

Aysin Kale
Cem Kopuz
Metec Edýzer
Mennan Ece Aydin
Mehmet Demýr
Yener Ýnce

Anatomic variations of the shape of the menisci: a neonatal cadaver study

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A. Kale · C. Kopuz (✉) · M. Edýzer ·
M. E. Aydin · M. Demýr
Department of Anatomy,
Medical School Ondokuz Mayıs
University, Körfez Mah. Atatürk Bulvarı
No. 124, Kurupelit, Samsun, Turkey
E-mail: drckopuz@yahoo.com
Fax: +90-362-4576091

Y. Ýnce
Clinics of Orthopaedics and Traumatology,
Samatya SSK Hospital, İstanbul, Turkey

Abstract Meniscal injuries in children and adolescents are being seen with increased frequency. The menisci are two crescentic lamellae whose functions are to deepen the articular surfaces of the tibial plateau for reception of the condyles of the femur. In our study, our aim is to determine the variations of the shapes and attachments of the menisci in newborns. This study was performed on 11 neonatal cadavers, 22 knee joints that were obtained from the anatomy laboratory. The variations of the shape of the menisci were noted. We found that 77% of the lateral menisci were discoid. This percent is higher than the previously reported percents of the lateral discoid menisci. The different shapes of the menisci were deter-

mined as horse shoe, sickle, sided U, sided V and C shaped. We did not determine any discoid medial menisci. We believe that our study will provide support to the neonatal anatomy of the knee, concerning with the surgical procedures and arthroscopy of the knee joint.

Keywords Knee · Meniscus · Shape · Newborn · Variation

Introduction

The snapping knee syndrome is usually related with the type of the meniscus or to the presence of a tear of the meniscus. This syndrome appears more often in children and young adolescents [18, 23, 36, 37].

The menisci are two crescentic lamellae, which serve to deepen the surfaces of the articular fossae of the head of the tibia for reception of the condyles of the femur [26, 31, 35]. There are many studies on general anatomy of the menisci of the adults [5, 11, 30]. Although anomalous shapes of the menisci of the adults have been reported before [2, 4, 5, 6, 8, 13–22, 24, 25, 27–29, 32–34], the gross anatomy of the menisci of the newborns have been poorly studied.

The anatomic abnormalities and variations of the intraarticular structures of the knee joint have recently become significant because of the new imaging techniques such as arthroscopy, computed tomography and magnetic resonance imaging. Also the investigation of these variants is important in order to define the morphologic features for clinical diagnosis and for surgical procedures. The aim of this study is to determine the variations of the shape of the menisci in newborns.

Materials and methods

Our study was performed on 22 knee joints of 11 neonatal cadavers (7 girls and 4 boys) who were born dead

and these belonged to the anatomy collection of Ondokuz Mayıs University Medical Faculty. All of the cadavers were aged between 37 and 40 weeks of gestational age and they had been stored in 10% buffered formalin and they had no musculoskeletal system anomalies.

After removal of the skin and muscles, the approach to the menisci was performed, opening anteriorly by a longitudinal incision on each side of the joint capsule, cutting the patellar ligament and the collateral ligaments transversely. In order to expose the menisci clearly, the joint capsule and the intraarticular ligaments were cut, and the femurs were separated. We measured the width of the midpoint of the anterior horns, posterior horns and lateral sides of the menisci. Morphologic variants of the shapes of the menisci were macroscopically noted and classified.

The lateral menisci (LMs) were subgrouped as discoid and undiscoid menisci. The discoid menisci were divided into subgroups as the complete and incomplete discoid menisci. The undiscoid LMs were subgrouped as crescentic (semilunar) shaped and C shaped menisci. The medial menisci (MM) were subgrouped as sickle shaped, sided U shaped, sided V shaped and C shaped (Fig. 1a, b, c, d, e, f, g).

