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Prevalence of types of intercondylar notch shape on anterior cruciate ligament-injured patients

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Abstract

Introduction: The anterior cruciate ligament (ACL) is the most injured knee ligament, with intercondylar notch shape as a key risk factor. Narrower, A-shaped notches, common in females, increase injury risk. This study evaluates the prevalence of notch types and their links to demographic and anthropometric factors in ACL injuries.

Method: This retrospective study was conducted at Pokhara Academy of Health Sciences, among adults aged 18 years and above with arthroscopically confirmed ACL injuries between July 2023 and July 2025. Preoperative MRI scans were analyzed to classify intercondylar notch morphology into three types: A, U, and W based on axial T2-weighted images. BMI was calculated and categorized using WHO Asian cutoffs, and associations between notch type and demographic or anthropometric variables were analyzed, with $p < 0.05$ set as the threshold for statistical significance.

Result: A total of 45 patients with ACL injury were included, with a median age of 33 years (IQR: 25–43) and an age range of 20–60 years. The majority, 31(68.9%), were aged 20–39 years, and 27 (60%) were male, while 18(40%) were female. The most common intercondylar notch type was Type U in 28 (62.2%) patients, followed by Type A in 16 (35.6%) and Type W in 1 (2.2%). A statistically significant association was found between gender and notch type, and between age group and notch morphology. However, no significant association was observed between BMI category and notch type.

Conclusion: Type U notch was the most common among ACL-injured patients, with notch morphology significantly associated with gender and age but not with BMI.

Keywords: ACL injury; Intercondylar notch shape; MRI; Prevalence

INTRODUCTION

The anterior cruciate ligament (ACL) is the most injured knee ligament, with an annual incidence of approximately 1 in 3500 people and 400,000 ACL reconstructions performed annually in the United States.¹ Intercondylar notch morphology, the anatomical configuration of the space between the medial and lateral femoral condyles, has emerged as a significant intrinsic anatomical risk factor for ACL injury.² A systematic analysis of 560 patients demonstrated that Type A notches were present in 42.9% of the cohort, with 73% sustaining ACL tears compared to only 32% with Type U or W notches.³

A study by Jin et al. found that females had narrower intercondylar notch dimensions, which significantly increased ACL injury risk compared to males.⁴ A prospective MRI study of 269 healthy knees aged 3-18 years found that adolescent females had significantly narrower femoral notches than males (differences of 1.4-2.7 mm, $P < 0.001$), contributing to the understanding of sex-specific ACL injury vulnerability during skeletal growth.⁵ Age-related variations in notch morphology are substantial, with transitions from A-shaped notches in childhood to inverse U-shaped and W-shaped notches in adults beyond the 4th decade reflecting ongoing skeletal remodeling.⁶ The relationship between body mass index (BMI) and intercondylar notch morphology remains incompletely characterized, with height correlating with absolute notch dimensions but weight status effects on notch type classification remaining underexplored.^{6,7}

Despite the established relationship between intercondylar notch morphology and ACL injury risk, comprehensive epidemiological characterization of notch type prevalence in ACL-injured populations with simultaneous assessment of associations with demographic and anthropometric variables remains limited, particularly in South Asian populations. Understanding the prevalence of specific notch types (A, U, W) in ACL-injured populations and their associations with gender, age group, and BMI would enhance risk stratification capabilities and contribute to understanding sex-based and age-related variations in ACL injury epidemiology within the Nepali population.

METHOD

This retrospective study was conducted in Pokhara Academy of Health Sciences (PoHS), Pokhara, Nepal. The study included adult patients aged 18 and above. The records of patients with ACL injury (with or without meniscus injury) confirmed by arthroscopy who visited the center and were admitted to the Department of Orthopedics and Trauma Surgery with ACL injury between July 2023 and July 2025 were analyzed. Patient records showing any knee deformities or dysplasia, connective tissue or hematologic disorders, fractures involving the articular surface, prior knee arthroscopy, severe osteoarthritis, or multi-ligamentous injuries were excluded. In this study, none of the records met the exclusion criteria, so all patients records were included. A total of 45 adult patients with arthroscopically confirmed ACL injuries were included in the analysis.

