ORIGINALNI RAD / ORIGINAL ARTICLE

UDC: 572.781(497.11)"2010/2017"

DOI: 10.5937/erhs2201001J

MORFOMETRIJSKO-ANATOMSKI PARAMETRI INTERKONDILARNE JAME KOLENA KOD ODRASLIH OSOBA U SRBIJI

Dejan Jeremić[1], Ivana Živanović-Mačužić[1], Maja Vulović[1], Marija Kovačević[1], Miloš Minić[1]

[1]Univerzitet u Kragujevcu, Srbija, Fakultet medicinskih nauka, Katedra za anatomiju

THE MORPHOMETRIC-ANATOMICAL PARAMETERS OF THE INTERCONDYLAR NOTCH IN ADULT KNEE OF SERBIAN POPULATION

Dejan Jeremić[1], Ivana Živanović-Mačužić[1], Maja Vulović[1], Marija Kovačević[1], Miloš Minić[1]

[1]University of Kragujevac, Serbia, Faculty of Medical Sciences, Department of Anatomy

Sažetak

Cilj: ovog istraživanja je bio da ispita morfometriju interkondilarne jame srpskog stanovništva i utvrdi da li postoji polna razlika ovih anatomskih parametara kod asimptomatskih ispitanika bez strukturnih promena.

Metod: Studija je obuhvatila MR snimke 90 pacijenata (45 muškaraca i 45 žena) kojima je urađen

1,5-T snimak kolena. Snimanje je sprovedeno na našem radiološkom institutu po odobrenju etičke komisije u periodu od 2010. do 2017. godine. Kolena su snimana u neutralanom položaju, a MR slike su dobijene korišćenjem konvencionalnih spin eho tehnika. Morfologija interkondilarne jame (oblika slova U i A) je merena za svako koleno.

Rezultat: Interkondilarna jama U-oblika pronađena je kod 46 pacijenata (51,2%), a interkondilarna jama A-oblika kod 44 (48,8%). Nije bilo statistički značajne razlike u incidenciji oblika u srpskoj populaciji ($p>0,05$). Prema kriterijumima indeksa širine jame (NWI) i indeksa oblika jame (NSI) pronašli smo interkondilarnu jamu U-oblika kod 24 muškarca i 22 žene, a interkondilarnu jamu A-oblika kod 23 muškarca i 21 žene. Nije bilo statistički značajne razlike u incidenci između polova ($p>0,05$).

Zaključak: Zaključili smo da za ispitivane anatomske parametre interkondilarne jame nema značajnih razlika i da ne postoji polni dimorfizam oblika interkondilarne jame u srpskoj populaciji.

Ključne reči: interkondilarna jama, anatomski parametri, koleno odraslih, MR merenja, polna razlika, srpska populacija

Abstract

Objective: The aim of this investigation was to examine normal intercondylar notch morphometry in Serbian population and to determine whether there are gender differences in anatomical parameters of the intercondylar notch among asymptomatic subjects without structural change.

Method: The study included MR images of 90 patients (45 men and 45 women) receiving a 1,5-T knee scan at our radiological institute after the approval from the Ethics committee, which were taken in the period from 2010 to 2017. The knee was placed in the neutral position, and MR images were obtained using conventional spin echo techniques. The morphology of the intercondylar notch (U-shaped and A-shaped notch) was measured for each knee.

Results: The measurements of parameters for intercondylar notch geometry were obtained by analyzing coronal MR images. U-shaped intercondylar notch was found in 46 patients (51.2%) and A-shaped intercondylar notch in 44 (48.8%). There was no significant difference in the shape incidence in Serbian population ($p>0.05$). According to the Notch width index (NWI) and the Notch shape index (NSI) criteria, we found U-shaped intercondylar notch with 24 men and 22 women and A-shaped intercondylar notch with 23 men and 21 women. There was no significant difference in incidence between the genders ($p>0.05$).

Conclusion: We concluded that for all examined anatomical parameters of the intercondylar notch there were no significant differences in Serbian population. According to our findings in this study, we concluded that there was no sexual dimorphism for anatomical parameters of intercondylar notch in Serbian population.