When the meniscus covers the tibial plateau circularly, the meniscus is said to be discoid type. The incomplete discoid menisci had an opened area at the center of the menisci and they were all horseshoe shaped. The menisci which did not have any opened area at the center of the menisci were defined as the complete discoid menisci. The menisci, which had thin anterior and posterior horns and a thin body, were defined as the crescentic (semilunar) type. The menisci, which had thick anterior and posterior horns and a thick body, were named as the thick horse shoe shaped type. The

menisci, which had thin anterior and posterior horns and a thick body, were defined as the sickle shaped type. The menisci which resembled like sided U, sided V and C were named as sided U, sided V and C shaped, respectively. The data were analysed statistically using Student's *t*, variance analysis tests.

Results

Seven morphological types of the shape of menisci were determined. There were no significant meniscal morphological differences between boys and girls ($P < 0.05$). Of all cadavers, 73% (8 cadavers) had the same shape of menisci on each side.

We found that 77.27% (17 LM) of the LMs were discoid. 54.54% of the LMs were incomplete discoid (thick horse shoe shaped), and 22.72% of the LMs were complete discoid. It was found that 22.72% of the LMs were undiscoid. The undiscoid ones had two shapes. Their percentage of existence of all the LM were as follows: 13.63% of the LMs had a crescentic shape, and 9.09% of the LM (2 LM) were C shaped.

We did not find any discoid medial menisci. 36.36% of the MMs were sickle shaped, 22.72% of the MMs were sided V shaped, 18.18% of the MMs had a crescentic shape, 13.63% of the MMs were C shaped, and 9.09% of the MMs were sided U shaped (Table 1, Figs. 2, 3, 4, 5, 6, 7, 8).

The mean width of the midpoint of the anterior horn, posterior horn and the lateral side of the LMs were recorded as 0.29, 0.34 and 0.37 cm, respectively. The mean width of the midpoint of the anterior horn, posterior horn and the lateral side of the medial menisci were recorded as 0.28, 0.29 and 0.26 cm, respectively.

Fig. 1 Diagrams of the shapes of the menisci in newborns. **a** Incomplete discoid, **b** complete discoid, **c** crescentic shaped, **d** sickle shaped, **e** C shaped, **f** sided U shaped, **g** Sided V shaped

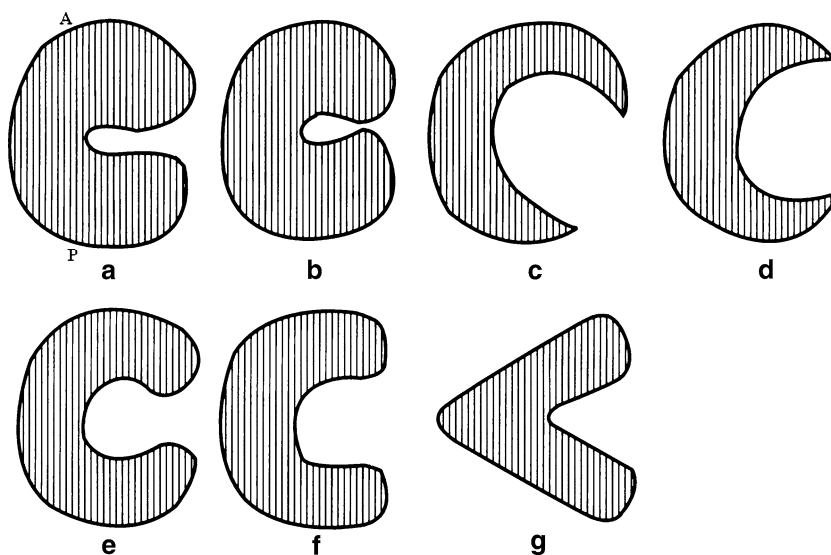


Table 1 Incidence of the variations of the shape of the menisci in neonatal cadavers

Lateral menisci (LMs)		Medial menisci (MM)				
Discoid LM	Undiscoid LM	Sickle shaped MM	Sided V shaped MM	Crescentic shaped MM	C Shaped MM	Sided U shaped MM
77.27% (17 LM)	22.72% (5 LM)	36.36% (8 MM)	22.72% (5 MM)	18.18% (4 MM)	13.63% (3 MM)	9.09% (2 MM)
Complete discoid LM	Incomplete discoid LM	C shaped LM	Crescentic shaped LM			
22.72% (5 LM)	54.54% (12 LM)	9.09% (2 LM)	13.63% (3 LM)			

