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The Anterior Notch Area for 3 Types of Notch Geometry, an Individualized Approach for Choosing the ACL Graft Size

Eduard M. Cernat[1,2], Andrei Neagu[3], Cezar Betianu[3], Dragoș-Eugen Georgescu[4,5]*, Adrian Barbilian[1,2] and Loredana Sabina Cornelia Manolescu[6†]

[1]Department of Clinical Education, Faculty of Medicine, Carol Davila University of Medicine and Pharmacy, 020021 Bucharest, Romania
[2]Department of Orthopedics, Dr. Carol Davila Central Military University Emergency Hospital, 010242 Bucharest, Romania
[3]Department of Radiology, Dr. Carol Davila Central Military University Emergency Hospital, 010242 Bucharest, Romania
[4]Department of Surgery, Carol Davila University of Medicine and Pharmacy, 020021 Bucharest, Romania
[5]Department of Surgery, Dr. I. Cantacuzino Clinical Hospital, 020475 Bucharest, Romania
[6]Department of Fundamental Science, Carol Davila University of Medicine, and Pharmacy, 020021 Bucharest, Romania

*Corresponding author:
Dragoș-Eugen Georgescu, M.D.
Department of Surgery
Dr. I. Cantacuzino Clinical Hospital
020475 Bucharest, Romania
E-mail: gfdragos@yahoo.com

†These authors contributed equally to the manuscript

Rezumat

Suprafața celor 3 variante de notch intercondilian anterior - abord individualiazat in alegerea dimensiunii grefei pentru reconstrucția LIA

Context: Fosa intercondiliană (ICN) reprezintă un element important al morfometriei genunchiului, fiind în strânsă legătură cu ligamentul încrucişat anterior (ACL). *Scop:* Identificarea suprafeței medii a fosei anterioare în fiecare formă specifică a ICN-ului (formă A-, W- sau U-).
Metode: Imaginile prin rezonanță magnetică (IRM) au fost analizate independent de doi experți, un chirurg ortoped şi un medic radiolog. În toate cazurile, au fost efectuate următoarele măsurători conform definițiilor existente: tipul ICN-ului, suprafața aICN.
Rezultate: 65 de cazuri (A-35,4%, W-26,2%, U-38,5%) au fost incluse în studiu; formele A şi W au suprafețe aICN mai mici, în timp ce forma de tip U prezintă o suprafață aICN mai mare.
Concluzie: Suprafața fosei intercondiliene anterioare variază semnificativ pentru fiecare formă specifică (A-, W- sau U) şi nu corelează cu înălțimea. Aceasta trebuie să fie luată în considerare în timpul reconstrucției ACL, la alegerea dimensiunii grefei.

Cuvinte cheie: fosă intercondiliană, grefă ACL, imagistică prin rezonanță magnetică

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Abstract

Background: The intercondylar notch (ICN) is an important element of knee morphometry, in close relation to the anterior cruciate ligament (ACL). *Aim:* To find the average are of the anterior notch in each ICN specific shape (A-, W-, or U-shape).

Methods: Magnetic resonance imaging (MRI) scans were independently analyzed by two experts, one orthopedic surgeon and one imaging physician. In all cases, the following measurements were done according to the existing definitions: ICN type, aICN area.

Results: 65 cases (A-35.4%, W-26.2%, U-38,5%) were included in study; A and W notch types have smaller aICN areas, while U-type notch has bigger aICN area.

Conclusion: The anterior intercondylar notch area varies significantly for each specific shape (A-, W, or U-shape), and does not corelates with height. This needs to be considered during ACL reconstruction, when choosing graft size.

Key words: intercondylar notch, ACL graft, magnetic resonance imaging

Introduction

The knee is the most exposed joint to sports trauma due to the significant loads' exposure and contact (1). Knee stability relies on its ligamentous structures and osseocartilaginous surfaces congruence (2,3). The anterior cruciate ligament is one of the most studied topics in medicine due to the high incidence of rupture (4).

The anterior notch is the closest contact point to the anterior cruciate ligament mid-substance (5). Notch geometry has been widely studied (6-9). The 3 types of notch geometry (A, W, U) have been described by nan Eck and all. The recorded notches were divided into two categories by two independent orthopaedic doctors who were blindfolded. Dimensions, notch form, and demographic variables were all associated. There were 102 notches analysed, and out of them it was determined that 55 were "A-shaped," 42 were "U-shaped," and 5 were "W-shaped." Compared to "U-shaped" notches, "A-shaped" notches were thinner in all width measurements (10). With the use of this information, surgeons who perform knee incisions and recognize the presence of a "A-shaped" notch may want to think about utilizing the anteromedial portal for the arthroscope and an auxiliary medial portal for the femoral tunnel in order to enhance vision and precision during the anatomic femoral tunnel creation process. So, this information may be essential to be considered when performing knee surgery.

