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Original Research Article

Morphology of Distal Tendon of Semimembranosus; Its Undescribed Insertion with Functional and Clinical Significance

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Abstract:

Background: Semimembranosus muscle is a well-recognised component of posteromedial corner of knee playing the role of stabilizer of the joint and restraining unwanted movements. Though the distal tendon of SM has been studied by many workers still there is a persistent confusion about the insertion of this tendon.

Aim: The present study throws light on the available information that can enhance the understanding of biomechanical role, radiographic imaging and clinical studies related to the importance of the structures in the posteromedial corner of the knee.

Setting and Design: The study was conducted in the department of Anatomy for a period of two and a half years.

Material and Methods: In the present study upper ends of 80 tibia were examined and presence of prominent edges, tubercles, vascular foraminas and rough areas in the groove were recorded and photographed. The dimensions of semimembranosus tuberosity (SMTb) were measured. Variable shapes of SMTb, prominence of ridges, tubercles and vascular foraminas were noted. The dissection of distal tendon of SM was carried out in 22 limbs.

Statistical Analysis Used: Chi- square test was applied to the various parameters included in the study and the 'p- value' was estimated to find the correlation.

Result and Conclusion: The Posterior surface of medial condyle of Tibia had a groove which was deep in 62.4%. In approximately 95% tibias 4-7 vascular foramina were present in the groove. The tubercle though presents on both the margins, but its incidence was higher on the lower margin of the groove in 43%. The SMTb was found in all the tibias examined and in almost 1/4th it was very prominent. In 54.9% it was triangular in shape, in 30% it was semilunar and in rest it was quadrangular. Vascular foramina, Vertical ridges and tubercles were also observed. In cadaveric dissection the distal part of SMT in approx. 73% limbs had a triangular expansion and in the remaining it was distinctly bifid. In 13.63% there was a Triangular flap connecting the tendon entering in to the groove and the vertical component reaching the tuberosity.

Keywords: Posteromedial Corner of Knee, Distal Semimembranosus Tendon, Semimembranosus Tuberosity.

Introduction

Semimembranosus (SM) muscle is a well-recognised part of posteromedial corner (PMC) of knee which has an important role to play as the stabilizer of the joint and restraining unwanted movements. [1] The PMC has been referred to as the semimembranosus corner due to the important role the semimembranosus tendon has in providing dynamic stability to the knee. [2] The distal tendon of SM (SMT) has been studied in great details by many workers and described in various textbooks and journals. Inspite of this there is a persistent confusion about the number of expansions of the tendon as well as presence and role of tendon sheath. Very few have mentioned about the tendon sheath and expansion arising from it. In the recent publication this has been dealt with in great detail by Joshi et.al. (2021). [3] When the posterior surface of upper end of tibia was examined, we not only observed a groove on the posterior surface of the medial condyle of tibia but also a rough area which was present inferolateral to the beginning of the groove: (a) We studied the variations of the depth of the groove, presence of tubercle and vascular foramina and the prominence of the edges of the groove; (b) The variations in size and shape of the rough area - semimembranosus tuberosity (SMTb).Their constant presence prompted us to carry out a detailed study of these two features on

the tibia which was further verified by carrying out dissection of the SMT in 22 limbs. The rough area has been mentioned by few workers & shown in a few illustrations. [4,5,6]

Material and Methods

In the present study upper ends of 80 tibia were examined [Right-42; Left-38] and presence of prominent edges, tubercles, vascular foraminas and rough areas in the groove were recorded and photographed. The height and width of the SMTb were measured with the digital vernier calliper (Fig: 1A). We observed variable shapes of SMTb, the prominence of ridges, tubercles and vascular foraminas on it which were noted and photographed.

The dissection of distal tendon of SM was carried out in 22 limbs [Right 14; Left 8]. To confirm these findings the posteromedial part of the knee & distal part of SMT were dissected. The tendon of SMT was cut & reflected inferiorly. The superficial surface & posterior margin of medial collateral ligament (MCL) were exposed. After splitting the sheath; the tendon of SM was traced inferiorly to its attachment. The lateral thick part of SMT was vertically directed and was spreading to get attached on to SMTb.

The medial margin of SMT formed a tendon which bent at right angle and was passing deep to MCL. This part of the tendon was found to be lodged in the groove on the posteromedial surface of medial condyle of tibia. The variations in the insertion of the distal SMT both in the groove and SMTb were noted and photographed.

