Original Article

Narrow Intercondylar Notch and Anterior Cruciate Ligament Injury in Female Nonathletes with Knee Osteoarthritis Aged 41–65 Years in Plateau Region

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Abstract

Background: Few data are available concerning intercondylar notch dimensions in female nonathletes with knee osteoarthritis (OA) in plateau region. The aim of this study was to assess the relation of intercondylar notch morphology to anterior cruciate ligament (ACL) injuries in female nonathletes with knee OA aged 41–65 years from the Chinese Loess Plateau.

Methods: The study was conducted on 330 patients with ACL injury (aged 31–65 years; 159 males, 171 females), 141 patients with OA (aged 31–65 years; 59 males, 82 females), and 89 female healthy controls (aged 41–65 years), and this evaluation included identifying the distribution of patients with OA or ACL injury and measuring the intercondylar notch width indexes (NWIs).

Results: There was a significant rising trend in patients with OA (the Kellgren and Lawrence grade = 3) with ACL injury (OA-S + ACL) aged 41–65 years, especially in females. We found that the notches of OA-S + ACL had a smaller NWI compared with control and OA without ACL injury (OA-S-only, $P = 0.000$, 95% confidence interval [*CI*] = −0.059–−0.030; $P = 0.000$, 95% *CI* = −0.049–−0.016). A similar trend was found in notch shape index (NSI), but not in notch depth index and the cross-sectional area. The cutoff of NWI and NSI value was 0.26, and 0.65, and area under the receiver operating characteristic curve was 0.82, and 0.79, respectively. Further study displayed a significant correlation between a reduced NWI and NSI and OA-S + ACL ($P = 0.000$, $\chi^2 = 14.012$; $P = 0.000$, $\chi^2 = 14.286$).

Conclusion: A narrower intercondylar notch and a plateau environment are risk factors of predisposing female nonathletes with knee OA to ACL injury aged 41–65 years.

Key words: Anterior Cruciate Ligament; Intercondylar Notch; Magnetic Resonance Imaging; Osteoarthritis; Plateau

Introduction

The anterior cruciate ligament (ACL) tear and ACL reconstruction lead to premature knee osteoarthritis (OA) among adolescents,[1-3] which possibly increases anteroposterior laxity of knee joint, accelerates degeneration of articular cartilage, and disturbs biochemical homeostasis with increasing time from injury.[4] However, few clinicians are able to be fully conscious of the issue of ACL injury in patients with OA, especially in plateau region.

OA is the most common disease of the knee joint in older adults around the world.[3] The prevalence of OA increases to 10% of males and 20% of females aged 45–65 years.[4] The proportions of OA with complete ACL tears were between 8.1% and 35%.[5-8] In our clinical practice, we found that 41.3% female patients with knee OA aged 41–65 years in plateau region had ACL injuries, far higher than the rate in previous reports.[5-8] However, the risk factors of predisposing an individual with OA in plateau region to ACL injury remain obscure. The further identification of risk factors contributing to knee OA in patients with ACL

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tear is necessary and urgent on account of some risk factors may be modifiable as to prevent exacerbation of knee OA.

Although the cause of disparity in ACL injury remains elusive, the extant research shows that both extrinsic and intrinsic factors of knee joint have been explored, which are considered to be relevant.[9-11] Intercondylar notch size is one of the anatomic variables suspected to predispose an individual to ACL injury.[12-17] Numerous studies measured notch width index (NWI), notch shape index (NSI), notch depth index (NDI), and the cross-sectional area (CSA), and considered a smaller or stenotic NWI, NSI, NDI, or CSA was a risk factor of ACL injury.[18-22] One of the main features of patients with OA is the growth of osteophytes, and ACL may be missing in patients of severe OA with significantly smaller intercondylar notch relative to the normal knee.[23]

Given the potentially important relation between the femoral condylar notch morphology and ACL injury in patients with knee OA in plateau region, we have carried out a research to evaluate the important of intercondylar notch size for ACL injury in the female nonathletes with knee OA aged 41–65 years. The influence of intercondylar notch size indexes (NWI, NSI, NDI, and CSA) for knee OA with ACL injury in these patients was also identified.