Keywords: intercondylar notch, anatomical parameter, adult knee, MR measurement, gender differences, Serbian population

Introduction

The intercondylar notch (IN) or fossa intercondylaris is located on the posterior side of the distal part of the femur between the lateral and medial condyle. The intercondylar notch contains connective tissue in the form of the anterior (ACL) and posterior (PCL) cruciate ligaments, the anterior (aMFL) and posterior (pMFL) meniscofemoral ligaments. These ligaments are crucial for stabilizing the knee, so their relationship with the osseous part of the intercondylar space is extremely important for normal knee function. (1) Many studies have investigated the morphometric characteristics of the intercondylar notch due to their impact on ligament damage and the outcome of arthroscopic ACL reconstruction.

Based on morphometric parameters of intercondylar notch, Hutchinsonet defined two types of intercondylar notch, U- shaped and A-shaped. (2) Tanzer considered narrowed and stenotic IN, as A-shaped and intercondylar notch with a normal, flattened top as U-shaped notch. (3) The literature also describes a W-shaped notch representing a variation of the U-shaped notch with two tops on the roof. (4, 5)

Intercondylar notch dimensions are considered as a significant predictive risk factor for ligament injury. (6) The aim of this study was to determine the morphometry of the intercondylar notch and the possible existence of a difference in shape of IN between women and men.

Materials and Methods

The study included MR images of the knees of 90 asymptomatic patients, 45 men and 45 women. They received a 1,5-T knee scan at our radiologic institute, after the approval from the ethics committee, which were taken in the period from 2010 to 2017. The knee was placed in the neutral position, and the MR images were obtained using conventional spin echo techniques. We measured the morphology of the intercondylar notch (U-shaped and A-shaped notch) for each knee.

The following exclusion criteria were defined:

- inadequate quality of the images
- fracture or dysplasia of the distal femur
- previous arthroscopy or open surgery
- osteoarthritic changes of the intercondylar notch.
- varus or valgus deformity of the knee

We measured the set parameters in horizontal images: the width of the medial and lateral femoral condyle, the notch width (NW), the total width of the distal femur. To calculate the notch height (ICH) we used the distance between the highest point of the intercondylar notch and the line passing through the last point of the lateral and medial condyle of the femur (Figure 1).

The cross section (a) on which measurements were conducted was determined on sagittal MR images, based on the vertical line (h) which passes through the most posterior point of the lateral and medial condyle (Figure 2).

The notch width (NW) was measured as the distance from the medial articular cartilage margin of the lateral femoral condyle to the lateral articular margin of the medial femoral condyle. (5)

We calculated the notch width index (NWI) as the ratio between the NW and the total width of the distal femur. We defined that NWI values of 0.270 or more were normal, and values of 0.269 or less were considered below normal (5). Notch shape index (NSI) was defined as the ratio between the NW and the ICH. Intercondylar notch stenosis was indicated when the NSI value was 0.532 or less. (7) All measurements were done by two independent investigators.

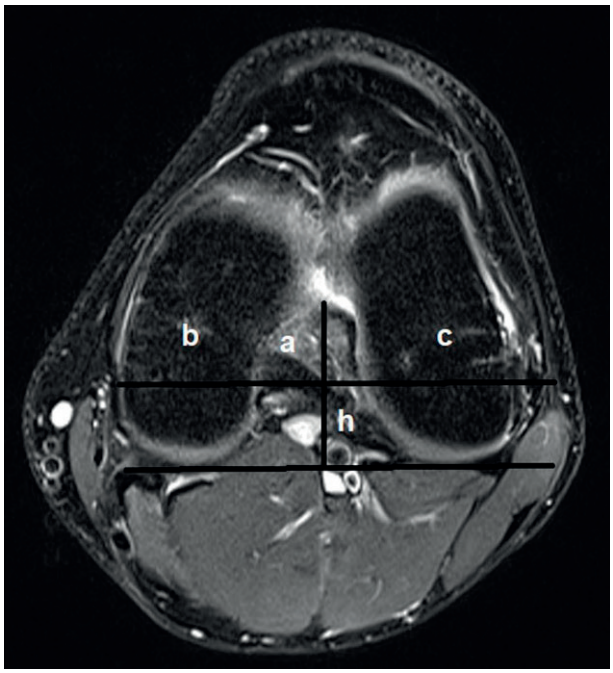

Figure 1. Intercondylar notch – A shaped: the notch width (a), width of the medial femoral condyle (b), width of the lateral femoral condyle (c) and the notch height (h) on horizontal MR images of a 30 – year old man.

Statistical analysis: Sex-related differences of anatomical parameters of intercondylar notch were assessed by paired samples of t-tests. A significance level of $p<0,05$ was assumed. The statistical differences between prevalence of A- or U-shaped IN on MR images were evaluated by x^2 tests. A *p*

value of less than 0.05 was regarded as statistically significant. SPSS statistical software version 11,5 was used for all calculations (SPSS, Chicago, IL).

