

Meniscus morphometric study in humans

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Abstract

The objective of this study was to evaluate the morphometric variations in human beings meniscus. For this, 40 menisci from 20 knees, previously dissected and preserved with Formaldehyde and/or glycerin solution, were utilized. In each meniscus, the following aspects were evaluated to check the width and thickness variations: outer circumference length and distance between posterior and anterior horns in three points (anterior, medium, and posterior part). With regard to the outer circumference length, there was no significant statistic difference between the medial and lateral meniscus. The distance between the anterior and posterior horns in the medial meniscus was significantly higher than that of the lateral meniscus. The lateral meniscus showed no significant difference regarding to the length between the anterior, medium, and posterior part, whereas the posterior part was wider in the medial meniscus. With regard to the medial meniscus length, the posterior part was thicker than the anterior and medium part. In the lateral meniscus, the medium part was the thickest followed by the posterior and anterior part, respectively. The meniscus morphometric findings are in accordance with studies on meniscus injuries.

Keywords: meniscus, morphometry, knees.

1 Introduction

The incongruity of the joint faces of femur and tibia knee joint can be “corrected” by two important semi-lunar meniscus formats (medial and lateral). These menisci structures are wedge-shaped and are located in the joint face edge of the tibia (MESSNER and GAO, 1998).

The menisci of the knee joint are important functional units able to improve joint congruence and load distribution, thereby reducing the stress on the knee joint, a function that is considered primordial to protect the articular cartilage and prevent osteoarthritis (MESSNER and GAO, 1998).

They consist of cells such as chondrocytes and fibroblasts, and the extracellular matrix is composed of collagen, proteoglycans, glycoproteins, and elastin (GRAY, 1999).

With regard to the menisci vascularization, the third peripheral part is irrigated by vessels from its junction with the capsule and the anterior and posterior horns constituting the most vascular segments (COHEN, ABDALLA, BARRETO et al., 1993).

Since the menisci perform important mechanical functions, they are anatomical structures which are exposed to injury. These lesions may occur as part of a rotational trauma or bending, as the evolution of a joint degenerative process, or an injury as a spontaneous injury resulting from a progressive structural failure without any correlation with trauma or a degenerative process. The latter is called meniscal injury due to fatigue (CAMANHO, 2009), whatever the trigger for the injury, its morphology can be closely related to the injury.

There are marked differences between the contour and the insertion of the medial and lateral menisci that are important concerning the mechanism of injury (ALMEIDA, DE MORAES, TASHIMIRO et al., 2004). Thus, based on general anatomy, the thickness of the outer circumference, width, and distance between the anterior and posterior horns of the knee joint menisci were topics that guided this study.

1.1 Meniscus histology

The meniscus consists of 75% of type I collagen in its organic composition, and most of these fibers are arranged in longitudinally and few are in radial, oblique, and vertical arrangements. The remaining 25% of its constitution corresponds to water, mucopolysaccharides, and proteoglycans providing the meniscus with its viscoelastic property (McDEVITT and WEBBER, 1990).

In the knee menisci, the diameter and orientation of collagen fibrils and cellular morphology vary from the surface to the central deeper regions. The surface regions that lie against the articular cartilage usually consist of a layer of thin fibrils. Immediately below them, there are collagen fibrils of a small diameter with a radial orientation towards the meniscus body forming a thicker layer. (WEINSTEIN and BUCKWALTER, 2000).

In the medial region, most part of the meniscus, bundles of collagen fibrils of larger diameter surround cells larger spherical cells (WEISNTEIN and BUCKWALTER, 2000). This circumferential arrangement allows the meniscus to

transmit weight-bearing forces through the joint and resist the elastic loads that occur during this function. In addition to the circumferential collagen fibers in the middle zone, there are also some radially aligned collagen fibers that provide structural support and resist the longitudinal division.

The deeper bundles of collagen fibrils follow the curve of the meniscus, and the bundles of smaller fibrils, radially oriented, are interwoven through the bundles of circumferential fibrils (WEINSTEIN and BUCKWALTER, 2000) and probably work similarly to the radial fibers area average.

Different types of cells were identified in the menisci. These include: 1) chondrocytes, 2) fibroblasts, 3) intermediate form of cells (cells of difficult classification in fibroblasts or chondrocytes), 4) myofibroblasts (only portions of the injured meniscus), 5) fibrocartilage (only in outer parts of the meniscus), and 6) degenerate and necrotic cells (GHADIALLY, LALONDE and WEDGE, 1983).