Methods

Samples

This was a retrospective case–control study. Between October 2013 and June 2015, we retrospectively reviewed the medical records of patients treated at our hospital for ACL injuries or OA. All cases, including 330 ACL injury, 141 OA, and 89 healthy controls, who were all from the Loess Plateau at Gansu Province in China, were included in this analysis. Informed consent was waived due to the retrospective study design. We identified 330 patients with ACL injury (including complete tear and partial tear) by magnetic resonance imaging (MRI). One hundred and forty-one patients with knee OA aged 31–65 years were imaged with MRI and plain films. Diagnostic evaluation of radiographs for OA was performed based on the Kellgren and Lawrence grade (KLG). The cases with OA and without ACL injury aged 41–65 years of KLG = 2 were defined as OA-M-only, and KLG = 3 were defined as OA-S-only. The control group (control) population were healthy females aged 41–65 years who came to our clinic for health examination other than a knee problem. All exclusion criteria were as follows: Patients with fractures involving articular surfaces, congenital abnormalities of knee, inheritable musculoskeletal disorders, bone and joint of tuberculosis, inflammatory arthritis, tumor around the knee joint, bilateral end-stage OA, knee arthroplasty, knee OA after ACL reconstruction, or KLG = 0, 1, or 4 were excluded from the study samples. In addition, patients with OA with clear prior trauma of knee were also excluded. The demographic data of the study sample are shown in Table 1.

Magnetic resonance imaging technique

All study cases underwent MRI of knee performed on a 3.0-T MR system (Ingenia 3.0T, Phillips Medical Systems, Best, The Netherlands) with an 8-channel SENSE knee coil. Coronal oblique fast spin echo images were obtained of both knees with a repetition time (TR) of 520 ms, an echo time (TE) of 20 ms, and a 3 mm slice thickness. Axial proton density fast spin echo images were obtained with a TR of 2886 ms, a TE of 25 ms, and a 3 mm slice thickness.

Assessment of the intercondylar notch

For the purpose of the notch measurements, the axial MRI was used [Figure 1]. The femoral condylar width (W) was measured on a line through the popliteal groove parallel to the reference line. The intercondylar notch width (N) was the distance between the most interior margins of the femoral condyles at the borders of the two-thirds intercondylar notch height. The intercondylar notch depth (D) was identified

Table 1: Age and gender distribution of patients with OA or ACL and controls

Group	*n*	Age range (mean), years	Males (*n*)	Females (*n*)
ACL injury	330	31–65 (45)	159	171
OA	141	31–65 (55)	59	82
OA (aged 31–40 years)	18	31–40 (36)	16	2
OA-M-only	26	41–65 (54)	9	17
OA-S-only	42	41–65 (58)	12	30
OA-M + ACL	28	41–65 (56)	15	13
OA-S + ACL	27	41–65 (59)	7	20
Controls	89	41–65 (58)	0	89

OA-M-only: Samples with OA of KLG = 2, and without ACL injury; OA-S-only: Samples with OA of KLG = 3, and without ACL injury; OA-M + ACL: OA-M with ACL injury; OA-S + ACL: OA-S with ACL injury; Control: Health samples; KLG: Kellgren and Lawrence grade; ACL: Anterior cruciate ligament; OA: Osteoarthritis.