Results

Within a group of 90 patients, according to NWI and NSI criteria, we found an intercondylar notch in the shape of the letter U in 46 patients (51.2%) and an intercondylar notch in the shape of the letter A in 44 patients (48.8%), based on the images analyzed in coronary MR. There was no significant difference in incidence between the groups (p>0.05). According to NWI and NSI criteria we found U-shaped intercondylar notch in 24 (26,6%) men and 22 (24,4%) women analyzed coronal MR images. There was no significant difference in incidence between the genders (p>0.05). We found an A-shaped intercondylar notch in 23 (25.5%) men and 21 (23.3%) women. Also, in this group there was no significant statistical difference between the genders (p> 0.05).

Table 1. Values of intercondylar notch by gender in Serbian population

Intercondylar notch	Male	Female	total	p value
U - shaped	24 (26,6%)	22 (24,4%)	46 (51,2%)	>0.05*
A - shaped	23 (25,5%)	21 (23,3%)	44 (48,8%)	>0.05*

U - normal sized intercondylar notch. A- narrowed intercondylar notch

*No significant difference

Discussion

The results of our study did not show a significant difference in incidence between the U-shape and the A-shape of the intercondylar notch between men and women. There was no significant difference in the shape of the intercondylar fossa in the total sample of subjects.

Shape, NW, NWI and NSI are the characteristics that most often describe the structure of the intercondylar notch and whose changes are considered to be indicators of the risk of ligament injuries. The question is whether gender has influence on the morphology of IN and whether it can be a significant risk factor for these injuries.

MR studies that examined IN of patients with and without anterior cruciate ligament impairment, indicate that some of its changes may cause ACL injuries. The narrow, A-shape of the intercondylar notch is associated with more frequent occurrence of ACL damage, which is not the case with the U-shape. (8, 9, 5, 10, 4, 11) Patients with ACL rupture have significantly more often A-shaped, 60% of them, while the control group with normal ligament has the most common U-shaped IN 73.3%. (11)

Observing the existence of different representation of IN shapes between the sexes, the same representation of shapes was observed in men and women, which is in line with the results of our study. (10,4) Examining the association of gender with IN shape and the frequency of ACL recurrences, it was found that both women and men who have A-shaped IN are more likely to experience ACL injury. (8, 10) In a study that examined damage only in women, it was found that the A-shape has a significantly higher association with ACL rupture than the U-shape. (9) Even if not statistically proven, there is a significant trend that A-shaped notch are more prone to ACL rupture with women. (4)

Van Eck and colleagues described IN shapes by measuring its width at three levels: base, middle, and top. They confirmed that shape A is narrower at all levels than shape U and narrows from base to top. Age, sex, weight, and BMI did not show an effect on the shape of the notch, but the patient's height did. Taller patients are more likely to have an U-shaped notch. (4) Investigating whether the shape of the notch changes as we age, it was observed that the A-shape dominates during the youth, inverse U in the third decade, and the Ω-shape after 40 years of age. Women in the fifties show a greater tendency towards stenotic notch and thus increase the risk of ACL damage. (12)

The notch width is significantly smaller with patients with impaired ACL compared to the ones with intact ACL. (13, 14, 11) This parameter shows the gender difference because women have smaller NW than men. (15, 16, 12, 14, 17, 4) In men, there is no difference for this parameter between ruptured and intact ACL. (13, 14)

Studies conducted on cadavers indicate that NW is more common among women, which increases their chances of stenosis. NW among women are not affected by race, while among men, African Americans' NW are narrower than Caucasians'. Also, among men, height is positively related to notch width. (16)

Smaller values of the notch width index may be associated with stenotic A-shaped notches (9,10) but not necessarily (5). Attitudes among researchers differ regarding the impact of NWI on ACL impairment. There are studies that indicate that NWI is significantly lower in patients with ACL impairment (10, 11,18, 19, 20), but there are also those that do not confirm this. (9, 5, 21)

None statistically significant difference in NWI values was reported between men and women (6, 10, 12, 15, 22, 7), although there is a trend that it is lower among women. (10) The reduced width index increases the chances of failure of the ACL reconstruction. (20)

Posterior cruciate ligament is also closely related to IN, so lower NWI values increase the risk of ligament rupture. (22) Among women, PLC avulsion has been shown to occur more frequently at lower NWI values, which is not the case among men (24)