Biomechanical and histological studies showed that of 32 menisci that were composed of fibrocartilage, 31 were internally composed of hyaline cartilage (MCDEVITT and WEBBER, 1990). This dual organization is probably essential for the tissue ability to resist compressive forces.

Four morphologically distinct types of cells were found in the menisci of rabbits. Two of these cells were present in the region composed of fibrocartilage. The third cell was found in the inner region composed of hyaline cartilage, and the fourth type of cell was found in the surface region of the meniscus (GRAVERAND, OU, SCHIEDL-YEE et al., 2000).

1.2 *Meniscis vascularization*

Blood supply was identified in the peripheral third of the meniscus around the 22nd week of gestation (PETERSEN and TILLMANN, 1995). At birth, almost the entire meniscus is vascularized. In the second year, a vascular area along the central margin of the meniscus is developed.

The vascular supply of the meniscus is provided by the medial and lateral genicular artery forming a perimeniscal capillary plexus with radial branches facing towards the center of the joint (ARNOCZKY and WARREN, 1982).

In adults, the proportion of the penetration of periphery vessels is 10 to 30% of the width in the medial meniscus and 10 to 25% in the lateral meniscus. The anterior and posterior horns of the menisci are better vascularized than their bodies (ARNOCZKY and WARREN, 1982).

Cohen, Granata Júnior, Ejnisman et al. (1998) observed that the medial meniscus in the region of the anterior horn is the most vascularized area with rates from 22 to 83% (average 40%) followed by the meniscal body front, with indexes of vascularization between 20 and 62% (average 30%). In the lateral meniscus, the two most vascularized regions were the anterior horn, with rates from 18 to 95% (average 48%), and the posterior horn, with rates between 22 and 52% (average 31%). There was also a relationship between the vascular indices in these regions and ages indicating that the values of the vascularization indices decreased with their increase.

1.3 *Menisci anatomical and functional aspects*

The incongruity between the semicircular shape of the femoral condyles compared to the surface of the tibial plateau is adapted by a pair of menisci that are described as C-shaped

fibrocartilage wedges (GRAY, 1999). They measure about 35 mm in diameter (MESSNER and GAO, 1998).

The outer edges of menisci are thick, and their non-fixed edges in the inner part of the joint are sharp. Cuneiform in transversal cut, the menisci are firmly attached to the intercondylar area of tibia. Their outer edges are attached to the fibrous capsule of the knee joint. The coronary ligaments are capsular fibers clinging to the margins of the menisci to the tibial condyles (MOORE and DALLEY, 2001).

A body and two horns can be distinguished in the menisci (anterior and posterior), and these wider regions serve as the basis for the insertion of the meniscus.

The firm bony insertion of the anterior and posterior horns is considered crucial to the meniscus function of loads distribution (GAO, ÖQVIST and MESSNER, 1994).

The medial meniscus is C-shaped and it is wider anteriorly than posteriorly. (MOORE and DALLEY, 2001). Its anterior insertion is fan-shaped, and it is attached to the tibial plateau and to the intercondylar notch above, about 6 to 7 mm anterior to the fixation of the anterior crossed ligament (KOHN and MORENO, 1995). Its posterior insertion attaches to the posterior intercondylar area of the tibia between the posterior insertion of the lateral meniscus and anteriorly to the fixation of the posterior crossed ligament (MESSNER and GAO, 1998).

The lateral meniscus is almost circular and it is smaller and more freely movable than the medial meniscus. The anterior insertion of the lateral meniscus is attached to the anterior intercondylar fossa of the tibia, anteriorly to the lateral eminence of the tibia, and. Parts of its fibers blend with the anterior crossed ligament (MESSNER and GAO, 1998). The insertion of the posterior lateral meniscus is fixed in the tibia posteriorly to the insertion of the medial meniscus. In 50% of cases, the anterior fibers of the posterior insertion of the lateral meniscus are set out in the intercondylar notch of the medial condyle of the femur anteriorly to the origin of the posterior crossed ligament forming the posterior crossed meniscofemoral (KOHN and MORENO, 1995; WAN and FELLE, 1995).