Approval from the Institutional Ethics Committee was taken (IEC no: SAIMS/IEC/25/22). Statistical analysis was performed by using the 'chi square test' and the p- value was calculated.

Observations:

A. Bone- Posterior surface of medial condyle of Tibia:

1. Groove-

i) Depth: In the majority of the bones (62.4%) the groove was shallow (Fig: 1B) on both the sides. In 18.6% (Rt.: 21.42%; Lt 15.78%) it was deep (Fig: 1A); and medium in 16.35%. In 2 Lt. tibias (2.5%) the groove was absent. The p-value is insignificant being > 0.05. (Table-1).

ii) Vascular foramina: In approx. 95% tibias vascular foramina were present in the groove. In about 76% tibias the number of foramina was between 1-4; in 18.85% there were more than 5 vascular foramina in the groove and in approx. 5% no vascular foramina were found (Fig: 1C, 2A, 3A). The p-value is insignificant being > 0.05 (Table-2).

iii) **Margins:** Both margins of the groove were found to be prominent in 22.8%. In 34.58% the upper margin was prominent (Fig: 1A) and in 11.46% the inferior margin was prominent. In the remaining the margins were not prominent (Fig: 1C). The p-value is insignificant being > 0.05 (Table-3).

iv) **Tubercle:** The tubercle though presents on both the margins, but its incidence was higher on the lower margin (43%) of the groove (Fig: 1A, 2A, 2B). The p-value is insignificant being > 0.05 (Table-4).

2. SM Tuberosity:

i) **Incidence**: SMTb was found in all the tibias examined. Based in the qualitative assessment in almost 1/4th of the tibia (23.86%) it was very prominent. (Fig: 1C, 3B)

ii) **Shape:** In the majority (54.9%) it was triangular in shape (Fig: 1A, 1B, 1C). In approximately 30% it was semilunar (Fig: 2A, 2B) and in a small percentage it was quadrangular (Fig: 3A, 3B. The p-value is significant being < 0.05. (Table-5).

iii) **Vascular foramina**: In the majority of SMTb (60.27%) there were 4-7 vascular foramina (Fig: 1B,1C, 2A, 3B). In 5% tibias no vascular foramina were observed on SMTb. The p-value is insignificant being > 0.05 (Table-6).

iv) **Vertical ridges**: Well defined vertical ridges were observed on the surface of this tuberosity in approx.75% (Rt.- 78.57%; Lt.- 71.05%). (Fig: 1C, 2A, 3B)

v) **Tubercles**: In approx. 65% SMTb a variable number of tubercles (1-4) were observed.

vi) **Dimensions**: The average vertical height on the right side was 17.25 mm and on the left it was 16.68 mm. The average vertical height of SMTb on the two sides was 16.96 mm (range: 8.7- 33.59 mm).

The average width on the right side was 20.79 mm and on the left it was 21.49 mm. The average width on both the sides was 21.14 mm (range: 11.9 - 32.59 mm).

3. Flap Tubercle: In the junctional zone between the beginning of the groove and the upper part of SMTb there was seen a smooth tubercle in 42.85% (Fig: 1A, 2B).

B. Cadaveric Dissection:

1. SM tendon sheath was present in all the cases but in some of them it was very thick (fig.4).
2. The distal part of SMT in approx. 73% limbs had a Triangular expansion (Rt-71.42% and Lt.75%) (fig.4, 7 A, 7B). In 27% it was distinctly Bifid (Rt.28.57%; Lt.25%) (fig.5).

3. The SMTb which gives insertion to the vertical part of SMT was large in approx. 45% (based on qualitative assessment) and the tendinous fibers were distinctly found getting attached to this tuberosity (fig.6,8).
4. In a small number of cases (13.63%) there was a Triangular flap (fig.9) connecting the tendon entering in to the groove and the vertical component reaching the tuberosity and this flap was placed superficial to a smooth tubercle (flap tubercle) in the tibia examined (fig. 1A,3B).
5. The tendon entering the groove was thick in 87.5% of left limbs and 53% of the right limbs (fig.5, 7B).
6. In approximately half of the cases the tendon of SM at its entry point in the groove (which was inclined) had the presence of a synovial bursa between the tendon and the groove with its predominance in the left limbs (fig. 7B).