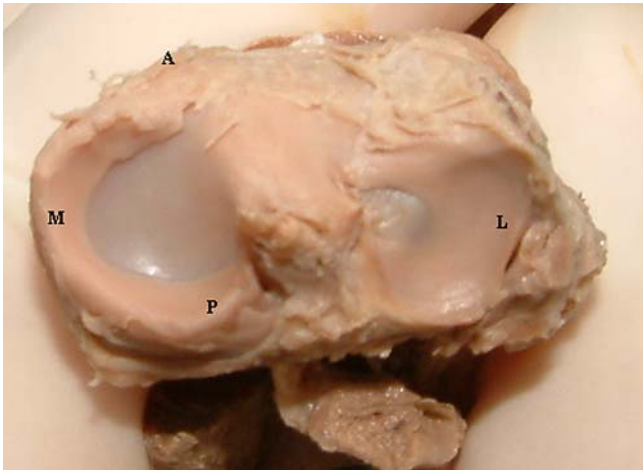


Fig. 2 Incomplete discoid form of the lateral meniscus and C shaped medial meniscus of the *right side* of a neonatal cadaver. *L* lateral meniscus, *M* medial meniscus, *A* anterior horn, *P* Posterior horn

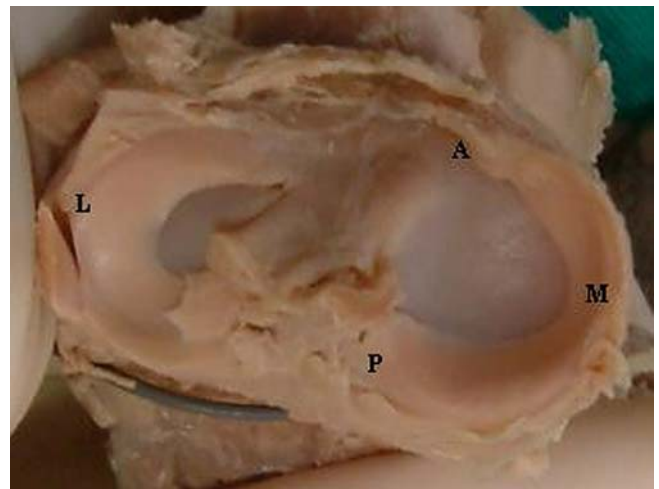


Fig. 4 Sided U shaped medial meniscus of the *left side* of a neonatal cadaver

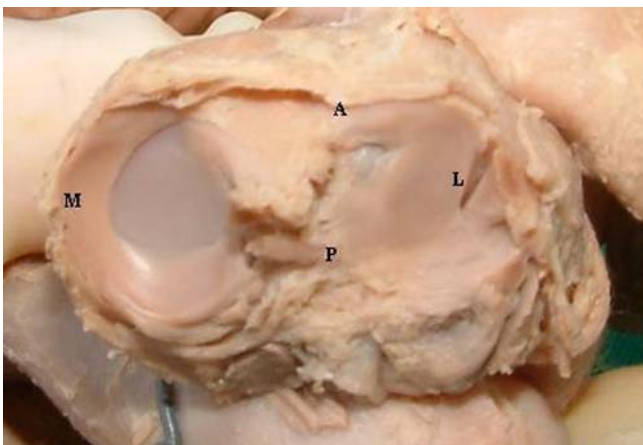


Fig. 3 Complete discoid form of the lateral meniscus of the *right side* of a neonatal cadaver