The preoperative MRI report was analysed to classify notch shape into three types: Type A (figure 1(A)), Type U (figure 1(B)), and Type W (figure 1(C)). Axial T2-weighted images were selected for analysis. The section of the notch, seen at the level of the popliteal groove in the lateral femoral condyle, was identified, and notch morphology at various levels was assessed. The type of notch identified as Type A, where the notch appears narrow from the base to the midsection, as well as at the apex, whereas Type U, is identified as a notch at the midsection that does not taper and has a wider contour than Type A. Another type, i.e., Type W, is identified as a notch with characteristics similar to those of Type U, but with two apparent apices and no classic flat roof.^{3,8}

Type W intercondylar notch BMI was calculated as weight in kilograms per square meter of height and categorized according to WHO cut-off values for Asians.⁹ For the purpose of our study, normal weight was defined as 18.5–22.9 kg/m², and overweight was defined as BMI ≥ 23.0 (combining the overweight and obese groups per the WHO classification).

The collected data were entered, cleaned, and coded in Microsoft Excel 2010 and then exported to Statistical Package for the Social Sciences (SPSS) version 23 for

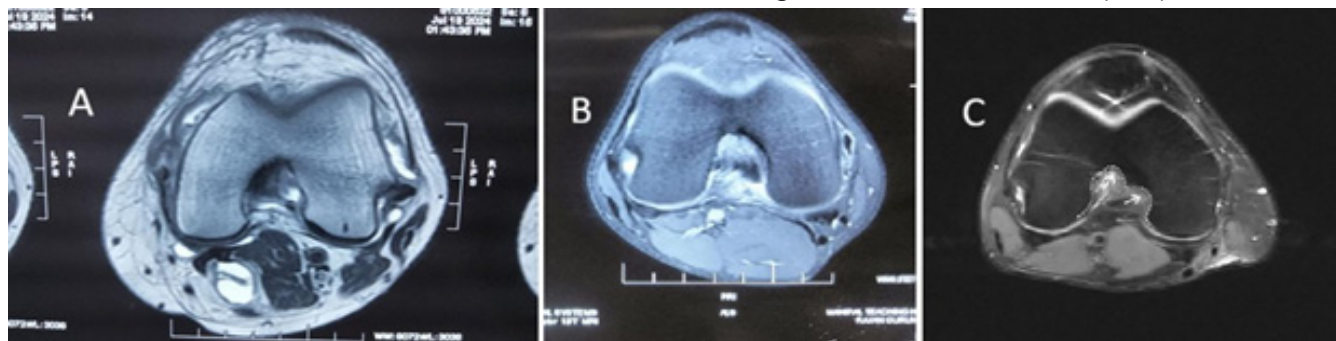


Figure 1. (A) The MRI image demonstrates the narrowed morphology of the notch from the entrance to the apex, simulating the letter 'A' named Type A intercondylar notch. (B) The MRI image demonstrates a wider apex than in A, giving the appearance of an inverted 'U'. Type U intercondylar notch. (C) The MRI image demonstrates the notch characteristics of Type U but has two apices, appearing as an inverted 'W'

statistical analysis. Results were expressed as frequencies and percentages for qualitative data, checked for normality using the Shapiro-Wilk test, and presented as mean $\pm$ standard deviation or median and interquartile range for quantitative data. For the association Chi-square test, Fisher's exact test, or likelihood ratio was used wherever they were applied. A p-value of <0.05 was considered statistically significant at a 95% confidence level.

Ethical approval for the study was obtained from the PoHS Institutional Review Committee (PoHS-IRC) on 23rd September 2025 (Ref. No.: 32/082).