Legends – Bones

(Red arrows: vascular foraminas; black arrows: tubercle; yellow arrow: prominent margin; SMTb demarcated)

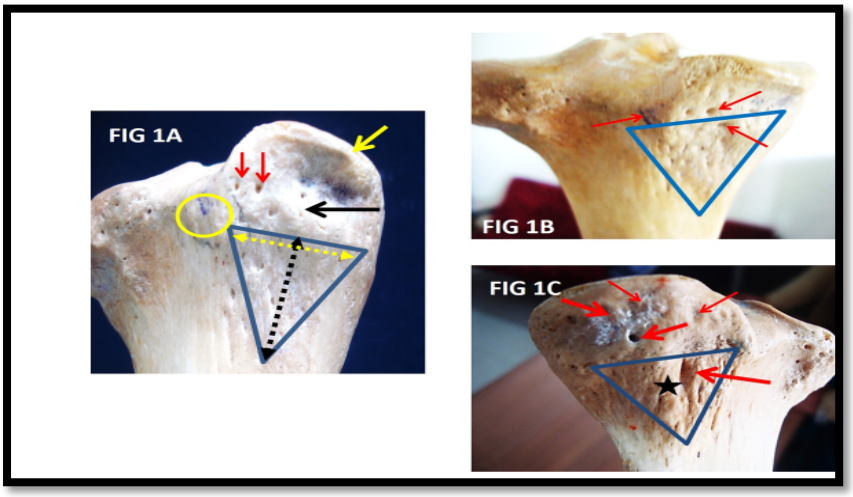

Figure 1: A,B,C

Figure 1. A. – Shows a broad deep groove with prominent upper margin (“Yellow Arrow”). The groove also shows the presence of vascular foramina (“Red Arrow”) and a tubercle at the inferior margin (“Black Arrow”). The double headed dotted black arrow denotes the height and the double headed dotted yellow arrow denotes the width of the SMTb. The yellow circle demarcates a tubercle lying deep to the triangular flap.

Figure 1. B. – Shows broad shallow groove showing a large number of vascular foraminas. The rough triangular area below it also shows numerous vascular foramina. The triangular area demarcated by the blue lines is SMTb.

The red arrows are the vascular foramina and the black one shows the tubercle.

Figure 1. C. – The area of the groove is irregularly elevated with a number of vascular foramina.

The rough triangular area shows a vertical elevation (denoted by a black star) and large vascular foramina (red arrow).

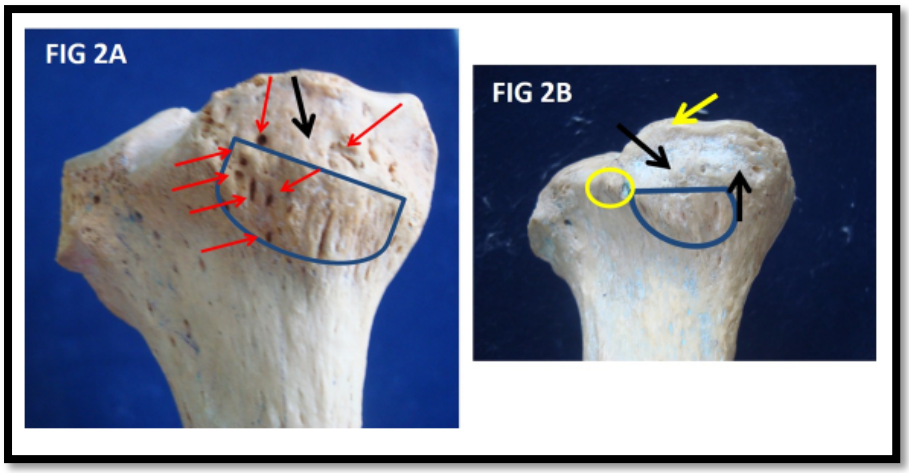

Figure 2 A,B:

Figure 2. A. – The groove is shallow showing vascular foramina and tubercle at the inferior margin. The SMTb is semilunar in shape with prominent ridges and vascular foramina.

Figure 2. B. – The groove with a prominent upper margin (yellow arrow) and a tubercle at the inferior margin. The SMTb is small and semilunar in shape .The yellow encircled area is the flap tubercle.