The relationship between the femoral intercondylar notch and the shape of the anterior cruciate ligament (ACL) and the risk of an ACL injury has been the subject of previous studies (11). In a similar vein, emphasis has been placed on measurements that are easily obtained in the majority of clinical settings, such as the notch type or shape of the femur, as well as the orientation of the notch, which is defined by the angle formed by the Blumensaat line (BL), also referred to as the alpha angle, and the long axis of the distal femur (12-14). The literature does not appear to agree on anything regarding the connection between these geometric factors and ACL damage, though (15). Additionally, the importance of the intercondylar notch type and alpha angle in conjunction with other geometric risk factors is not understood (16).

An anterior cruciate ligament injury may result in osteoarthritis as well as harm to the meniscus and articular cartilage. Thus, is important to evaluate the diagnostic efficacy and viability of magnetic resonance imaging indicators for ACL injuries to the knee joint. When it comes to the non-traumatic diagnosis of ACL injury, magnetic resonance imaging is

a highly accurate diagnostic tool with good consistency and non-invasive when compared to arthroscopic diagnosis. As such, it can offer dependable guidance for the selection and development of clinical surgery plans (17).

The aim of the present study is to evaluate the median size of each type of notch on MRI evaluation, at the level of the anterior socket of the notch. Furthermore, knowing the diameter range for each notch we propose a model of planning the graft size for each notch type to avoid the impingement.

Materials and Methods

Study Population

This study is a retrospective, cross-sectional, single-center research that includes individuals who did not undergo knee MRI in our department between September 2019 and September 2022. After going over every medical file, we included all adult patients (those over 18) who had non-contact knee discomfort in a sequential manner. A history of trauma, a history of previous surgery or a history of a fracture in the knee region, being older than 50 at the time of evaluation, and the presence of morphologic abnormalities such as arthritis were the exclusion criteria that were used. Additionally, occurrences where the femur and tibia's shown length was less than 5 cm were disregarded (because 5 cm is the minimum length required to draw the longitudinal axes of these bones). Even if it wasn't intentional, no professional athletes were included in our study. We did not obtain weight information when collecting the data, but the department's MRI weight limit for tall patients (>1.85 m) is 100 kg, and it drops for individuals under 1.80 m. This body mass index (BMI < 30) association between height and weight is believed to be representative of the overall population.

Magnetic Resonance Imaging Procurement

Similar techniques were used to perform the MRI exams using two 1.5-T magnets from Siemens Medical Solutions: Magnetom Essenza and Magnetom Aero. The typical three orthogonal techniques (axial, coronal, and sag-ittal) were used to acquire 3 mm knee slices for each, and a mix of fluid-sensitive sequences, T2-weighted (T2W) non fat-saturated (NFS) or proton density-weighted (PDW) sequences, and T1-weighted (T1W) NFS imaging was applied. The mainstays are often the PD-weighted sequences with and without fat saturation. In the axial plane, it occasionally substituted the T2 NFS sequence for the PD fat-saturated (FS). We mostly employed T2W NFS or PDW FS genuine axial pictures for our investigation. We applied references from the sagittal and coronal planes to the custom plane that we created using post-processing techniques. The custom plane is aligned in the sagittal plane along the axis of the ACL, which is slightly angular from Blumensaat's line's intercondylar roof, and in the coronal plane along a line that is parallel to the posterior femoral condylar line. Consequently, the plane is parallel to the posterior condylar line and perpendicular to the ACL axis. This plane (*Fig. 1*) will be referred to as the custom axial plane (CAP).

Variables and Measurements

Three classifications were made for the intercondylar notch: A-shaped, U-shaped, and W-shaped. The measurements of the intercondylar notch's greatest width and surface area in the antero-superior aspect came next. Drawing a circle outlined by cortical bone from three of the four sides - the anterosuperior, left, and right - was how the area was measured. The custom plane has a slice thickness of 1 mm

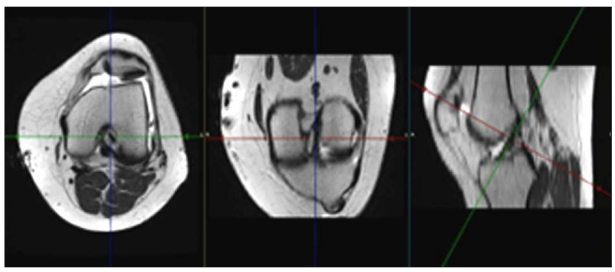


Figure 1. Custom Axial Plane (CAP)

after post-processing, therefore *Fig. 2*'s 3 mm (± 3 mm from the slice used for aICN measurement) allows for measurement uncertainty. The accompanying findings of knee disease were seen and quantitatively evaluated using the other sequences available to us.

Dimension's Measurements

One orthopaedic surgeon and one radiologist physician, each with more than five years of experience in knee MRI evaluation, analysed all of the included MRI scans. The following definitions were followed when doing the dimensions measurement:

- aICN region: in the custom axial plane/CAP, the area of the circle bounded by the three cortical walls of the antero-superior notch - *Fig. 3* and *Fig. 4*.

