ANATOMICAL STUDY OF THE GRACILE AND SEMITENDINOUS MUSCLES INSERTION

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SUMMARY

The crescent use of the tendons of the gracile and semitendinous muscles in knee ligament reconstruction procedures was accompanied by an increase of the number of complications originated by their removal, such as: tibial collateral ligament injury, saphenous nerve injury, wrong removal of the sartorio muscle tendon, the very section of the tendons, and increase of surgical procedure time due to inexperience or lack of knowledge of the knee medial region anatomy[1-6]. As the removal of such tendons has been a limiting factor in some orthopaedic procedures, we conducted this study by dissecting 30 cadaver knees, with the following purpose: to locate the insertion of the gracile and semitendinous muscles in the tibia; to check the correlation, if existent, between this location with the cadaver height and to evaluate the potential anatomical changes. We observed that the gracile muscle tendon insertion was, in average, at 4.6 cm below knee joint surface, and the semitendinous was, in average, at 7.4 cm. There is a correlation between people's heights and the location of those tendons. Gracile and semitendinous muscles usually present some kind of anatomical change, with the semitendinous accessory insertion being the most frequent one, accounting for 70%, followed by the merge between them, which accounted for 56%.

Keyword: Knee/anatomy & histology; Tendons/anatomy & histology; Anterior cruciate ligament; Posterior cruciate ligament; Tibia.

INTRODUCTION

Gracile and semitendinous muscles' tendons, secondary knee flexors, are largely used in knee ligament reconstruction procedures for treating anterior cruciate ligament (ACL), posterior cruciate ligament, collateral, tibial, and fibular ligaments injuries, and in patellar tendon's chronic injuries reconstruction. Due to the increased use of such tendons, complication rates related to their removal have also increased, such as: tibial collateral ligament injury; saphenous nerve injury; wrong removal of the sartorio muscle tendon; tendons sectioning, and; increased surgergy time due to difficulties for isolating and extracting those tendons as a result of inexpertness or unawareness of the anatomy of knee medial region[1-6].

This lack of detailed knowledge about the knee medial region anatomy by some orthopaedic doctors is partially justified by a usually superficial description of this region in most anatomy books[7-14] and in articles describing surgical techniques using those tendons in orthopaedic procedures[6,15-17].

As the removal of gracile and semitendinous muscles tendons has been a limiting factor in some orthopaedic procedures[5,6] we performed this study by dissecting 30 cadaver knees with the following objectives: To find the insertion of gracile and semitendinous muscles at the tibia; to check for a relationship between that location to cadaver's height and to assess potential anatomical changes.

MATERIALS AND METHODS

Thirty knees of 30 cadavers were assessed during a period comprehending May to November 2000, with 4 female knees and 26 male knees, with an average age of 50.4 years old, ranging from 20 to 78 years old. According to our inclusion criteria, they must have been adult cadavers, previously submitted to necropsy at the Department of Pathological Anatomy, Santa Casa de Misericórdia de São Paulo. Cadavers presenting scars, knee convexities or retractions, or congenital deformities affecting lower limbs have been excluded from the study. Through a longitudinal access way, about 15 cm long, beginning at five centimeters above the joint surface of the medial tibial condyle, at half-way between medial femoral epicondyle and patellar medial edge, ending at five centimeters posteriorly and medially to tibia's crest.

After dissection of the skin and subcutaneous cellular tissue, we exposed layer I as described by Warren and Marshall[18] that is, the sartorio muscle fascia. By performing a cross-sectioned incision at the level of the gracile muscle tendon's superior edge, which is palpable through layer I, we can see the other two tendons composing the "goose foot", the gracile and the semitendinous. Measurements were then performed with the aid of a pachymeter for the following parameters:

1) Distance between the insertion of the gracile muscle and the medial edge of tibia tuberosity (TT).

2) Distance between joint surface of the medial tibial condyle and the upper edge of the gracile muscle tendon, near its tibial insertion.

3) Distance between the insertion of the semitendinous muscle and the medial edge of TT.

4) Distance between joint surface of the medial tibial condyle and lower edge of the semitendinous muscle tendon, near its tibial insertion.

5) Width of gracile and semitendinous muscles tendons at 10 cm from their tibial insertions. We also checked for any anatomical changes such as merge of two or more tendons, tendon splits and

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accessory insertions of tendons forming the "goose foot". Height measurements were taken of all cadavers in order to evaluate a potential association with the measurements mentioned above.