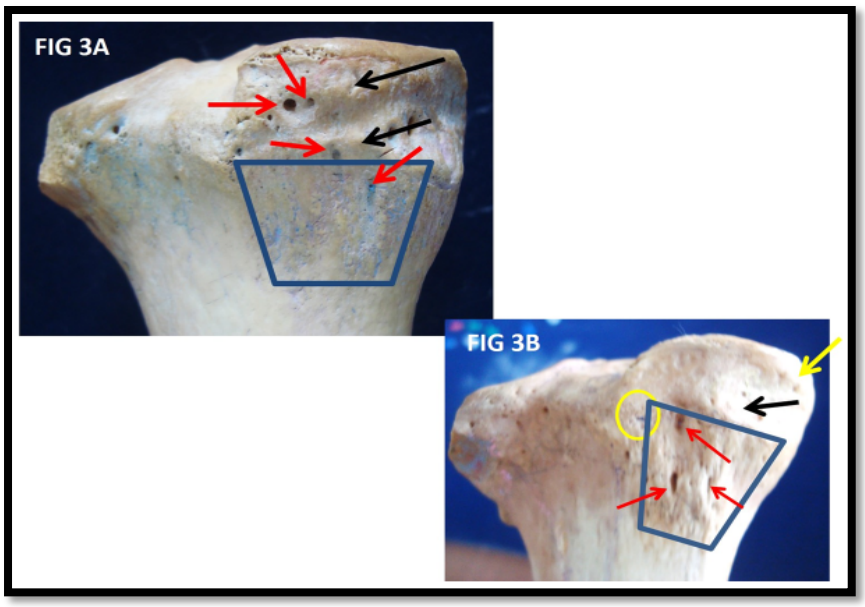

Figure 3 A,B:

Figure 3. A – Showing a broad groove that is shallow and irregular with presence of tubercles and the vascular foraminas. The SMTb is quadrangular in shape with a few vascular foramina.

Figure 3. B. – Broad shallow groove with prominent upper margin and a tubercle at the inferior margin. The SMTb is quadrangular in shape with many vascular foramina and ridges. The yellow circles show the flap tubercle.

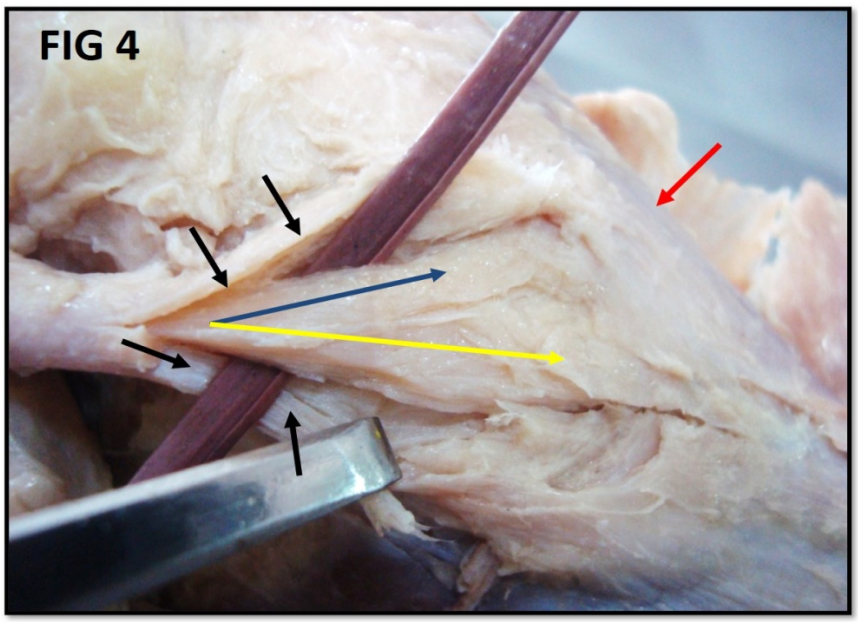

Figure 4: This shows the medial aspect of the left knee that is, a thick fibrous sheath surrounding the SMT marked by the black arrows. The tendon of SM is in the form of a triangular expansion. The blue arrow indicates the thick tendon entering the groove passing deep to MCL ("Red Arrow") and the yellow arrow indicates the expansion which is attached to the SMTb.