The functions of the meniscus include load transmission, shock absorption, stress reduction, increase joint congruence, improve joint stability, limit extreme flexion and extension, proprioception, and joint lubrication and nutrition (GRAY, 1999)

2 **Materials and methods**

This study was submitted to the Ethics Committee in Research of UniEVANGÉLICA, and it was approved without restrictions.

Data collection was performed in June 2009.

For this study, 40 menisci of 20 human knees, 7 right and 13 left, previously dissected and preserved with a solution of formaldehyde and/or glycerin were used. Since the pieces were removed from the cadavers thus presenting an isolated knee joint, it was not possible to determine whether the knees were from the same or different cadavers nor to determine other aspects related to weight, sex, and height, even though these factors may influence certain anatomical variations.

The cadavers belonged to the Anhanguera College of Anapolis, the University Center of Anápolis - UniEvangélica and the Federal University of Goiás (UFG), which after being informed about the research objectives accepted and made

them available by signing a consent form for handling the anatomical specimens. All menisci that showed any structural change that could prevent the morphometric analysis, such as injuries or advanced degenerative processes, were excluded from the sample.

There were no risks of any damage to the pieces since the anatomy laboratory technician aided the data collection thus ensuring the preservation of the material used.

The data were collected with the aid of a digital pachymeter (JOMARCA -0.01-150 mm), and were recorded manually and with a digital camera. The collection followed the following protocol in both menisci (lateral and medial): firstly the length of each meniscus was measured, for this, a piece of thread was placed across the outer edge of the meniscus from the apex of the anterior horn to the apex of posterior horn. Next, the thread length was measured using a digital pachymeter. Then, the distances between the anterior and posterior horns were measured using the internal pachymeter face, which was placed between the apex of the anterior horn and the apex of the posterior horn. The width was measured at three points - the anterior third, middle third, and posterior third (Figure 1). From each point, the pachymeter was positioned from the outer edge to the inner edge of each meniscus. The thickness of the meniscus was determined using the same width points, and then the pachymeter was placed between the top and bottom edge in the outer circumference only.

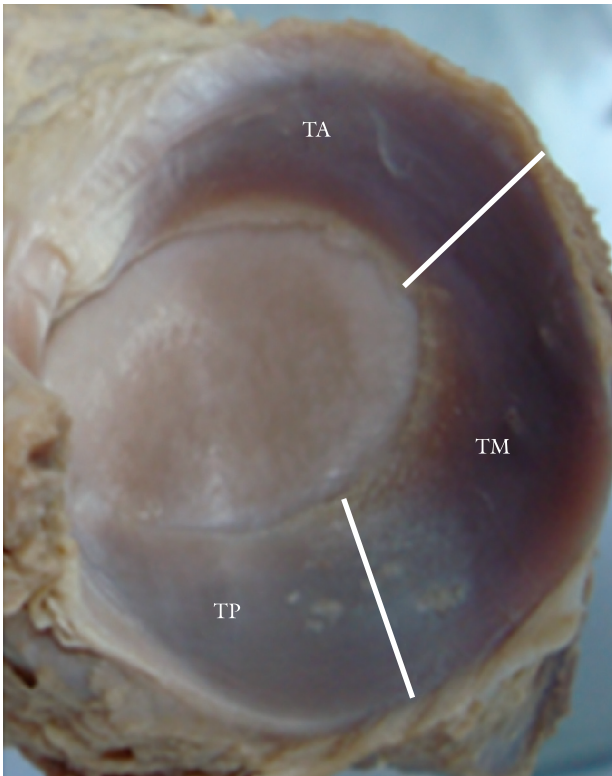


Figure 1. Top view of the meniscus representing the three points of the morphometric analysis: anterior third (TA), middle third (MT), posterior third (PT).

The data were analyzed statistically using the Student *t*-test for independent samples, and the level of significance was 0.05.

3 Results

From the results obtained, it was observed that there was no statistically significant difference in the length of the outer circumference ($p > 0.05$) between the medial (91.85 ± 5.66 mm) and lateral meniscus (92.80 ± 7.52 mm).

The distance between the anterior and posterior horn of the medial meniscus (25.88 ± 3.33 mm) was significantly higher than that of the lateral meniscus (12.55 ± 1.98 mm).