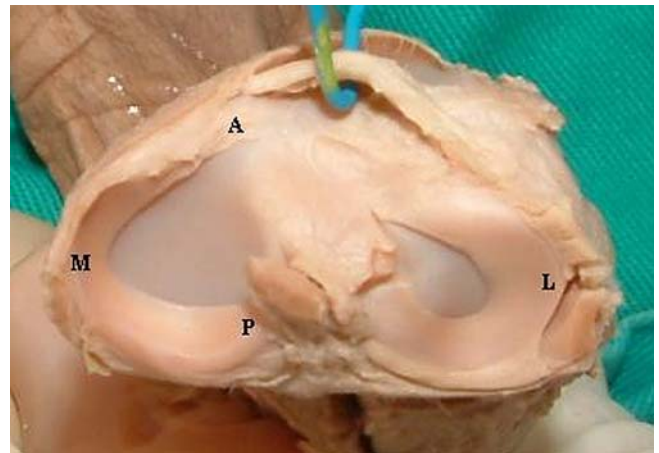


Fig. 5 Sided V shaped medial meniscus of the *right side* of a neonatal cadaver

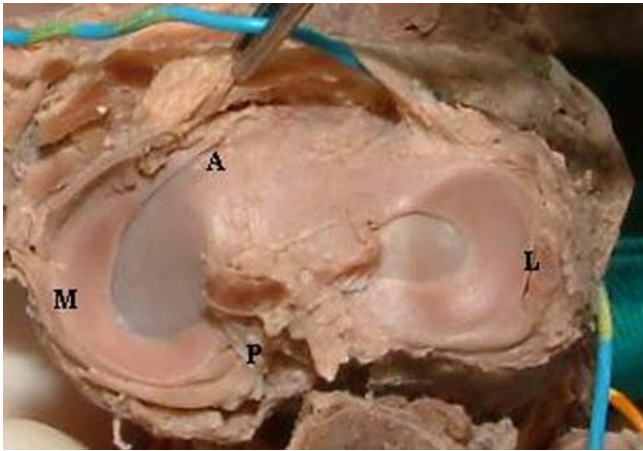


Fig. 6 Crescentic shaped medial meniscus of the *right side* of a neonatal cadaver

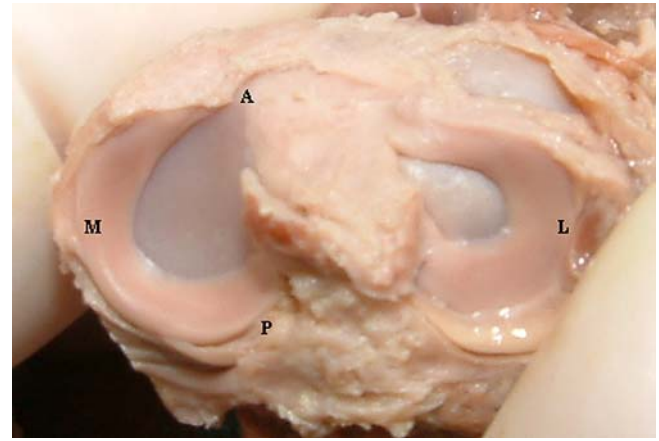


Fig. 8 Sickle shaped medial meniscus of the *right side* of a neonatal cadaver

Discussion

Meniscal injuries in children and adolescents are being seen with increased frequency. Meniscal tears are typically traumatic injuries in adolescents. Another pathological finding of the menisci of the children is discoid meniscus [17]. It has been reported that the lateral meniscus has a crescentic shape [13]. Young [34] first described a lateral discoid meniscus in 1889. It typically presents as a snapping knee in younger children or as a meniscal tear in older children [17]. The discoid meniscus is the most common abnormal meniscal variant in children [8, 17, 18]. Discoid meniscus is an atavistic anomaly in which the meniscus of the knee, predominantly the LM, is discoid rather than semilunar in shape [8, 24]. Additional anomalies of the meniscal shape have been

classified as hypoplasia or hyperplasia. The meniscal hyperplasia or discoid menisci, have been the object of many studies, because they are frequently the source of symptoms [4, 14, 15, 22, 32]. Davidson et al. [8] reported that this abnormality was diagnosed relatively infrequently and might even go unrecognized or be untreated. They also reported that partial resection of discoid menisci was preferable in children, but they added that in complete dislocation of the entire menisci, total removal was necessary.

