The morphological information of normal and variant anatomy of the ligaments of knee joint is essential to prevent the incorrect diagnosis (23). The allograft meniscal transplantation will not retain the attachment of TL (3), however, few surgeons have tried to conserve this ligament (12). Some authors considered the TL as an anatomically variant structure (24).

The variable insertion of the TL into the LM anterior horn can mimic as the tear of the meniscus in the MRI examination. It was reported that, this pseudo-tear sign due to the TL has a frequency of 5.9% (25). The prior knowledge about this pseudo-tear of meniscus can prevent the arthroscopic surgical procedure, which is unnecessary in this variation (26). The TL is not assessed in routine ultrasound examina-

tions of the knee and the MRI is highly suggested (7). The topography and direction of the pseudo-tears along with the continuous views of the sagittal and the coronal planes of the MRI can help in the accurate diagnosis (27). The understanding of the normal anatomical variations of the inter meniscal ligaments can prevent the unwanted procedures and subsequent iatrogenic injury (28).

Since this study utilized embalmed specimens, there may be slight bias in the morphometric data of the present study. This can be considered as another limitation of this study. The future implication of this study is that, the TL can also be measured *in vivo* by utilizing the MRI films and we can compare the data of this present study with the *in vivo* morphometric data.

CONCLUSIONS

The present study provided additional information about the attachments of the TL, along with their dimensions like length, width and thickness. The topographical location of the TL from the ACL insertion in the tibial plateau and the TT is also determined in this study. It is believed that the morphometric and morphological records of this anatomical investigation is important to the operating arthroscopic surgeons in their surgical practice.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

BVM: conceptualization and design, data analysis and results interpretation, draft of the manuscript. VSN, RG, BVM, NPB: data collection. SSN, MMP, RV, LVP: revision. MMP, RV: handled the remaining aspects. All authors: results revision and final approval.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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