Statistical analysis in our study was comprised of:

a) Description: We computed the average and standard deviation for all measurements performed.

b) Correlation: We computed Pearson's correlation coefficient for each of the five measurements mentioned above regarding cadaver's height.

c) Regression: We used the single linear regression equation taking as a dependent variant each of the five measurements mentioned above, and as an independent variant, cadaver's height.

For statistical analysis purposes, the application SPSS FOR WINDOWS, release 11.0 was used, and the significance level adopted was 5%. Dissections, measurements and photographs of all studied cases have been performed by the author, assisted by an assistant and a photographer.

RESULTS

The distance between joint surface of the medial tibial condyle and the upper edge of the gracile muscle tendon was, in average (±S.D.), 4.6 (±0.5) cm, ranging from 3.7 to 6.0 cm. We tried to find a correlation between that mentioned measure (UE) and cadaver's height. We used the Pearson's correlation method, with a correlation coefficient of 0.406 with p = 0.026 being found, therefore considered as statistically significant.

Graph 1 presents the relationship between the UE measurement, cadaver's height, and regression line.

By using the single linear regression method, a relationship was shown between the independent variant (height) and the dependent variant (UE measurement), expressed by the single linear regression equation: Y = bX , with Y being the UE distance, b being the constant obtained from single linear regression calculation, and X being cadaver's height.

Thus, the single linear regression equation would be as follows: BS = 0.0279 x cadaver's height in centimeters.

Regarding the distance between the insertion of this tendon and the medial edge of tibial tuberosity (TT), the G-TT distance, we found the average value (±S.D.) of 1.5 cm(±0.3), ranging from 1.0 to 2.3 cm.

Again, aiming to correlate the distance mentioned above to cadaver's height, we used the Pearson's correlation method, when a correlation coefficient of 0.389, with p = 0.033 was found.

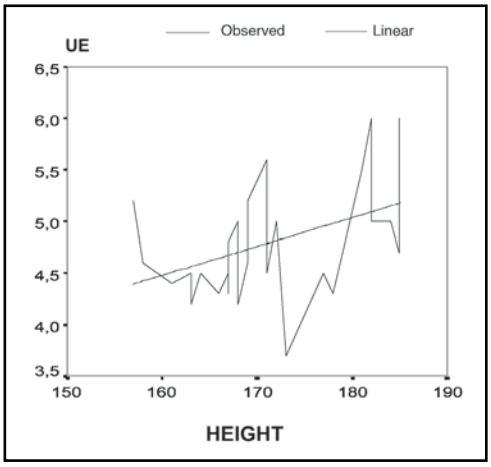
By the single linear regression method, a relationship was shown between the independent variant (height) and the dependent variant (G-TT distance), expressed by the single linear regression equation: Y = bX , with Y being the G-TT distance, b being the constant obtained from single linear regression calculation, and X being cadaver's height.

The single linear regression equation for computing the G-TT distance would be as follows: G-TT = 0.0092 x cadaver's height in centimeters. Similar measurements were taken for semitendinous muscle tendon.

Distance between the joint surface of medial tibial condyle and the lower edge of that tendon was in average (±S.D.), 7.4 cm (±1.2), ranging from 5.0 to 12.0 cm.

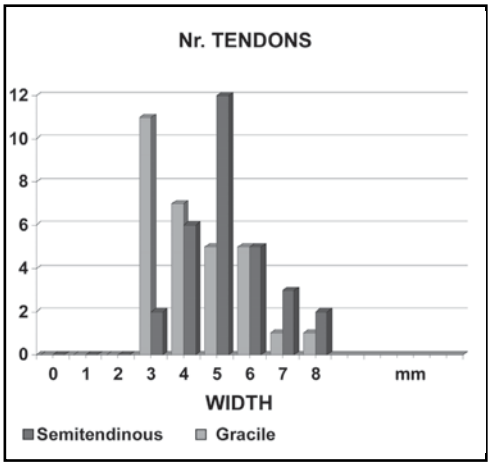
We checked for a correlation between this mentioned measurement (LE) and cadaver's height, thus we used the Pearson's correlation method, and a correlation coefficient of 0.561 with p = 0.001 was found.

By the single linear regression method, a relationship was shown between the independent variant (height) and the dependent variant (LE measurement), expressed by the simple linear regression equation: Y = bX, where Y is the LE distance, b is the constant obtained by the single linear regression calculation, and X is cadaver's height.



Source: Pathologic Anatomy Service, Santa Casa de São Paulo.