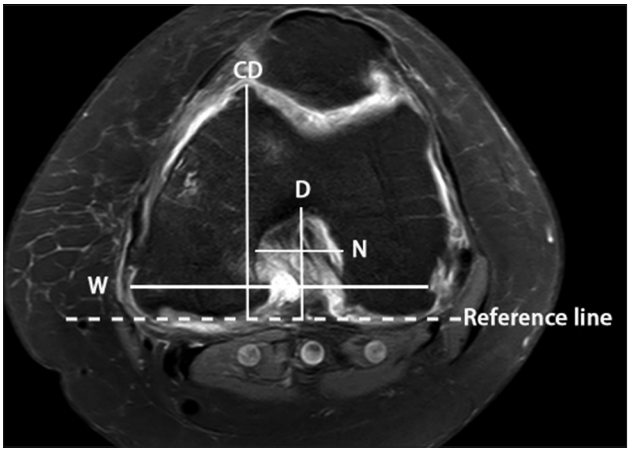

Figure 1: Schematic diagram of the measured parameters of the intercondylar notch in axial magnetic resonance imaging. N: The intercondylar notch width; W: The femur condylar width; D: The intercondylar notch depth; CD: The lateral femoral condylar depth; The white dotted line: Reference line. NWI = N/W; NSI = N/D; NDI = D/CD; CSA = N*D. NWI: Notch width index; NSI: Notch shape index; NDI: Notch depth index; CSA: Cross-sectional area.

as the maximum height of notch. The maximum height of the lateral femoral condyle was measured as the femoral condylar depth (CD). The intercondylar NWI is the ratio of the intercondylar notch width to the femoral condylar width. The NSI is calculated by dividing the intercondylar notch width by the intercondylar notch depth. The ratio of the intercondylar notch depth to the lateral femur CD forms the NDI. The intercondylar notch width multiplied by the intercondylar notch depth was defined as the CSA of the femoral intercondylar notch.

All of condylar notch dimensions were independently measured twice by a researcher specializing in MRI and by an orthopedic surgeon to determine reproducibility. Comparison of the measurements by these examiners demonstrated no significant differences.

Statistical analyses

Analysis of variance test with *post hoc* Least Significant Difference analysis was performed to test the differences of various measured intercondylar notch indexes among different groups. Receiver operating characteristic (ROC) curves were prepared from the measured data of MRI to determine the cutoff value. The Pearson Chi-square test was calculated to determine the correlation between ACL injury with OA-S and the NWI and NSI. All statistical analyses were performed using SPSS version 17.0 (SPSS, Chicago, IL, USA), and $P < 0.05$ was considered statistically significant. ROC curve was analyzed using MedCalc statistical software 15.2.2 (MedCalc, Ostend, Belgium).

Results

Female nonathletes with knee osteoarthritis aged 41–65 years had a high prevalence of anterior cruciate ligament injury in plateau region

The distribution of patients (from plateau region) with ACL injury or knee OA by age is shown in Figure 2. The proportion of patients with ACL injury in male patients decreases rapidly after age of 50 years, but an opposite trend in OA patients aged 41–65 years [Figure 2b]. Unlike in males, a high prevalence of OA and ACL injury is found in females [Figure 2a]. Further research for samples of OA with ACL injury is presented in Figure 2c and 2d. The results indicate a significant rising trend in OA-S + ACL after age of 41 years, especially in females. Although a similar trend was observed in males and females, of 27 cases of OA-S + ACL aged 45–65 years, 74% (20) samples were females [Table 1]. Thus, the females aged 41–65 years in OA-S + ACL were the emphasis in this study. In addition, we found 41.3% female patients with knee OA aged 41–65 years had ACL injuries, far higher than the rate in previous reports.[5-8] This shows that a plateau environment might be a risk factor of predisposing female nonathletes patients with knee OA to ACL injury.

A narrower notch width index and notch shape index were detected in those population

To further investigate the relationship between a high prevalence of OA-S + ACL in females and intercondylar