RESULT

During the study period, 45 cases of anterior cruciate ligament injury that met the inclusion criteria were enrolled. In this study, the patient's age was not normally distributed (as determined by the Shapiro-Wilk test). The median age of the patients was 33 years (IQR: 25-43). The minimum age of the patient was 20 years, and the maximum age was 60 years. The most common age group was 20-39 years (i.e., 31(86.9%)).

In our study, 45 patients where 27 (60%) were male and 18 (40%) were female. In this study, the most common type of intercondylar notch was type U, accounting for 28 (62.2%), as shown in Table 1.

Table 1. Distribution of different types of intercondylar notch (n=45)

SN	Type of notch	f (%)
1	Type A	16(35.6%)
2	Type U	28(62.2%)
3	Type W	1(2.2%)

The association between intercondylar notch type and gender was analyzed. There was an association between the gender and the type of intercondylar notch type (i.e. A, U and W) when analyzed individually. This means a statistical analysis showed a non-random, significant relationship between participants sex (male vs. female) and their intercondylar notch morphology.

Table 2. The association between the gender and type of intercondylar notch(n=45)

Type of notch	Male	Female	P-Value
A type	6(13.3%)	10(22.2%)	0.011*
U-Type	22(48.9%)	6(13.3%)	0.004*
W-Type	0(0%)	1(2.2%)	0.378**

*Chi-square test, **Fischer Exact test

The nature of weight (i.e. Normal BMI and High BMI) and type of notch was analyzed. This showed that there is no association between the type of intercondylar notch and the BMI pattern of the patient

Table 3. The association between the BMI pattern and type of intercondylar notch(n=45)

Type of notch	Normal BMI	High BMI	P-Value
A type	10(22.2%)	6(13.3%)	0.634*
U-Type	16(35.6%)	12(26.7%)	0.912*
W-Type	0(0%)	1(2.2%)	0.422**

*Chi-square test, **Fischer Exact test

The association between age group and notch type was analyzed. There was an association between A-type and U-type in the age group, as indicated by the likelihood ratio (cell counts were less than 5 or 0). There was no association between Type W and age group. This means a statistical analysis showed a non-random, significant relationship between participants' age group and their intercondylar notch morphology.

Table 4. The association between the age group and type of intercondylar notch (n=45)

Type of notch	20-39 years	40-59 years	≥ 60 years	P-Value
A type	6(13.3%)	8(17.8%)	2(4.4%)	0.002**
U-Type	24(53.3%)	4(8.9%)	0(0%)	0.004**
W-Type	1(2.2%)	0(0%)	0(0.0%)	0.685**

**Likelihood ratio

DISCUSSION

In this study, the prevalence of intercondylar notch shapes among patients with ACL injuries was studied, and the association between notch morphology and demographic factors, age, sex, and BMI was analysed. The increased interest in ACL injury is likely due to the increased incidence of injury among the young population and sporting activities, and its major morbidity and financial burden.³

Our results demonstrate narrower notch types: the U- and A-shaped notches combined to 97.8%, with the W-shaped notch accounting for only 2.2% in ACL-injured patients. This aligns with prior research by Al-Saeed et al., which found that the narrower notch types A and U combined showed 98.21% in ACL-injured patients.¹⁰ A study by van Eck et al. among 102 ACL-injured patients showed that 53.92% of notches were "A-shaped," 41.17% were "U-shaped," and the remaining were "W-shaped."⁸ Likewise, Basukala, et al., with a narrower notch (A and U types combined), reported 94.15%, indicating that a narrow intercondylar notch acts as an anatomical risk factor for ACL tears.⁷ Our study confirms that narrow intercondylar notch types (A-shaped and U-shaped) predominate in ACL-injured patients, consistent with prior research, suggesting that narrow notch morphology might be a key anatomical risk factor for ACL tears via impingement mechanisms; however, further study is required to establish this finding.