Graph 1: *Diagram showing the dispersion between UE and cadaver's height in centimeters*



Source: Pathologic Anatomy Service, Santa Casa de São Paulo.

Graph 2 - *Gracile and semitendinous tendons' width in mm.*

The single linear regression equation for computing the LE distance would be as follows: LE = 0.0431 x cadaver's height in centimeters.

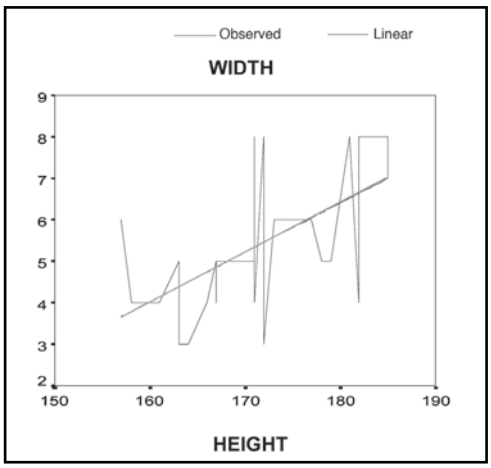
The insertion of semitendinous muscle tendon was located, in average (±S.D.), at 1.6 cm (±0.3) from TT medial edge, the S-TT distance, ranging from 1.0 to 2.4 cm. We found a correlation between this measurement (S-TT) and cadaver's height, by using the Pearson's correlation method, with a correlation coefficient of 0.389 and p= 0.033.

By the single linear regression method, a relationship was shown between the independent variant (height) and the dependent variant (S-TT measurement), expressed by the single linear regression equation: Y = bX , where Y is the S-TT distance, b is the constant obtained by computing the single linear regression, and X is cadaver's height. Thus, the single linear regression equation would be as follows: S-TT = 0.0097 x cadaver's height in centimeters.

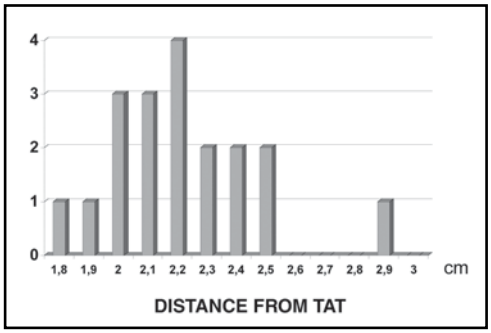
Tendons width, measured at 10 cm from the tibial insertion of each cadaver, was, in average (±S.D.), 4.4 mm (±1.6) for gracile, ranging from three to eight mm, and of 5.4 mm (±1.6) for semitendinous, also ranging from three to eight mm (Graph 2).

We aimed to see if there was a correlation between the studied tendons width and cadaver's height. We used the Pearson correlation method, and, for gracile muscle tendon, a correlation coefficient of 0.131 with p = 0.491 was found, thus not considered as statistically significant. However, for semitendinous muscle tendon, a correlation coefficient of 0.585 with p = 0.001 was found, considered

as statistically significant (Graph 3).
We observed the merge of semitendinous and gracile muscles tendons in 56% of the cases. This merge was located, in average (±S.D.), at 2.2 cm (±0.2) from their tibial insertion, ranging from 1.8 to 2.9 cm (Graph 4). The merge of three tendons of the "goose foot" was seen just in one case, and occurred at 2.0 cm from the tibial insertion.
Accessory insertion coming from the lowest bundles of the tendons was seen in four cases with the gracile muscle, approximately 13%, and in 21 cases with the semitendinous muscle, 70%. Three accessory insertions of the gracile and 18 of the semitendinous muscles were directed to leg's aponeurosis, while one of the gracile muscle and other three accessory insertions of the semitendinous muscle were directed to tibial crest, to a point a little more distal than main insertion.
Another anatomical change, observed in only one case, was a wide, five-centimeter long, fanlike tibial insertion.