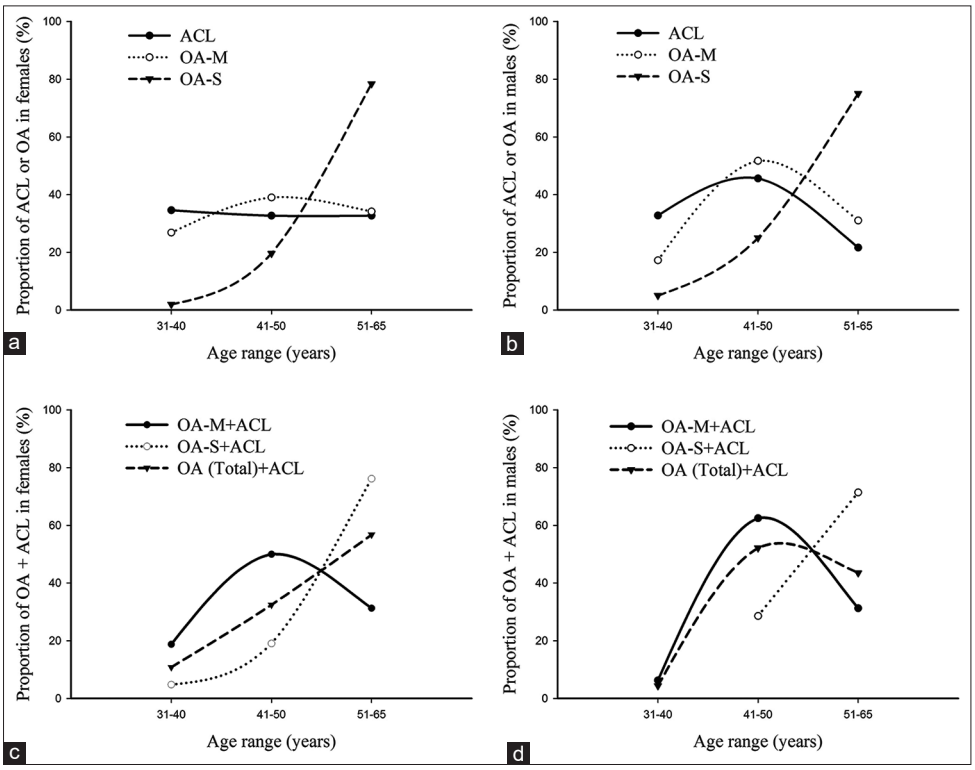

Figure 2: Distribution of anterior cruciate ligament injury (anterior cruciate ligament), knee osteoarthritis, or osteoarthritis with anterior cruciate ligament injury (osteoarthritis + anterior cruciate ligament) by age. (a and b) The proportion of anterior cruciate ligament or osteoarthritis in females or males. (c and d) The proportion of osteoarthritis + anterior cruciate ligament in females or males. ACL: Cases with anterior cruciate ligament injury; OA-M: Osteoarthritis patients with KLG = 2; OA-S: Osteoarthritis patients with KLG = 3; KLG: Kellgren and Lawrence grade.

notch dimensions, data from females aged 41–65 years were analyzed for the four indexes (NWI, NSI, NDI, and CSA) appeared in Table 2. We found that the notches of patients with OA-S + ACL had a smaller NWI compared to Control or OA-S-only. A similar trend was found in NSI, but not in NDI and CSA. Interestingly, these data of means (NWI, NSI, NDI, and CSA) all showed a decline trend among these groups.

A narrower intercondylar notch is associated with predisposing a female with osteoarthritis-S aged 41–65 years to anterior cruciate ligament injury

To obtain NWI and NSI cutoff value for ACL injury with OA-S, ROC curves were performed [Figure 3a and 3b]. The cutoff of NWI and NSI value was 0.26, and 0.65, and area under the ROC curve was 0.82, and 0.79, respectively. The further research displayed a significant correlation between a reduced NWI and NSI and OA-S + ACL [Table 3, $P = 0.000$, $\chi^2 = 14.012$; $P = 0.000$, $\chi^2 = 14.286$]. Hence, these results have also shown that a smaller NWI and NSI of intercondylar notch positively correlated with predisposing an individual with OA-S aged 41–65 years to ACL injury.

Discussion

The main finding of the present study was a narrower intercondylar notch was associated with the progress of ACL injury in a population with knee OA (KLG = 3) in plateau region. Compared to OA samples with an intact ACL, OA patients with ACL tears had a smaller NWI and NSI and showed a decline trend of NDI and CSA. Therefore, the intercondylar notch stenosis acts as a pathogenic factor for ACL injury in patients with severe OA, and a plateau environment was a risk factor of predisposing female nonathletes' patients with knee OA to ACL injury.