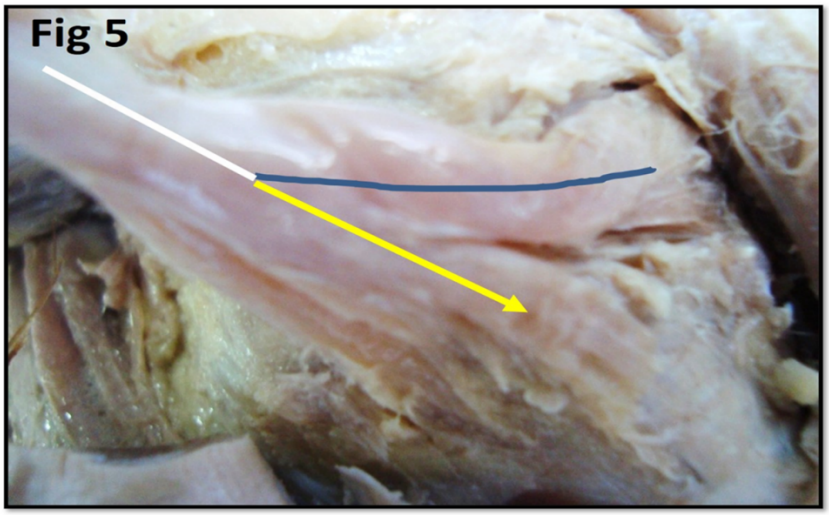

Figure 5: PMC left knee. The thick distal tendon of SM ("White Line") is bifurcated into two limbs. The thick tendon shown by the blue line is curving forwards to enter the groove. The yellow arrow indicates the second tendinous limb that is expanding to be attached to SMTb.

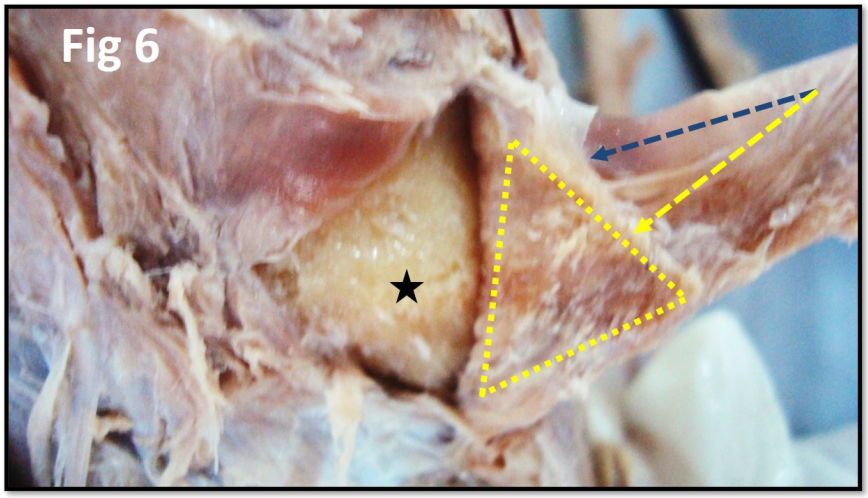

Figure 6: The distal part of SMT of the left knee has been pulled downwards and forward. The upper part of the tendon ("Blue Dotted Arrow") is entering the groove whereas the vertical limb ("Yellow Arrow") is forming a triangular expansion which has been detached from SMTb (black star).