The measurements were carried out using an MRI's image calibration and a specially designed anatomic plane. Because defining the ACL area and the circle in the anterior notch depends on the user, we did not validate our method and find it challenging to do so. One of the patients admitted to the trial had an ACL with a circular portion, which we measured intraoperatively. The ACL area was measured to be 0.38 cm^2 on the MRI, and the diameter was measured in vivo to be 7 mm. This corresponds to an area of 0.3848 cm^2 and a radius of 3.5 mm (see *Figs. 2* and *5*).

Statistical Analysis

Numbers (%) and percentages were used to represent the nominal qualitative variables. For continuous variables with normal distributions, the mean and standard deviation were shown, while for non-normal distributions, the median and interval (min – max) were displayed. To find correlations such as the one between the intercondylar notch and ACL aria, a bivariate analysis utilising the Spearman's rho coefficient was carried out for the continuous variable. A dichotomous variable, like gender (male, female), can also have its subgroups compared using the Mann-Whitney test. A Kruskal Wallis test with post-

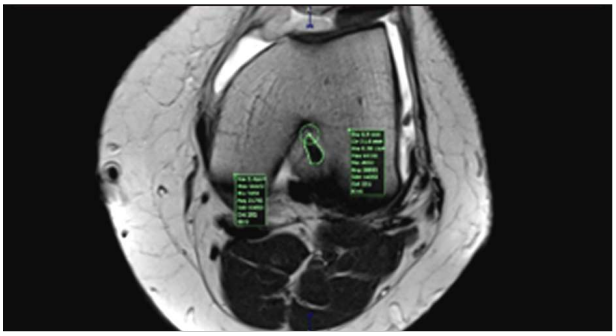


Figure 2. Measurements of aICN area and ACL area in the same section in a A type notch

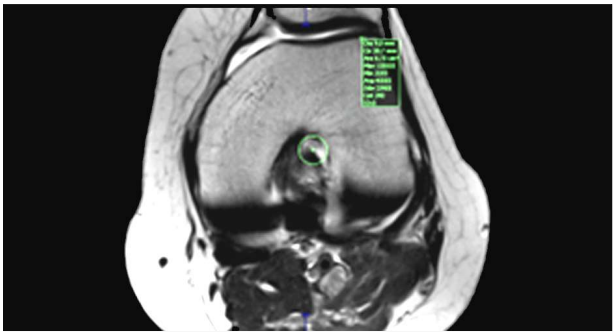


Figure 3. aICN area of a U type notch

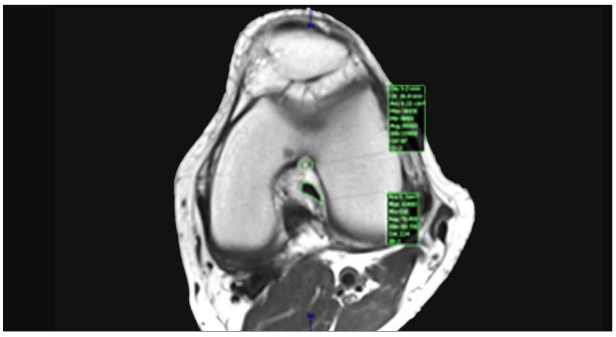


Figure 4. aICN are of an W type notch

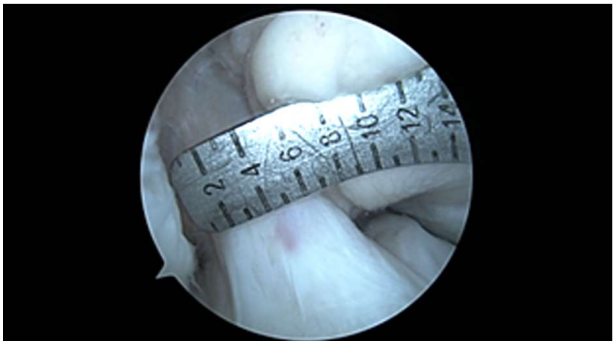


Figure 5. Intraoperatively measured ACL diameter corresponding to the MRI measured ACL in figure 2 – an attempt to validate the method

hoc ANOVA analysis was carried out when there were more than two subgroups (e.g., the notch shape: A-, W-, or U-shape). Additionally, Spearman's rho coefficient was used to find correlations between the patient's height and the anterior ICN size as well as between the patient's height and the aICN shape (A,W,U). In all tests, p-values less than 0.05 were considered statistically significant. IBM SPSS Statistics, version 25.0 for Windows (Armonk, NY, IBM Corp.), software was used.

Ethics

Patient consent was obtained at admission and evaluation. The Hospital's Ethical Committee approved the research (no 404 / 17.09.2020). All procedures in the study respected the ethical standards of the Helsinki Declaration.