This study identified a statistically significant association between gender and intercondylar notch type (A-shaped, U-shaped, and W-shaped), demonstrating that the distribution of these distinct morphological categories differs between males and females. A study by Van Eck et al., including 102 ACL-injured patients, confirmed that women had smaller notch widths at both the base and midsection than men, and that taller individuals had a higher prevalence of U-shaped and W-shaped notches ($P=0.011$).¹¹ Zhang et al., using a novel morphological classification, confirmed gender distribution patterns and noted that inlet-and-outlet stenosis notch types (comparable to Type A) showed a higher prevalence in females and were associated with a higher

ACL injury risk.¹² Conversely, study by Hosseinzadeh, et al., examining 269 healthy knees across ages 3-18 years, which found that while absolute notch width dimensions differed significantly between adolescent males and females, when normalized to bicondylar width (notch width index), no significant sex differences were observed, suggesting that apparent gender dimorphism may reflect overall skeletal size scaling rather than morphologically distinct notch types in asymptomatic populations.⁵ Comparing our study findings and other study findings, it contributes to the well-established evidence that gender and intercondylar notch morphology are significantly associated.

This study found no statistically significant association between intercondylar notch type and BMI pattern (normal BMI 18.5–22.9 kg/m² versus high BMI ≥23.0 kg/m²), suggesting that body weight classification does not significantly influence the morphological distribution of intercondylar notch types in this population. A study by Ustabaşoğlu, et al., showed that BMI was not associated with notch morphology.¹³ Although comparative literature is limited, this study's lack of association between BMI and notch type is consistent with available evidence from Ustabaşoğlu, et al., suggesting that intercondylar notch morphology represents a primary skeletal anatomical feature independent of metabolic factors; however, larger prospective studies across diverse populations are needed to definitively establish this relationship and its implications for understanding intrinsic versus modifiable ACL injury risk factors.

This study found a statistically significant association between age group and intercondylar notch type, with A- and U-shaped notches showing age-dependent distributions, whereas W-shaped notches showed no significant age-related variation. A study by Hirtler, et al., examining 329 individuals across the lifespan found that A-shaped notches predominated in childhood (11.6%), inverse U-shaped notches in young adulthood (39.8%), and W-shaped notches increased from the 4th decade onward (48.6%).⁶ Study by Hosseinzadeh, et al., in a prospective study of 269 knees (ages 3-18 years) found significant age-related changes in notch geometry during adolescent growth, with differences of 1.4-2.7 mm between early and late adolescence ($P < 0.001$).⁵ Study by Zhang et al. noted that stenotic notch types were more common in younger cohorts and wider types in older populations.¹² The finding that W-shaped notches remain age-independent aligns with the observation that this uncommon morphology (2-5% of populations) may represent a distinct developmental variant less influenced by age-related remodeling.¹² This study demonstrates that A-shaped and U-shaped notches associate significantly with age group while W-shaped notches remain age-independent, contributing important evidence that intercondylar notch morphology undergoes developmental re-modelling during skeletal maturation, with stenotic notches more prevalent in younger

individuals when ACL injury incidence peaks, underscoring the importance of age stratification in assessing notch morphology's role in injury risk across different age groups.

CONCLUSION

In this study, the U-type intercondylar notch was the most common morphology among patients with ACL injuries. Notch shape was significantly associated with gender and age group, suggesting that these factors may affect the risk of ACL injury. No connection was found between BMI and notch type. These results emphasize the need to consider anatomical differences and demographic factors when evaluating ACL injury risk in the Nepali population.

DECLARATIONS

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None

Conflict of Interest

None

Funding

None

Ethical Clearance

Ethical approval for the study was obtained from the PoHS Institutional Review committee (PoHS-IRC) on 23rd September 2025 (Ref. No.: 32/082).

Consent of Publication from the Author

All the authors have given consent for the publication of research findings.

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