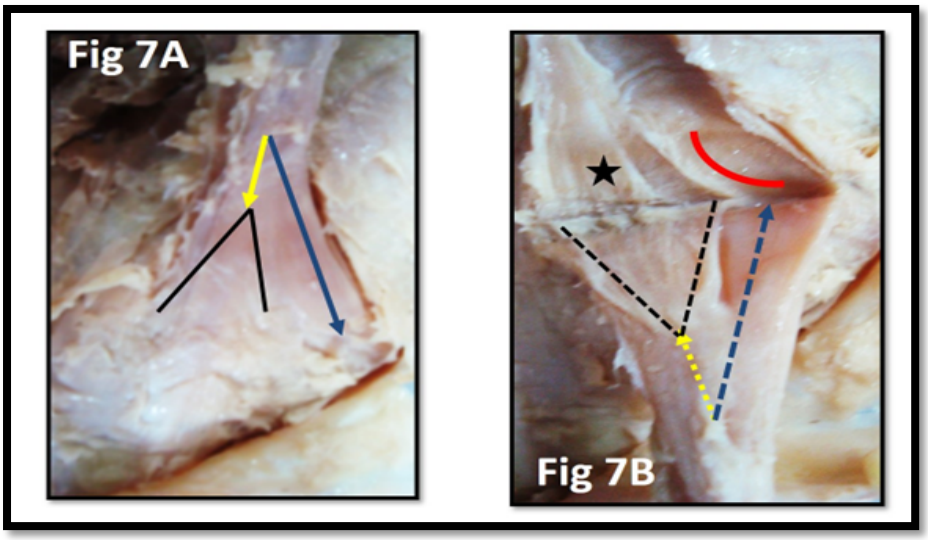

Figure 7: A,B

Figure 7. A. – After reflecting the fibrous sheath, the SMT is exposed which shows a triangular expansion in its distal part .The medial tendenous part ("Blue Arrow") is entering the groove whereas the remaining part (yellow arrow) is showing a triangular expansion (black lines) that is seen in continuity with the main tendon.

Figure 7. B. – The distal tendon of SM has been pulled downwards to see its deep surface.

A part of the thick tendon (Blue Dotted Arrow) is entering the groove (Red Curved Line) and the triangular expanded part of the tendon has been partly detached from the SMTb (Black Star).

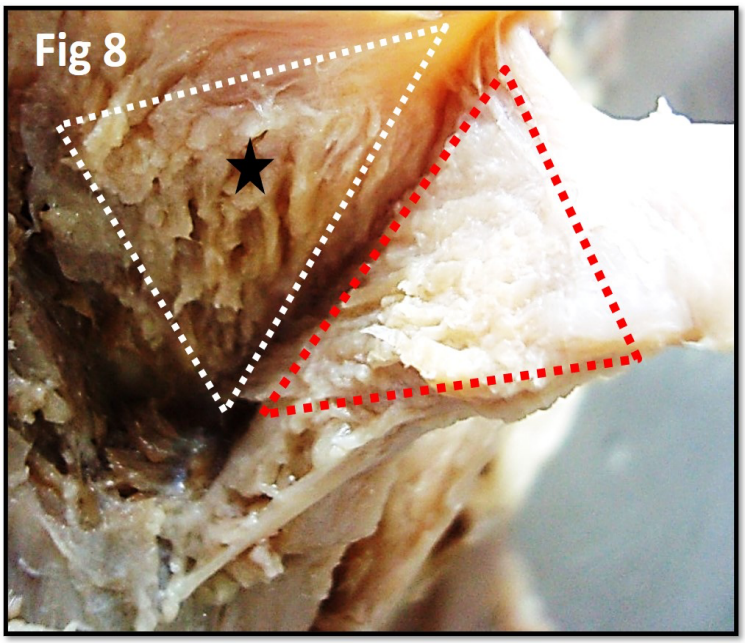

Figure 8: The distal expanded SMT has been pulled downwards and forwards to show it's deeper surface. The blue dotted curved line shows the tendon entering the groove. The remainder of SMT has a triangular expansion indicated by the dotted red line that is detached from the SMTb indicated by the dotted white line and the black star. The SMTb is showing well defined ridges.

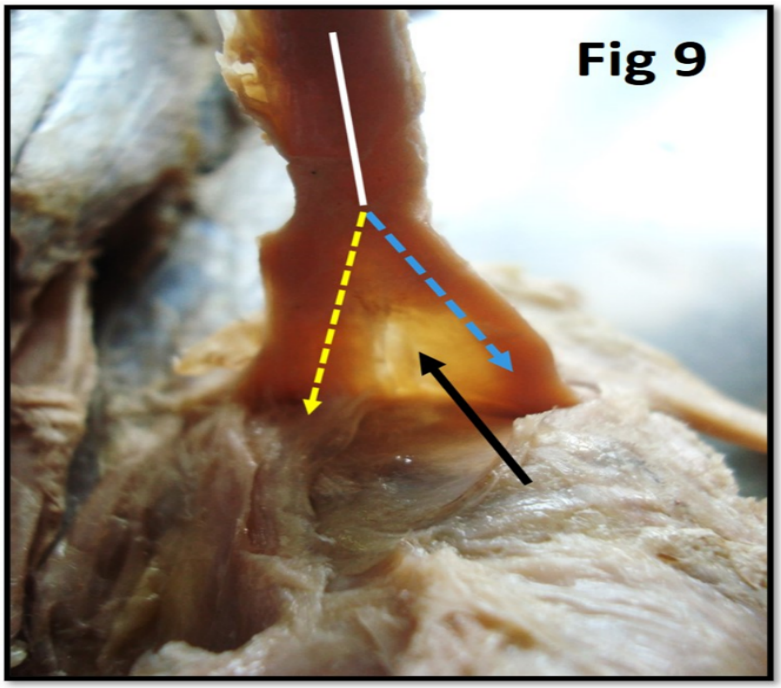

Figure 9: The deep surface of SMT (White Line) is seen to bifurcate into two limbs (Blue and Yellow Dotted Arrows) and stretching between the two is a translucent flap connecting the two limbs (Black Arrow).