Stein *et al*.[5] identified whether patients with knee OA and ACL ruptures had smaller NWI independent of previous knee trauma and osteophyte volume through 160 cases from the progression subcohort of OA initiative (OAI) study. Of the 160 patients, 14.4% (23 patients) had an ACL rupture. This study indicated that NWI was significantly different in cases with ACL ruptures having a notch stenosis compared to those without ACL ruptures. Although patients in our study are all from plateau region, our results are consistent with those findings regarding the correlation of ACL ruptures and NWI in that report. However, 41.3% female patients with knee OA had ACL injuries in our study, far higher than 14.4% in that report. This also indicates that plateau environment predisposes female patients with OA to ACL injury.

In general, some extrinsic and intrinsic factors of knee joint are considered to be relevant to predisposing an OA

Table 2: Descriptive statistics of NWI, NSI, NDI, and CSA in females aged 41–65 years

Indexes	Control ($n = 89$)	OA-S-only ($n = 30$)	OA-S + ACL ($n = 20$)
NWI	0.29 ± 0.02	0.28 ± 0.03*	0.25 ± 0.02*,†
NSI	0.64 ± 0.06	0.63 ± 0.10	0.55 ± 0.05*,†
NDI	0.54 ± 0.04	0.52 ± 0.05*	0.52 ± 0.04*
CSA (mm^2)	530.30 ± 62.80	522.82 ± 78.18	487.91 ± 56.68*

Compared to control, *P<0.05; Compared to OA-S-only, †P<0.05. NWI: Notch width index; NSI: Notch shape index; NDI: Notch depth index; CSA: Cross-sectional area; OA: Osteoarthritis; OA-S-only: Samples with OA of KLG = 3, and without ACL injury; OA-S + ACL: OA-S with ACL injury.

Table 3: Correlation between a reduced NWI and NSI and OA-S + ACL

NWI	OA-S + ACL ($n = 20$)	OA-S-only ($n = 30$)	χ^2	P
NWI				
Normal	2	19	14.012	<0.001
Reduced	18	11		
NSI				
Normal	0	15	14.286	<0.001
Reduced	20	15		

"Reduced" represents NWI or NSI are smaller than the cutoff value (0.26 or 0.65). NWI: Notch width index; NSI: Notch shape index; OA: Osteoarthritis; OA-S-only: Samples with OA of KLG = 3, and without ACL injury; OA-S + ACL: OA-S with ACL injury.

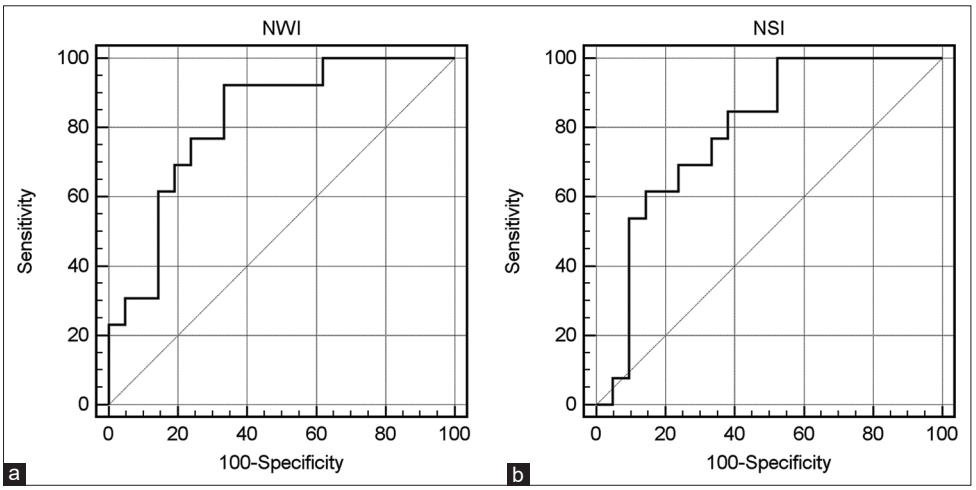

Figure 3: The receiver operating characteristic curve were performed using measured data of notch width index (a) and notch shape index (b) in knee osteoarthritis patients with anterior cruciate ligament injury.

individual to ACL injury. Our study showed that the plateau environment is a greater extrinsic risk factor of ACL injury in female nonathletes with knee OA aged 41–65 years. Some probable reasons are as follows: First, the plateau environment may accelerate progressive damage of articular cartilage in health or OA population. Second, intercondylar notch stenosis of knee OA is aggravated among female nonathletes patients living in plateau region.