Discoid LM is more common than the discoid MM [24, 34]. This fact was mentioned in the research of Kelly and Green [18] as the discoid meniscus was most likely a congenital deviation and usually occurred laterally. Moreover it was reported that the discoid shape resulted in greater coverage of the tibia and usually was associated with increased thickness of the meniscus that might lead to abnormal shearing forces across the knee joint [18]. Le minor [24] reported that the frequency of discoid LM in man varied, according to the series, between 1 and 15.5%. These series were based either on meniscectomies or on arthrographies. He also reported that it was difficult to extrapolate this figure to the whole species, especially as racial variations seemed to exist [4, 16, 24]. Also Chiang and Jiang [6] reported that discoid LM was rare in western races, but not uncommon among oriental people. Moreover Le minor [24] reported that the discoid LM was usually unilateral, however bilateral observations were reported in the literature [15, 22, 24]. Of 10,000 meniscectomies reported by Smillie [33], 467 had a discoid LM [33]. Tachibana et al. [34] reported that Dickason et al. had determined that 102 of 6691 LM were discoid. Kim et al. [21] reported that 72 of 543 symptomatic patients were found to have a discoid LM.

The most commonly used classification system for discoid LM, by Watanabe et al. [37], is based upon their shape and tibial attachments [18, 27]. This classification

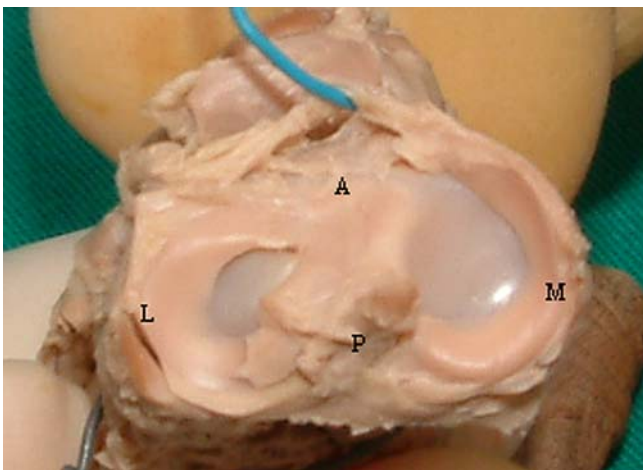


Fig. 7 C shaped lateral meniscus of the *left side* of a neonatal cadaver

has been developed from arthroscopic observations and it has classified discoid LMs into three types: complete (type 1), incomplete (type 2), and Wrisberg ligament (type 3). The complete and incomplete types have normal posterior capsular attachments and are distinguished by the amount of the tibial plateau covered. According to Watanebe's [37] classification, Type 1 discoid menisci cover the entire tibial plateau, whereas type 2 discoid menisci vary in size, shape, and structure. The classically described type 3 does not necessarily have a discoid shape and is characterized by absent normal posterior tibial attachments with only the meniscofemoral ligament of Wrisberg providing femoral attachment. This structure results in significantly increased mobility that may clinically manifest as the snapping knee syndrome [37].

Kelly and Green [18] mentioned in their study about the discoid LM in children that Husson et al. [14] proposed a new classification based upon both arthroscopic and clinical findings. This system provided a more complete description of the lateral meniscal types and suggested how types might influence treatment. In this classification system, both the complete and incomplete discoid menisci were considered stable because they had the same firm anterior and posterior tibial attachments, regardless of the presence of a meniscofemoral ligament attachment. The stable types were further subclassified as symptomatic or asymptomatic and as torn or not torn [18]. The unstable types in this system were classified as either unstable with a discoid shape or unstable with a normal shape.

In our study, the LMs were subgrouped as discoid and undiscoid menisci. The discoid menisci were divided into subgroups as the complete and incomplete discoid menisci. The undiscoid LMs were subgrouped as crescentic (semilunar) shaped and C shaped menisci. Moreover in the present study, the medial menisci (MM) were subgrouped as sickle shaped, sided U shaped, sided V shaped and C shaped. The way how we have made this classification has been explained in the materials and methods section of the present study. In the present study, we found that 77.27% of the LMs were discoid. 54.54% of the LMs were incomplete discoid (thick horse shoe shaped), and 22.72% of the LMs were complete discoid. It was found that 22.72% of the LMs were undiscoid. The percentage of existence of the types of the undiscoid LM were as follows: 13.63% of the LMs had a crescentic shape, and 9.09% of the LMs were C shaped.