With regard to the width of the lateral meniscus, there was no significant difference between the anterior (11.32 ± 1.46 mm), medium (11.16 ± 1.64 mm), and posterior thirds (11.67 ± 1.54 mm). However, in the medial meniscus, the posterior third was the widest part (14.96 ± 2.66 mm) followed by the mid (9.32 ± 2.24 mm) and anterior third (7.68 ± 1.36 mm). Comparing the width of the medial and lateral menisci, a statistically significant difference ($p < 0.05$) in three points was found (Figure 2).

When analyzing the thickness of the outer circumference of the medial meniscus, the posterior third (5.18 ± 1.55 mm) appeared thinner compared to the anterior (6.17 ± 1.68 mm) and medium thirds (6.31 ± 1.73 mm). There was no

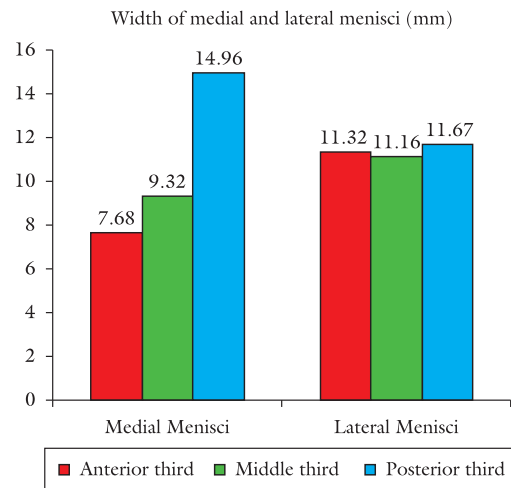


Figure 2. Average values of the width of the meniscus.

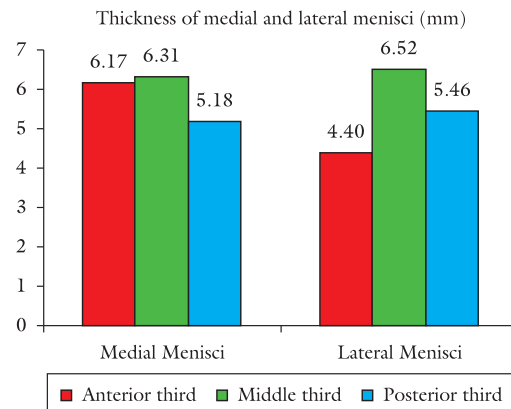


Figure 3. Average values of the thickness of the meniscus.

significant difference between these two last thirds. In the lateral meniscus, the middle third (6.52 ± 1.81 mm) was the thickest followed by the posterior (5.46 ± 1.19 mm) and anterior third (4.40 ± 0.83 mm), respectively (Figure 3).

Comparing the average thickness value of the medial meniscus with the value of the lateral meniscus, it was observed that only the anterior third of the medial meniscus was significantly thicker ($p < 0.05$) compared to the lateral meniscus.

4 Discussion

The data related to the morphology of the menisci are scarce; therefore, the main objective of this study was to analyze the morphometric variations present in the human meniscus, enriching the literature on this subject, and correlating these variations with the possibility, location, and type of lesion as shown in the literature review. In this study, the average length of the outer circumference was 91.85 mm for the medial meniscus and 92.80 mm for the lateral meniscus. There was no statistically significant difference. According to Moore and Dalley (2001) and Didio (1998), the lateral meniscus is smaller than the medial, but when referring to the size of the meniscus these authors did not describe values confirming the lack of data on morphometry menisci in the literature.

Kapandji (2000), reports that the horns of the lateral meniscus are closer together than those of the medial meniscus. This description is in agreement with our results, which showed that the distance between the anterior and posterior horns of the lateral meniscus is 12.55 mm and the medial meniscus is 25.88 mm. Due to the fact that the lateral meniscus has the form of an almost complete ring, whereas the medial is more like a half-moon, since it presents a larger interruption between its horns, it can be explained why the outer circumference measures showed no significant difference since even the medial meniscus being apparently higher, due to the larger size of the medial condyle of the tibia, it also has a bigger distance between its horns, whereas the lateral meniscus has a smaller distance between its horns thus compensating for the difference in size of the tibial plateau, which is bordered by the menisci.

This greater proximity of the horns of the lateral meniscus may explain why they are less prone to injury.

According Motta Filho, LAJ., Motta and Motta Filho, GR. (1999), the lateral meniscus has an average width of 12 mm. On the other hand, Hayashi, Yamaga, Ida et al. (1988) defined the normal display of the meniscus as 12-13 mm wide.