Through above comprehensive analyses, we considered that female patients with OA from plateau region have a stenotic intercondylar notch and might have a correspondingly smaller ACL which would be fragile and easily damaged. Furthermore, we considered that a smaller notch would amplify the impact force between ACL and the medial wall of femoral condylar, and then ACL would be excessively abraded.

Therefore, a hypothetical theory is presented – a probable vicious circle between OA and ACL injury [Figure 4]. Patients with ACL injury in plateau region will increase knee anteroposterior laxity resulting in augmenting articular surface loading and typically progressing to knee OA after long-term actions. Accordingly, a narrower notch in patients with severe knee OA might predispose ACL to damage, and then ACL injury appears. ACL injury could aggravate the severity of OA, and OA, in turn, might exacerbate the extent of ACL injury. Thus, a probable vicious circle between OA and ACL injury is formed. The above-mentioned hypothesis might have a positive, practical significance in promoting diagnosis and treatment of ACL injury and/or knee OA. According to the hypothesis, any part of this circle is broke will be helpful for delaying the development of OA or ACL injury. Therefore, the early-stage knee OA after an ACL reconstruction should be disposed as early as possible avoiding developing a final-stage OA needs a total knee arthroplasty, or a dissatisfied ACL reconstruction should be revised early. Similarly, severe OA with a narrower notch should be treated by arthroscopy for decreasing the impact on ACL. ACL injury might be one of the sources of anterior knee pain, thus removing the narrow intercondylar notch might alleviate the symptom of knee OA. In brief, this theory is helpful for the clinical diagnosis and treatment of ACL injury and/or knee OA in plateau region.

There are several limitations to this study. First, the study population are all Chinese people. The distinction of race is not considered in this study. Second, our study samples are all nonathletes. Because majority of athletes are younger people, those cases are not assessed. Third, many extrinsic and intrinsic factors of knee joint, such as proprioception, height, weight, and quadriceps and hamstring muscle strength, have not been eliminated in this study. In brief, we considered that the influence of the above factors is limited for our research. Despite these limitations, we hope that the findings of this study will be helpful for guiding clinical decisions about diagnosis and treatment of ACL injury and/or knee OA in plateau region.

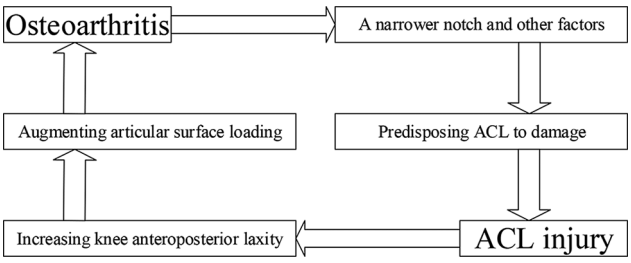

Figure 4: A probable vicious circle between osteoarthritis and anterior cruciate ligament injury in plateau regions is hypothesized.

In conclusion, the findings from this comprehensive analysis lead us to understand that a narrower intercondylar notch was associated with the progress of ACL injury in a population with knee OA aged 41–65 years in plateau region. Furthermore, plateau environment predisposes female patients with OA to ACL injury. We considered that an interaction between OA and ACL injury result in forming a vicious circle that immensely deteriorated the structures and functions of knee joint. Therefore, in plateau regions, the present study suggested that a smaller NWI and NSI of intercondylar notch may be two potential diagnostic indexes for female nonathletes OA patients complicated with ACL injury based on MRI manifestations; female OA patients with a narrower intercondylar notch living in plateau environment treated under arthroscopy must take into account the possibility of ACL injury existed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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