A: Groove

Table 1: Depth of the groove

Depth	Right	Left	Average	P- Value
Shallow	64.28%	60.52%	62.4%	0.423
Medium	14.28%	18.42%	16.35%	
Deep	21.42%	15.78%	18.6%	
Absent	-	5.26%	2.5%	

Table 2: Vascular Foramina in the Groove:

No. of foramina	Right	Left	Average	P- Value
1-4	80.95%	71.05%	76%	0.433
5-10	16.66%	21.05%	18.85%	
Absent	2.38%	7.89%	5.13%	

Table 3: Prominent Edge of the Groove:

Prominent Edge	Right	Left	Average	P- Value
Upper	42.85%	26.31%	34.58%	0.226
Lower	7.14%	15.78%	11.46%	
Both	16.66%	28.94%	22.8%	
None	33.33%	28.94%	31.13%	

Table 4: Presence of Tubercle in the Groove:

Tubercle at	Right	Left	Average	P- Value
Upper margin	4.76%	2.63%	3.69%	o.111
Lower margin	54.76%	31.57%	43.16%	
Both margins	4.76%	2.63%	3.69%	
Absent	16.66%	47.36%	32.01%	

B. Semimembranosus Tuberosity (SMTb)

Table 5: Shape OF SMTb:

	Right	Left	Average	P- Value
Triangular	57.14%	52.63%	54.9%	0.049
Semilunar	21.42%	39.47%	30.44%	
Quadrangular	21.42%	5.26%	13.34%	

Table 6: Vascular Foramina in SMTb:

No. of foramina	Right	Left	Average	P- Value
1 - 3	33.33%	26.31%	29.82%	0.669
4 - 7	54.76%	65.78%	60.27%	
>7	7.14%	2.63%	4.9%	
Absent	4.76%	5.26%	5.01%	

Discussion and Review of Literature

There is no clarity in the literature regarding fate of the main tendon of SM. Many text books of Anatomy and Atlases mention about the variable number of expansions of the distal tendon of SM varying from 3 to 8 as discussed in details by Joshi et al. (2021) [3]; but the insertion of the SMT has not been described in details including its functional significance. The anatomy of the posteromedial corner (PMC) of the knee is quite complex. The present study was intended to collect all the detailed information that can pave way in proper understanding of the biomechanical, radiographic imaging and clinical studies related to the importance of SMT at PMC. For this purpose, posterior surface of upper end of 80 tibia were minutely observed in the region of the groove on the medial condyle and SMTb below it. These findings on tibia had prompted us to undertake a detailed study of attachment of distal SMT and were confirmed in the limbs dissected.

Cave and Porteous (1959) stated that the vertical slip of SMT is in direct line of the muscle pull hence it must be recognized as the main attachment of the SM on tibia. [7] This is precisely what we have observed, noted and have named it as Semimembranosus Tuberosity (SMTb). Cave and Porteus have described the same as a squarish tubercle and some others [8,9] have mentioned this just as a tubercle. In the present study the SMTb was found to be very prominent in 25% tibia. They were of varied shapes (Table- 5): triangular (54.9%); semilunar (30%) and quadrangular (15%) (Fig 1A,2A,3A). The average vertical height of SMTb was 16.96 mm and avg. width was 21.14 mm (Fig: 1A). In approx. 75% well defined vertical ridges were observed on SMTb (Fig: 1C,2A,3B). This is the feature which has not been mentioned in the literature reviewed.