Results

Descriptive Data. General Characteristics of the Studied Group

Magnetic resonance imaging acquisitions of a total number of 65 cases fulfilling the inclusion and exclusion criteria were analyzed. The distribution according to gender was balanced in the study group, 33 male (50.8%) and 32 female (49.2%). The mean age at inclusion was 33.8±10.2 years. The aICN area was 0.75 cm^2 (0.2-0.8), with higher values in male gender when compared to females, 0.96 cm2 vs 0.52 cm^2, p=0.002 (*Table 1*).

Anterior Intercondylar Notch Size in Each Intercondylar Notch Shape

As presented in *Table 2*, the values of the aICN area weas significantly higher in cases with the ICN U-shaped.

It is to note that the U-shape was the predominant ICN shape in male gender (*Table 3*).

Patient's Height Correlation with Anterior Intercondylar Notch Size and Shape

We found no statistical correlation between the notch shape and patient's height, and no correlation between patient's height and anterior intercondylar notch shape (*Tabel 4*).

Discussion

The morphometry of the femoral notch and its distribution on the risk of an ACL injury were described using imaging techniques in

Table 1. Descriptive statistics

Parameter	Total N=65	Male gender N=33	Female gender N=32	p-value
Age, years	35 (18-50)	34 (18-50)	35 (18-50)	0.680
aICN area, cm^2	0.75 (0.15-3.60)	0.96 (0.22-3.60)	0.52 (0.15-1.68)	0.0008
ICN A form, N (%)	23 (35.38%)	6 (26.09%)	17 (73.91%)	0.004
ICN W form, N (%)	17 (26.15%)	8 (47.05%)	9 (52.95%)	0.720
ICN U form, N (%)	25 (38.46%)	19 (76%)	6 (24%)	0.020

Abbreviations: aICN = anterior intercondylar notch; a p-value less than 0.05 was considered statistically significantA

Table 2. Comparative analysis of the size measured in regard to the intercondylar notch shape

Parameter	A-shape (N = 23)	W-shape (N = 17)	U-shape (N = 25)	p-value	post-hoc
Age, years	33 (13-19)	32 (14-51)	37 (12-47)	0.877	-
aICN area, cm^2	0.47 (0.15-0.95)	0.37 (0.15-0.81)	1.16 (0.57-3.60)	<0.001	A-U, W-U

Abbreviations: aICN = anterior intercondylar notch; rho = Sperman's rho coefficient
A p-value less than 0.05 was considered statistically significant.

Table 3. Comparative analysis of the intercondylar notch shape and gender

Parameter	A-shape (N = 23)	W-shape (N = 17)	U-shape (N = 25)	p-value
Male gender, (%)	(26.1)	(47.1)	(76.0)	0.002

A p-value less than 0.05 was considered statistically significant

Table 4. Comparative analysis of the patient's height and intercondylar notch shape/aICN size

Parameter	A-shape (N = 23)	W-shape (N = 17)	U-shape (N = 25)	aICN area, cm^2
Patient's height	rho=0.04 p=0.7	rho=0.01 p=0.91	rho=0.05 p=0.64	rho=0.17 p=0.15

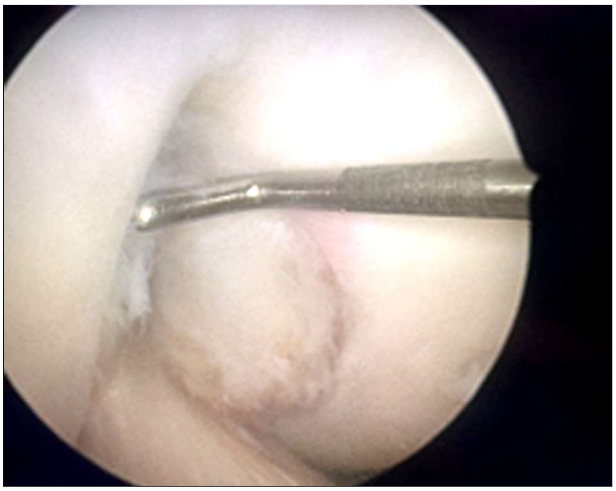
Abbreviations: aICN = anterior intercondylar notch; rho = Sperman's rho coefficient
A p-value less than 0.05 was considered statistically significant.

other research with comparable results (18-23).

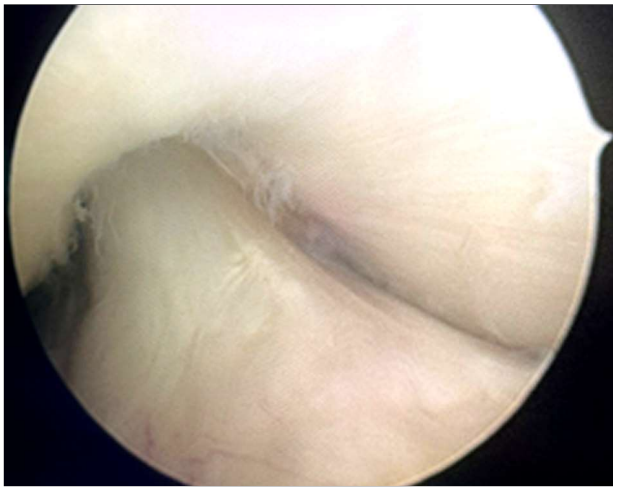
The anterior notch area ranged from 0.15 cm^2 to 3.6 cm^2. If we put the values in to the circle area formula that gives a diameter that range from 4,3 mm to 21,4 mm. We need to analyze each notch shape independently to understand the values.