Graph 3 - *Diagram showing the dispersion between semitendinous' width and cadaver's height in centimeters.*



Source: Pathologic Anatomy Service, Santa Casa de São Paulo

Graph 4 - *Location of the gracile and semitendinous tendons merge.*

DISCUSSION

Currently, gracile and semitendinous muscles tendons are being widely used in ligament reconstruction procedures, especially at the knee. Additionally, some complications originated by their removal emerged, such as, for example, the tibial collateral ligament injury, saphenous nerve injury, the wrong removal of the sartorio muscle tendon, section of the very tendons, and increased surgical time due to difficulties for isolating and removing those tendons[1-6].
Those complications are a result of the lack of detailed knowledge of the anatomy of the region comprehending knee medial region in the majority of anatomy books[7-14] and in articles describing surgical techniques using those tendons in orthopaedic procedures [6,15-17]. There are few reports in textbooks or in articles describing the accessory insertion of semitendinous muscle tendon's lower fibers at the tibial crest or at the leg's aponeurosis[2,3,5,19-25].
In our study, we assessed the anatomical aspects of the gracile and semitendinous muscles tendons at the knee medial region.
The gracile muscle tendon insertion, at the upper and medial portion of the tibia, occurred in average at 1.5 cm from the medial edge of the tibial anterior tuberosity (G-TT distance) and at 4.6 cm from the joint surface of the medial tibial condyle (UE distance). Regarding TAT distance, our findings showed an intermediate condition as compared to studies by Ivey and Prud'Homme[23] and Pagnani et al[3]., where mean results were 1.1 cm and 2.2 cm, respectively. Regarding the UE distance, only Ivey and Prud'Homme[23] took this measurement, finding an average value nine millimeters higher than ours, that is, 5.5 cm. A hypothesis to such a higher result could be the average height of the population studied by this author maybe higher than average height in our population, as this measurement presents a correlation with the individual's height, as previously described.
Having in mind the existence of a correlation between those measurements and cadavers' height, and the fact that this has not been previously described in literature, and by using the single linear regression equation for computing the UE and G-TT distances presented in our results, we can anticipate this tendon's location and perform smaller and more aesthetic incisions, as in the example below, of a 1.70 meter-high individual.
Example 1: Calculation of the UE distance (Y) for a 1.70 meter-high individual (X).
Y = bX (single linear regression equation)
UE = 0.0279 x 170
UE = 4.74 cm
In case an orthopaedic doctor desires to be more accurate and locate the tendon's center, he/ she should just add the UE measurement, 0.22 cm, which is half the mean width of this tendon.
Example 2: Calculation of the G-TT distance for a 1.70 meter-high individual.
Y = bX (single linear regression equation)
G-TT = 0.0092 x 170 G-TT = 1.56 cm
Semitendinous muscle tendon was located, in average, at 1.6 cm from the medial edge of the tibial anterior tuberosity (S-TT distance) and at 7.4 cm from the medial edge of the tibial condyle (LE distance). Again, the distance from the medial edge of the tibial anterior tuberosity was intermediate as compared to studies by Ivey and Prud'Homme[23] and Pagnani et al[3]., which show 1.1 cm and 2.2 cm, respectively. The distance from the medial edge of the tibial condyle was seven millimeters (mm) shorter than the distance of 8.1 cm described in a study by Ivey and Prud'Homme[23]. Again, the hypothesis of different heights among studied populations may explain the difference on this LE measurement.
Similarly to gracile muscle tendon, there is a correlation between those measurements and cadavers'' height (correlation coefficient = 0.561 and p = 0.001 for LE distance; correlation coefficient = 0.389 and p = 0.033 for S-TT distance) and it is possible to anticipate this tendon's location based on an individual's height by using the following formulas:
LE = 0.0431 x individual's height in centimeters.
S-TT = 0.0097 x individual's height in centimeters.
Again, when it is desired to locate the center of the semitendinous muscle tendon, one must only subtract half of the average width of that tendon, that is, 0.27 cm from LE measurement.
Gracile and semitendinous muscles tendons' width, at 10 cm from tibial insertion, were in average 4.4 and 5.4, respectively. When compared to literature, we see a great similarity with the study by *Pagnani et al*,3 who also took this measurement at 10 cm from tibial insertion and obtained, as an average, 4.2 and 5.2 cm, respectively. Ivey and Prud'Homme[23] gauging those tendons' width, reported much higher values, of 7.7 and 11.4 mm, respectively, but, as they didn't specify the place where measurements were taken, we assume that it was near tibial insertion, where tendons are flattened and larger.

Regarding anatomical changes on those tendons, as observed in our study, we disagree with authors 1,11,26 who state that this region's anatomy is steady.

We saw gracile and semi-tendinous muscles tendons' merge in 56% of the studied knees. This occurred, in average, at 22 mm from tibial insertion (Figure 1).