In the present work in the majority (62.4%) (Table- 1) the groove on the posterior surface of medial condyle was shallow on both sides. It was more prominent and deeper on the right side. The depth of the groove on the medial condyle has not been studied in the literature reviewed. The upper margin of groove was prominent in 34.58% of tibia studied (Table- 3). Whereas Standring [4], Cave and Porteous [7] have mentioned about the attachment of the tendon to the inferior margin. We have found a variable number of vascular foramina (Table- 2) in the groove and SMTb (Table- 6) in 95%

tibia (Fig: 1C, 2A,3A). The presence of a tubercle was seen predominantly at the lower margin of groove (43%) (Table- 4) and on SMTb (65%) (Fig: 1A,2B,3A,3B). In the junctional zone between the beginning of the groove and the upper part of SMTb there was seen a smooth tubercle – 'flap tubercle' in 42.85% (Fig 1A,3B).

During the dissection in the present study SMT sheath was found in all the cases and in few cases it was very thick (Fig.4). We found that the distal part of the SM main tendon was either bifurcated (27%) (Fig.5) or was in the form of a triangular expansion (73%) (Fig. 7A). The vertical limb of SMT was attached to the SMTb (Fig. 6), which was large in 45% (based on the qualitative assessment). In the remaining limbs SMTb were either small or medium in size. The medial limb of SMT was found to bend at right angle to enter the groove on the posterior aspect of medial condyle passing deep to MCL (Fig. 5). It was thick in the left limb (87.5%) compared to the right limb where it was found to be thick in 53%. Loredo et al. (1999) [9] have also stated that the direct attachment was to the tibial tubercle on the posterior aspect of medial tibial condyle below the joint line.

Standaring [4] mentions that the cord like main tendon is attached to a tubercle (sometimes called the Tuberculum Tendinis) and the inferior lip and the adjacent part of the groove. Cave and Porteous [7] described a short strong tendon getting firmly attached to a prominent squarish tubercle on the posterolateral aspect of medial tibial condyle and a thick funicular recurrent tendon gains attachment on to the inferior lip and neighborhood of the groove for SMT on the medial tibial condyle. They stated that the tendon in the groove can bring about the flexion of knee only when genuflexion has attained an angle of 900. Kim (1997) [10] citing the work of Kaplan (1961) stated that a direct insertion is firmly attached to a tubercle (infraglenoid) on the posterior surface of medial condyle of tibia below the articular line and another insertion forms the tendon like structure and enters the groove below the articular surface. Warren and Marshal (1979) [8] described two main insertions of SMT in the form of direct and anterior arm. Lundquist et. al (2015) [11] have also stated that the main tendon bifurcates into a direct and an anterior arm just below the joint line. Maeseneer et.al (2014) [12] in their MRI study have also shown that the distal arm attaches directly in the groove on the posteromedial aspect of tibial condyle. They also stated that the SMT was seen to fan out in the form of broad structure inferiorly made up of direct and anterior arm with no clear separation between the arms. This is in agreement with what we have also observed in the form of a triangular expansion. In addition to this we also found a flap in 13.63% limbs (Fig. 9) connecting the vertical component reaching the SMTb and the tendon entering in to the groove. Benninger and Delamarter (2013) [5] in their review article have described that the main SMT inserts mainly on the horizontal groove on the posteromedial aspect of medial condyle of tibia. In all our specimens dissected we have found it to get attached not only on the groove but also on to the SMTb. The semimembranosus is the main dynamic stabilizer of the PMC. The PMC has been referred to as the semimembranosus corner due to the important role the SMT has in providing dynamic stability to the knee. [11]

At the entry point in the groove the tendon was separated by a synovial bursa from the groove (Fig. 7B) and this finding has not been mentioned in the literature reviewed. Nature has demarcated and placed part of the tendon in the groove so that, besides actively producing flexion at the knee with other muscles, semimembranosus can also bring about the medial rotation of the leg in genuflexion.

Conclusion

The anatomy of the posteromedial aspect of the knee is quite complex. The detailed findings of the present work regarding the distal SMT emphasize its role in maintaining the strength and stability of knee joint. Although the distal end of SMT may have a triangular expansion or may be bifid, it can efficiently bring about the flexion at the knee joint and medial rotation of the leg in genuflexion. The vascular foramina in the groove and SMTb probably would help to strengthen the bony parts giving attachment to the tendon. The presence of vertical ridges on SMTb will increase the biomechanical strength of the muscle. The present study helps to throw more light on the available information that can further enhance the understanding of biomechanical role, radiographic imaging and clinical studies related to the importance of the structures in the postero-medial corner (PMC) of the knee.

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