A Type Notch

In a A type notch the values ranged from 0.15 cm^2 to 0.95 cm. In this type of notch, the ACL lies in close contact with the aICN walls in extension. Considering a hamstring graft for reconstruction, with a diameter greater than the aICN size, will lead to impingement. Putting the values in the circle area formula gives a diameter range from 4,3 mm to 10.9 mm. Choosing the right size of the graft in an A type notch can be done using intraoperative measurement of the aICN diameter – *Fig. 6*. In a native knee ACL with an A type notch, the close relationship between ACL and aICN can be observed in extension, *Fig. 7*. There is a close matching between a small aICN and the native ACL. In *Fig. 8* there's an example of an A type notch with an area of 0.40 cm^2 measured on MRI, which gives a diameter of 7.1 mm. To reproduce the anatomy, a graft diameter similar to the aICN can be chosen. We proved in a prior article that the native ACL area corelates with the aICN area strong/very strong when the notch type is A or W (5).



Figue 6. A type notch



Figue 7. aICN – ACL match in 10° flexion, A-type notch

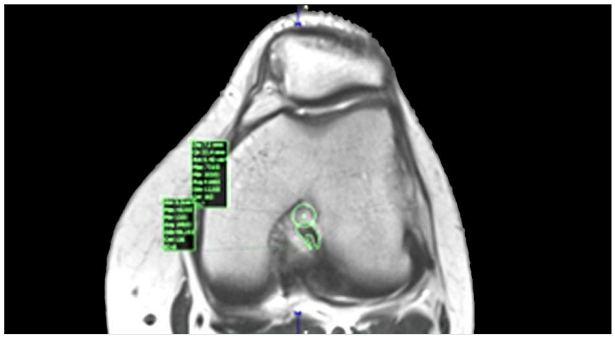


Figure 8. aICN area of 0.4 cm² measured on MRI in an A type notch

W Type Notch

In W type notch the values range from 0.15 cm2 to 0.81 cm². Similar to an A type notch, the ACL lies in close contact with the aICN walls in extension. Putting the values in the circle area formula gives a diameter range from 4,3 mm to 10.1 mm. Choosing the right size for the graft can be done in the same way, using intraoperative measurement of the aICN diameter – *Fig. 9.* In *Fig. 4* there's an example of a W type notch with an area of 0.22 cm² measured on MRI, which gives a diameter of 5.3 mm. These small values are examples of narrow native notches that need to be considered during surgery, but in clinical practice these are rare cases.

U Type Notch

In the U type notches, the ACL is not filling all the anterior ICN area, although we proved in a prior article the native ACL area corelates with aICN area in this type of notch also (5). In U type notch the values range from 0.56 to 3.6 cm² which gives a diameter range from 8.4 mm to 21.4 mm. Because in U type notches the smallest diameter of aICN is 8.4 mm, during the reconstruction a graft bigger than 8 mm diameter can be a reasonable target, with no/very low risk of impingement. Park et al., found that patients with graft size < 8 mm had a 5.2% failure rate when compared to 0% in grafts ⩾ 8 mm. But, among the 12 failures in their study, most of them had combined injuries and needed additional procedures

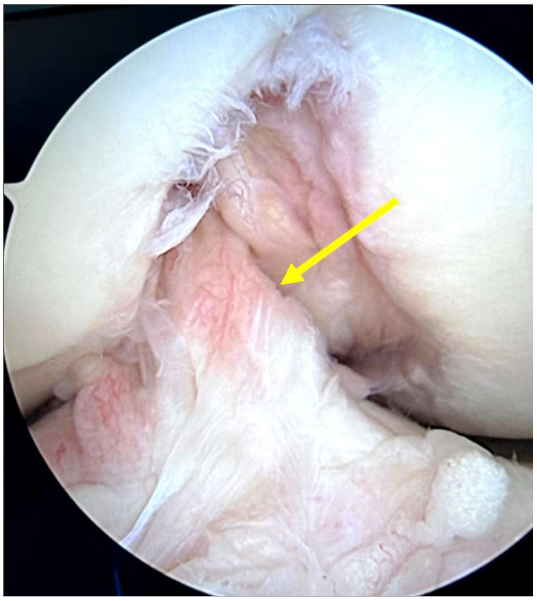


Figure 9. Intraoperative W type notch, notice the small size of the native ACL (yellow)