Within this project, we conducted another study which showed that the shape of the intercondylar notch affects the occurrence of MFL. The U-shaped intercondylar notch contains MFLs more often than the A-shaped one. (25)

Notch shape index - NSI does not show statistically significant gender differences within groups with and without ACL impairment. (6,10, 26) The influence of race on this parameter does not exist. (7)

Conclusion

The data obtained during our study did not show sexual dimorphism in the shape of intercondylar notch. More detailed studies of the morphometric characteristics of IN are needed in order to introduce the influence of sex on IN shape and the occurrence of ligament damage within this fossa. Findings indicating that stenotic A-shape increases the chance of anterior and posterior cruciate ligaments damage are of great clinical importance. Understanding the structure of intercondylar notch will help in interpreting MR images of the knee and diagnosing ligaments ruptures. It is of special importance in the planning and execution of arthroscopic reconstructions of ACL, the most common orthopedic intervention.

Napomena: Ovaj rad je podržan Junior projektom 04-18 "The influence of anatomical parameters of the intercondylar fossa of the femur on the morphometric features of meniscofemoral ligaments". Projekat je odobren 2018.godine od strane Fakulteta medicinskih nauka u Kragujevacu.

Note: This paper is supported by the project grants Junior Project 04-18 "The influence of anatomical parameters of the intercondylar fossa of the femur on the morphometric features of meniscofemoral ligaments". Project approved in 2018 at the Faculty of Medical Sciences in Kragujevac.

Conflicts of interest: The authors confirm that there is no conflict of interest regarding the publication of this article.

References

1. Hirtler L, Kainberger F, Röhrich S. The intercondylar fossa-A narrative review. Clin Anat 2022; 35(1):2-14.
2. Hutchinson MR, Ireland ML. Knee injuries in female athletes. Sports Med 1995; 19(4):288-302.
3. Tanzer M, Lenczner E. The relationship of intercondylar notch size and content to notchplasty requirement in anterior cruciate ligament surgery. Arthroscopy 1990; 6(2):89-93.
4. van Eck CF, Martins CA, Vyas SM, Celentano U, van Dijk CN, Fu FH. Femoral intercondylar notch shape and dimensions in ACL-injured patients. Knee Surg Sports Traumatol Arthrosc 2010; 18(9):1257-62.
5. Al-Saeed O, Brown M, Athyal R, Sheikh M. Association of femoral intercondylar notch morphology, width index and the risk of anterior cruciate ligament injury. Knee Surg Sports Traumatol Arthrosc 2013; 21(3):678-82.
6. Balgovind SR, Raunak B, Anusree A. Intercondylar notch morphometrics in Indian population: An anthropometric study with magnetic resonance imaging analysis. J Clin Orthop Trauma 2019;10(4):702-705.
7. Tillman MD, Smith KR, Bauer JA, Cauraugh JH, Falsetti AB, Pattishall JL. Differences in three intercondylar notch geometry indices between males and females: a cadaver study. Knee 2002; 9(1):41-6.
8. Barnum MS, Boyd ED, Vacek P, Slauterbeck JR, Beynnon BD. Association of Geometric Characteristics of Knee Anatomy (Alpha Angle and Intercondylar Notch Type) With Noncontact ACL Injury. Am J Sports Med 2021; 49(10):2624-2630.
9. Bouras T, Fennema P, Burke S, Bosman H. Stenotic intercondylar notch type is correlated with anterior cruciate ligament injury in female patients using magnetic resonance imaging. Knee Surg Sports Traumatol Arthrosc 2018; 26(4):1252-1257.
10. Raja B, Marathe N, Desai J, Dahapute A, Shah S, Chavan A. Evaluation of anatomic risk factors using magnetic resonance imaging in non-contact anterior cruciate ligament injury. J Clin Orthop Trauma 2019; 10(4):710-715.
11. Fahim SM, Dhawan T, Jagadeesh N, Ashwathnarayan YP. The relationship of anterior cruciate ligament injuries with MRI based calculation of femoral notch width, notch

width index, notch shape - A randomized control study. J Clin Orthop Trauma 2021;17:5-10.