There were no significant variations in relation to the width between the points discussed in the lateral meniscus, with an average of 11.38 mm, whereas in the posterior third, the medial meniscus proved to be the widest followed by the middle and anterior third, with an average of 10.65 mm.

In accordance with our results, investigating the morphology of the meniscus, and using three points to measure the width and thickness of the meniscus, Almeida, De Moraes, Tashimiro et al. (2004) reported that the individual analysis of each meniscus showed that the posterior third was the widest in the medial meniscus, while no statistically significant difference was observed in the lateral meniscus between the three periods analyzed.

This description is also in agreement with Moore and Dalley (2001), who described that the medial meniscus is larger posteriorly than anteriorly.

According Motta Filho, LAJ., Motta and Motta Filho, GR. (1999), the lateral meniscus has an average thickness of 4-5 mm although Hayashi, Yamaga, Ida et al. (1988) state that the normal meniscus is 6-8 mm thick.

With regard to the thickness of the meniscus, which was also measured at three points, the posterior third of the medial meniscus was the smallest (5.18 mm) followed by anterior (6.17 mm) and medium thirds (6.31 mm) showing an average of 5.88 mm. On the other hand, in the lateral meniscus, the anterior third was the smallest (4.40 mm) followed by the posterior (5.46 mm) and medium (6.52 mm) thirds, and their average value was 5.46 mm.

With regard to the thickness of the medial meniscus, Almeida, De Moraes, Tashimiro et al. (2004) stated that the middle third was the smallest followed by the anterior and posterior thirds. This difference may be explained by the fact that the three points used to perform the measures did not coincide during the data collection.

It can be said that the width and thickness were inversely related, the greater the width of one of thirds, the smaller the thickness, while the opposite was also true.

In a study on the location of meniscal ruptures, Rico and Ayala (1997) observed that the medial meniscus is more commonly affected and topographically lesions were more frequent at the middle third (51%) followed by the posterior third (39%) and the anterior third (10%). According to Yazaki, Assis and Cundari (1995), lesions in the anterior horn of the medial meniscus are less frequent, either alone or associated with other locations. With regard to the lateral meniscus, it was noted that lesions of the body (middle third) appear more frequently, either alone associated with other locations.

Comparing the lower incidence of injury in the anterior third of the meniscus with the results of this study, it can be assumed that the wider the meniscus, the more susceptible it is to meniscal injuries. Such assumption could be justified by the fact that the greater the width of the meniscus, the more it is exposed to the actions of the femoral condyles. Great evidence is that the anterior third of the medial meniscus is the one with the smallest width compared with the other two points.

It was found in this study that the middle third was the thickest part of both the medial and lateral meniscus. Although being the thickest, the middle thirds of both menisci presented the highest incidence of injury. This may be related to the fact that the menisci have two fixed points, the horns, while the remainder point (middle third) is mobile, making it more prone to stress. This alone would justify this anatomical thicker feature.

Comparing the thickness of the middle third of both menisci, it was observed that the thickness of the middle third of the medial meniscus is smaller than that of the middle third of the lateral meniscus. This may explain the higher incidence of injuries in the medial meniscus.

Furthermore, the lateral meniscus deforms and moves more than the medial since the insertion of their horns are closer, and thus it can follow the movement of the femoral condyles on the tibial glenoids better.

All these factors together can make the middle third of both the medial and lateral meniscus more prone to rupture.

5 Conclusion

With regard to the length of the outer circumference, there was no statistically significant difference between the medial and lateral meniscus. The distance between the anterior and posterior horn of the medial meniscus was significantly higher than that of the lateral meniscus. The lateral meniscus presented no significant difference with respect to the width between the anterior, middle, and posterior thirds, whereas in the medial meniscus, the posterior third was the widest part. With regard to thickness, the middle third of both menisci was the thickest part.

The morphometric findings of the meniscus demonstrate accordance with studies regarding the location of meniscal injuries.

The anterior third of the medial meniscus presented smaller width, which explains the lower incidence of injuries at this point of the meniscus due to the weaker action of the femoral condyles. Similarly, the measures of the middle third confirmed that is the point of greatest tension, and also that it is the most frequently injured region in both menisci.

Therefore, health professionals that work with the treatment of meniscal injuries should be aware of the possible anatomical variations that may exist in the meniscus facilitating the rehabilitation process.

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