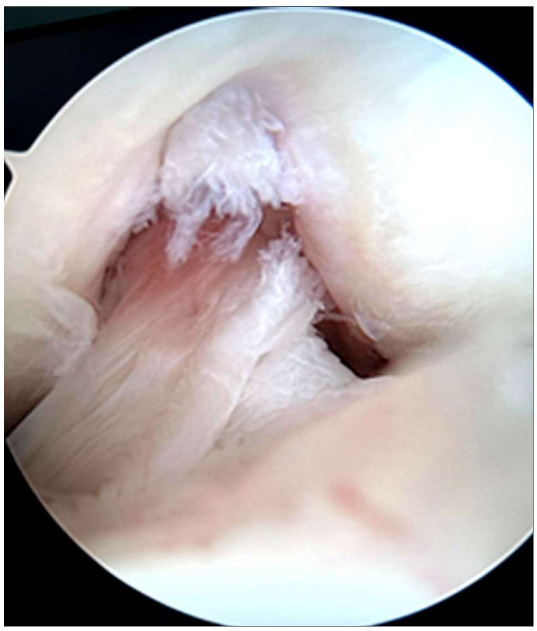


Figure 10. Close match between the native ACL and aICN in 10° flexion, W-type notch

along with ACL reconstruction, which may have contributed to the failure. In their study, factors including height, weight, BMI, gender and athlete versus non-athlete identity were found to be significantly related to graft diameter. Correlation was strongest with height ($p < 0.001$) (24).

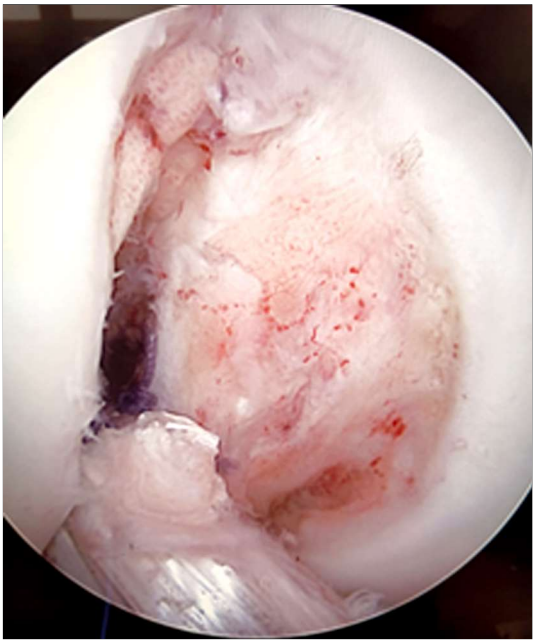


Figure 11. U type notch during ACL reconstruction, notice the wide aICN (yellow arrow)

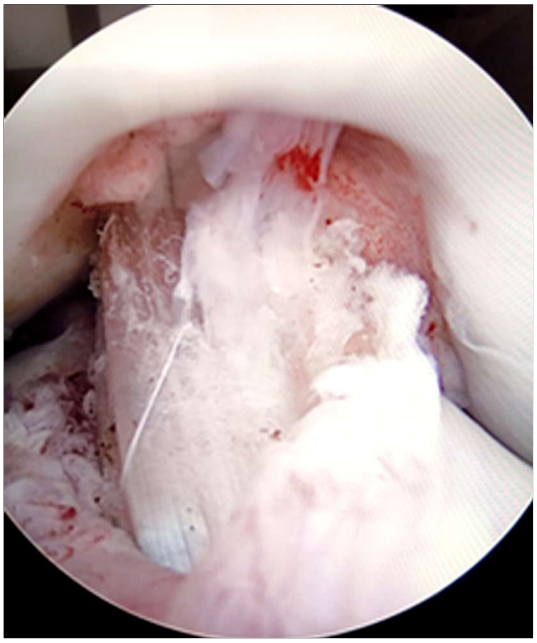


Figure 12. aICN – ACL graft relationship in 10° flexion, U-type notch; 8.5 mm graft, no-impingement

We find it important to consider the notch size and morphology before planning an ACL reconstruction. If the notch and the graft do not match, the surgeon might consider a notchplasty. Francesco Ranuccio et al. published a systematic review on the effects of notchplasty on ACL reconstruction. They included 16 studies and in conclusion suggest being aware of potential complications following notchplasty during ACLR before deciding to perform notchplasty in primary ACLR, reserving it for the surgical management of arthrofibrosis, treatment of notch osteophytosis and revision ACLR (25-26).