In literature, we found largely variable data regarding this merge. Some authors describe that those muscles' insertion is independently made, with no merge, at tibial medial and upper portions (Figure 2)[8,12,13,27,28,29] while other authors report that those tendons are joined, forming a joint tendon and then are inserted into the tibia (Figure 1)[3,5,7,18,19,22,23,30,31].

We also found, in just one case, with 3% incidence, the union of the three 'goose foot' tendons (Figure 3). as mentioned by some authors as a potential occurrence[18,19,22,30].

Other anatomical changes were seen in our study. The most frequent one was the accessory insertion of the semitendinous muscle tendon's lower fibers at the tibia or leg aponeurosis[2,3,5,19,20-25] (Figure 4), present in 70% of studied knees.

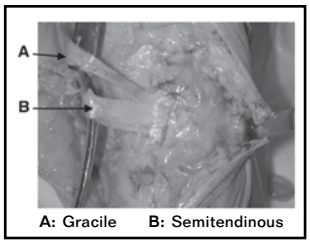


Figure 1 - *View of the medial region of leg's proximal third, showing merge of the gracile and semitendinous tendons.*

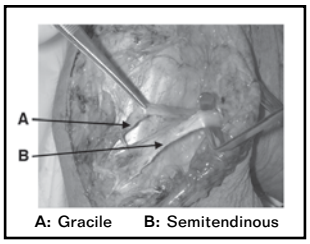


Figure 2 - *Separate insertion of gracile and semitendinous tendons*

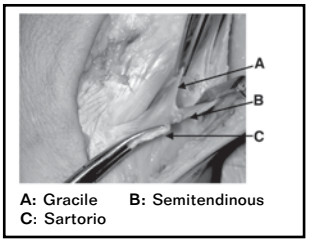


Figure 3 - *Merge of the three tendons forming the 'goose foot' (sartorio sectioned).*

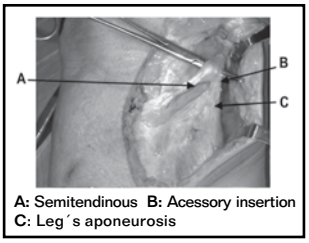


Figure 4 - *Accessory insertion of the semitendinous into leg's aponeurosis.*

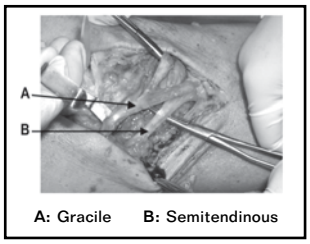


Figure 5 - *Accessory insertion of the gracile and semitendinous concurrently into the tibia.*

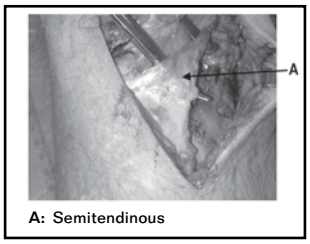


Figure 6 - *Fanlike insertion of the semitendinous muscle.*

Gracile muscle also presented such change in four knees, an incidence of 13%. In all of them, a concurrently variation of the semitendinous muscle tendon was present. In three knees, both tendons inserted into leg's aponeurosis and one knee showed a tibial insertion of those (Figure 5).

The awareness of this accessory insertion existence, especially that of the semitendinous muscle, which is most commonly seen, is very important during tendons removal procedures, because the failure to section it may cause tendon rupture when the tendon extractor passes through[5].

We also observed a variant semitendinous muscle insertion, in a fanlike shape, five centimeters long, in only one case, an incidence of 3% (Figure 6).

By knowing well the anatomy of the knee medial region, by being aware of the potential anatomical changes mentioned above, by performing an appropriate and well-localized access way, by taking care when dissecting structures, and by identifying the three tendons a little more proximally, it is possible to ease gracile and semitendinous tendons' removal surgeries, thus avoiding some troubles such as the wrong removal of a different tendon (sartorio), tendon rupture, tibial collateral ligament injury, and saphenous nerve injury.

CONCLUSIONS

The tendon of the semitendinous muscle is located, in average, at 1.6 cm from TT and its lower edge at 7.4 cm from the joint surface.

There is a correlation between individuals' height and the following measurements analyzed: distance from the insertion of gracile and semitendinous muscles tendons at the tibia to the joint surface of the medial tibial condyle and up to tibial anterior tuberosity; diameter of the semitendinous muscle tendon at 10 cm from its tibial insertion. Gracile and semitendinous usually present some kind of anatomical change, the most common ones being the accessory insertion of the semitendinous, present in 70% of the cases, and the merge among them, in 56%.

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