A discoid medial meniscus is an extremely rare anomaly [24, 25, 34]. The rare cases of it have been reported by the researchers as case reports [21, 24, 29, 34]. Le minor [24] reported that the frequency of a discoid MM was differently estimated and out of a total of 16,895 subjects recorded in the literature, 15 cases (0.009%) of discoid MM were mentioned [4, 24]. We did not find any discoid medial menisci. In our study,

36.36% of the MMs were sickle shaped, 22.72% of the MMs were sided V shaped, 18.18% of the MMs had a crescentic shape, 13.63% of the MMs were C shaped, and 9.09% of the MMs were sided U shaped.

In this study, of all cadavers, 73% had the same shape of menisci on each side. The difference of our results from the other researchers might be due to the fact that we performed our study in neonatal cadavers instead of adults. There are not many studies on the neonatal anatomy of the knee joint. Arrequi et al. [2] performed an examination on 20 frozen fetuses with standart arthroscopic surgical equipment and their results indicated minimal differences when compared with the adult knee. The only variation they saw was, the LM was disproportionately larger than the MM in fetuses of earlier gestational age [2]. In the present study, we also found that the LM was larger than the medial one.

The variations of the shape of the menisci are explained by embryological meniscal development [24, 33]. The meniscus arises from the differentiation of mesenchymal tissue within the limb bud, and it becomes a clearly defined structure by the eighth week of fetal development [1, 2, 18]. The menisci arise from the eccentric portions of the articular interzone during O'Rahilly stage 22, however until weeks 9 of development, they are not easily distinguishable [28]. On the other hand, during embryologic development, the blood supply of the meniscus enters from the periphery and extends throughout the entire width. However, by the ninth month of life, the central third will be avascular, and by adulthood, only the peripheral one third will receive any blood supply [7]. At 9 weeks' development, they are already perfectly formed. From that point on, the menisci grow at the same rate as the rest of the intra-articular structures, without undergoing any macroscopic structural changes [2] and assume the normal adult relationships with the rest of the knee by the 14th week [12, 18].

According to Le Minor [24], the classical explanation for the discoid LM in man is the persistence of the initial embryonic arrangement. The discoid shape is the first and normal stage of meniscal morphogenesis. The medial part of the meniscus later undergoes a progressive resorption. The origin of the discoid menisci can then be explained by a greater or lesser deficiency of resorption [24]. Smillie [33] who proposed the first theory on this subject, stated that there was a failure of resorption of the central area of the cartilage plate during fetal stages of normal development. Kaplan [23] stated that discoid meniscus developed because of the absence of the posterior tibial attachment of a normal meniscus in his adult series.

Nevertheless Le minor [24] reported that no embryological study in the human fetus had ever shown this initial discoid stage, the LM having its adult crescent shape from its inception. He added that most authors thought that the discoid LM did not originate by the

persistence of a normal embryonic structure but resulted directly from abnormal morphogenesis [24]. Most authors now believe that the discoid meniscus must be of congenital origin [3, 7, 10, 18, 20, 36] and that further support for a congenital theory comes from evidence of familial transmission [9] and reports of occurrence in twins [12, 18].

When our study is compared with the adult studies, our results indicate that the basic primordial shape of the meniscus is the discoid type and this form transforms to other shapes. Additionally, our series show that transformation can start earlier during the intrauterine period. The differences of the shape of meniscus may be due to the mesenchymal differentiation or to the development of the vasculature early in embryonic life.

In conclusion, our results show that in neonatal cadavers, four main types of the shape of the menisci, comparable to the adult form, exist. Since no degenerative changes are expected in the neonatal period, final form of the adult menisci might be due to developmental procedures, degenerative changes playing, at most, a secondary role. We believe that our study will provide support to the neonatal anatomy, concerning with the surgical procedures and arthroscopy of the knee joint.

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