In current practice we have to deal with Contact ACL ruptures and Non-Contact ACL injuries (NC-ACLI). Barry P. Boden and co. showed that the the axial compressive load is the driving force behind the majority of NC-ACLI with valgus moments and quadriceps force contributing to the overall load in the ACL. In their analysis 70% of the injuries involved minimal to no contact and occurred during landing or deceleration maneuvers in team sports with a minor perturbation prior to the injury that may disrupt the neuromuscular system leading to poor body dynamics (27). In this regard, focusing on the anatomical intrinsic factors of the knee to explain the injuries/re-injuries might be the wrong path. Our approach is to restore the anatomy, considering the various notch type when choosing the graft size. For the NC-ACLI, when the notch type is A or W and we choose a smaller graft, we consider the lateral extra-articular tenodesis (LET) using fascia lata, passed around the lateral collateral ligament - *Fig. 13*. The addition of LET to a single-bundle hamstring tendon autograft ACLR in patients at high risk of failure results in a statistically significant, clinically relevant reduction in graft rupture and persistent rotatory laxity at 2 years after surgery (28). Furthermore, pre-operative radiologic planning is crucial not only for the selection of the most appropriate anterior cruciate ligament (ACL) graft but also for various other orthopedic procedures (29). It is noteworthy that ACL injury can result in osteoarthritis, as well as damage to the meniscus and articular cartilage, necessitating specialized orthopedic intervention (30).

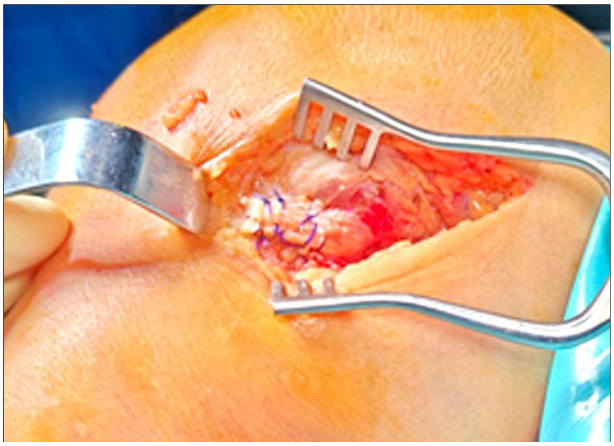


Figure 13. Lateral extra-articular tenodesis (LET)

Limitations of the Study

Our study is a cross-sectional study with retrospective inclusion and lacks interobserver agreement. The measurement technique is not validated.

Conclusions

The anterior intercondylar notch area varies significantly for each specific shape (A-, W-, or U-shape), and does not corelates with height. This needs to be considered during ACL reconstruction, when choosing graft size. Before arranging an ACL repair, we believe it is crucial to take the notch's size and anatomy into account. With this simple technique the notch can be assessed preoperatively on the MRI. In small A and W notch types, a small autologous/hybrid/artificial graft can be planned and reconfirmed during the surgery using in vivo measurements. In U type notches a graft of at least 8 mm can be planned due to the low risk of impingement.

Author's Contributions

Data curation, Cezar Betianu; Formal analysis, Andrei Neagu; Investigation, Andrei Neagu; Methodology, Cezar Betianu; Project administration, Adrian Barbilian; Resources, Dragos-Eugen Georgescu; Supervision, Loredana Sabina Cornelia Manolescu; Visualization, Loredana Sabina Cornelia Manolescu; Writing – original draft, Eduard Cernat; Writing – review & editing, Eduard Cernat and Loredana Sabina Cornelia Manolescu.

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Conflicts of Interest

The authors declare no conflict of interest.

Funding

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Institutional Review Board Statement

The Hospital's Ethical Committee approved the research (no 404 / 17.09.2020). All procedures in the study respected the ethical standards of the Helsinki Declaration.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study."

References

1. Desai P, Hacihaliloglu I. Knee-Cartilage segmentation and thickness measurement from 2D Ultrasound. J Imaging. 2019;5(4):43.
2. Mathiesen O, Konradsen L, Torp-Pedersen S, Jørgensen U. Ultrasonography and articular cartilage defects in the knee: An in vitro evaluation of the accuracy of cartilage thickness and defect size assessment. Knee Surg Sports Traumatol Arthrosc. 2004;12(5):440-3.
3. Swamy MM, Holi MS. Knee joint articular cartilage segmentation, visualization and quantification using image processing techniques: A review. Int. J. Comput. Appl. 2012;42(19):36–43.
4. Pedoia V, Li X, Su F, Calixto N, Majumdar S. Fully automatic analysis of the knee articular cartilage T1ρ relaxation time using voxel-based relaxometry. J Magn Reson Imaging. 2016;43(4):970-80.
5. Cernat EM, Dima A, Popescu C, Neagu A, Betianu C, Moga M, et al. Anterior intercondylar notch geometry in relation to the native anterior cruciate ligament size. J Clin Med. 2024;13(2):309.
6. Whitney DC, Sturnick DR, Vacek PM, DeSarno MJ, Gardner-Morse M, Tourville TW, et al. Relationship between the risk of suffering a first-time noncontact ACL injury and geometry of the femoral notch and ACL: A prospective cohort study with a nested case-control analysis. Am J Sports Med. 2014;42(8):1796-805.