12. Hirtler L, Röhrich S, Kainberger F. The Femoral Intercondylar Notch During Life: An Anatomic Redefinition With Patterns Predisposing to Cruciate Ligament Impingement. AJR Am J Roentgenol 2016; 207(4):836-845.
13. Fernández-Jaén T, López-Alcorocho JM, Rodriguez-Iñigo E, Castellán F, Hernández JC, Guillén-García P. The Importance of the Intercondylar Notch in Anterior Cruciate Ligament Tears. Orthop J Sports Med 2015; 3(8):2325967115597882.
14. Shelbourne KD, Facibene WA, Hunt JJ. Radiographic and intraoperative intercondylar notch width measurements in men and women with unilateral and bilateral anterior cruciate ligament tears. Knee Surg Sports Traumatol Arthrosc 1997; 5(4):229-33.
15. Anderson AF, Lipscomb AB, Liudahl KJ, Addlestone RB. Analysis of the intercondylar notch by computed tomography. Am J Sports Med 1987; 15(6):547-52.
16. Everhart JS, Flanigan DC, Chaudhari AM. Anteromedial ridging of the femoral intercondylar notch: an anatomic study of 170 archival skeletal specimens. Knee Surg Sports Traumatol Arthrosc 2014; 22(1):80-7.
17. Staeubli HU, Adam O, Becker W, Burgkart R. Anterior cruciate ligament and intercondylar notch in the coronal oblique plane: anatomy complemented by magnetic resonance imaging in cruciate ligament-intact knees. Arthroscopy 1999; 15(4):349-59.
18. Zeng C, Gao SG, Wei J, Yang TB, Cheng L, Luo W, et al. The influence of the intercondylar notch dimensions on injury of the anterior cruciate ligament: a meta-analysis. Knee Surg Sports Traumatol Arthrosc 2013; 21(4):804-15.
19. Li H, Zeng C, Wang Y, Wei J, Yang T, Cui Y, et al. Association Between Magnetic Resonance Imaging-Measured Intercondylar Notch Dimensions and Anterior Cruciate Ligament Injury: A Meta-analysis. Arthroscopy 2018; 34(3):889-900.
20. Tuca M, Gausden E, Luderowski E, Valderrama I, Pineda T, Potter H, et al. Stenotic Intercondylar Notch as a Risk Factor for Physeal-Sparing ACL Reconstruction Failure: A Case-Control Study. J Am Acad Orthop Surg Glob Res Rev 2021; 5(7):e21.00143.
21. Alentorn-Geli E, Pelfort X, Mingo F, Lizano-Díez X, Leal-Blanquet J, Torres-Claramunt R, et al. An Evaluation of the Association Between Radiographic Intercondylar Notch Narrowing and Anterior Cruciate Ligament Injury in Men: The Notch Angle Is a Better Parameter Than Notch Width. Arthroscopy 2015; 31(10):2004-13.
22. Anderson AF, Dome DC, Gautam S, Awh MH, Rennirt GW. Correlation of anthropometric measurements, strength, anterior cruciate ligament size, and intercondylar notch characteristics to sex differences in anterior cruciate ligament tear rates. Am J Sports Med 2001; 29(1):58-66.
23. van Kuijk KSR, Reijman M, Bierma-Zeinstra SMA, Waarsing JH, Meuffels DE. Posterior cruciate ligament injury is influenced by intercondylar shape and size of tibial eminence. Bone Joint J 2019; 101-B(9):1058-1062.
24. Fan N, Zheng YC, Zang L, Yang CG, Yuan S, Du P, et al. What is the impact of knee morphology on posterior cruciate ligament avulsion fracture in men and women: a case control study. BMC Musculoskelet Disord 2021; 22(1):100.
25. Minic M, Zivanovic-Macuzic I, Jakovcevski M, Kovacevic M, Minic S, Jeremic D. The influence of the morphometric parameters of the intercondylar notch on occurrence of meniscofemoral ligaments. Folia Morphol (Warsz) 2021 Jan 13.
26. Murshed KA, Çiçekcibaşi AE, Karabacakoğlu A, Seker M, Ziylan T. Distal femur morphometry: a gender and bilateral comparative study using magnetic resonance imaging. Surg Radiol Anat 2005; 27(2):108-12.

Korespondent: Marija Kovačević, Katedra za anatomiju, Fakultet medicinskih nauka Univerziteta u Kragujevcu, Svetozara Markovića 69, 34000 Kragujevac, Srbija
Email: marijakovacevic.mk@gmail.com
Corresponding author: Marija Kovačević, Department of Anatomy, Faculty of Medical Sciences, University of Kragujevac, Svetozara Markovica 69, 34000 Kragujevac, Serbia,
Email: marijakovacevic.mk@gmail.com