7. Wang P, Gao F, Sun W, Li Z, Wu X, Shi L, et al. Morphometric characteristics of the knee are associated with the injury of the meniscus. J Orthop Surg Res. 2022;17(1):498.
8. Jaibaji R, Khaleel F, Jaibaji M, Volpin A. Outcomes of Meniscal Repair in Patients Aged 40 and Above: A Systematic Review. J Clin Med. 2023; 12(21):6922.
9. Iijima H, Shimoura K, Aoyama T, Takahashi M. Biomechanical characteristics of stair ambulation in patients with knee OA: A systematic review with meta-analysis toward a better definition of clinical hallmarks. Gait Posture. 2018;62:191-201.
10. van Eck CF, Martins CAQ, 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.
11. Sturnick DR, Vacek PM, DeSarno MJ, Gardner-Morse MG, Tourville TW, Slauterbeck JR, et al. Combined anatomic factors predicting risk of anterior cruciate ligament injury for males and females. Am J Sports Med. 2015; 43(4):839-47.
12. Kızılgöz V, Sivrioglu AK, Ulusoy GR, Aydın H, Karayol SS, Menderes U. Analysis of the risk factors for anterior cruciate ligament injury: an investigation of structural tendencies. Clin Imaging. 2018;50:20-30.
13. Shen L, Jin ZG, Dong QR, Li LB. Anatomical risk factors of anterior cruciate ligament injury. Chin Med J (Engl). 2018;131(24):2960-2967.
14. Fernandez-Jaen T, Lopez-Alcorocho JM, Rodriguez-Inigo 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.
15. 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.
16. 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.
17. Zhao M, Zhou Y, Chang J, Hu J, Liu H, Wang S, et al. The accuracy of MRI in the diagnosis of anterior cruciate ligament injury. Ann Transl Med. 2020; 8(24):1657.
18. Kordon F, Maier A, Swartman B, Privalov M, El Barbari JS, Kunze H. Multi-stage platform for (semi-)automatic planning in reconstructive orthopedic surgery. J Imaging. 2022;8(4):108.
19. Cernat EM, Neagu A, Betianu C, Manolescu LSC, Avram G, Pogarasteanu ME, et al. Balancing Anterior and Posterior Cruciate Ligaments in Adults. Cureus. 2024;16(5):e59683.
20. Hunter DJ, Gerstenfeld L, Bishop G, Davis AD, Mason ZD, Einhorn TA, et al. Bone marrow lesions from osteoarthritis knees are characterized by sclerotic bone that is less well mineralized. Arthritis Res Ther. 2009;11(1):R11.
21. Roemer FW, Bohndorf K. Long-term osseous sequelae after acute trauma of the knee joint evaluated by MRI. Skeletal Radiol. 2002;31(11):615-23.
22. Kornaat PR, Ceulemans RY, Kroon HM, Riyazi N, Kloppenburg M, Carter WO, et al. MRI assessment of knee osteoarthritis: Knee Osteoarthritis Scoring System (KOSS) - Inter-observer and intra-observer reproducibility of a compartment-based scoring system. Skeletal Radiol. 2005;34(2):95-102.
23. Schmitz RJ, Wang HM, Polprasert DR, Kraft RA, Pietrosimone BG. Evaluation of knee cartilage thickness: A comparison between ultrasound and magnetic resonance imaging methods. Knee. 2017;24(2):217-223.
24. Park SY, Oh H, Park S, Lee JH, Lee SH, Yoon KH. Factors predicting hamstring tendon autograft diameters and resulting failure rates after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2013;21(5):1111-8.
25. Ranuccio F, Familiari F, Tedesco G, La Camera F, Gasparini G. Effects of Notchplasty on Anterior Cruciate Ligament Reconstruction: A Systematic Review. Joints. 2017;5(3):173-179.
26. Koga H, Muneta T, Yagishita K, Watanabe T, Mochizuki T, Horie M, et al. Effect of notchplasty in anatomic double-bundle anterior cruciate ligament reconstruction. Am J Sports Med. 2014;42(8):1813-21.
27. Boden BP, Sheehan FT. Mechanism of non-contact ACL injury: OREF Clinical Research Award 2021. J Orthop Res. 2022;40(3):531-540.
28. Getgood AM, Bryant DM, Litchfield R, Heard M, McCormack RG, Rezansoff A, et al. Lateral extra-articular tenodesis reduces failure of hamstring tendon autograft ACL reconstruction - two year outcomes from the STABILITY study randomized clinical trial. Am J Sports Med. 2020;48(2):285-297.
29. Dragosloveanu S, Petre MA, Gherghe ME, Nedelea DG, Scheau C, Cergan R. Overall accuracy of radiological digital planning for total hip arthroplasty in a specialized orthopaedics hospital. J Clin Med. 2023;12(13): 4503.
30. Cristea S, Predescu V, Dragosloveanu S, Cuculici S, Marandici N. Surgical approaches for total knee arthroplasty. InTech; 2016.