Intercondylar Notch Width as a Risk Factor for Medial Femoral Condyle Osteochondritis Dissecans in Skeletally Immature Patients

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Background: Juvenile osteochondritis dissecans (OCD) of the medial femoral condyle (MFC) is one of the most common causes of knee pain in adolescents. Wilson sign reproduces knee pain with internal rotation of the tibia during extension of the knee from 90 to 30 degrees due to impingement of the tibial eminence on the MFC. This impingement may result in microtrauma and contribute to lesion formation. The purpose of this study was to evaluate anatomic factors that may increase the likelihood of impingement by using magnetic resonance imaging scans of patients with MFC OCD lesions to measure tibial eminence height and femoral notch width.

Methods: A retrospective, case-control study was performed using the radiology database at our institution between July 2009 and February 2014. Magnetic resonance imagings of patients with MFC OCD lesions and matched controls were identified. For each patient, tibial eminence height and femoral notch width were measured and then normalized for patient size [creating the tibial eminence height normalized, and the notch width index (NWI), respectively]. Values for OCD and control knees were compared using Student *t* test. Interrater and intrarater reliability were calculated using intraclass correlation coefficients.

Results: Thirty-five MFC OCD patients and matched controls were identified. Comparison of the groups showed a significantly smaller NWI in MFC OCD knees than in the matched controls (0.2620 ± 0.0248 vs. 0.2886 ± 0.0323, $P = 0.0003$). There was no difference in tibial eminence height normalized between groups (0.1387 ± 0.0161 vs. 0.1428 ± 0.0108, $P = 0.21$). Interrater and intrarater reliability of all measurements was good to excellent (0.81 to 1.00) when measurements were made using bony margins.

Conclusions: Knees with MFC OCD lesions have significantly smaller NWIs than matched controls. This anatomic factor may increase the likelihood of tibial eminence impingement and contribute to OCD lesion formation.

Level of Evidence: Level III—case-control study.

Key Words: osteochondritis dissecans, knee, notch width index, magnetic resonance imaging, etiology

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Juvenile osteochondritis dissecans (OCD) of the knee is a localized disorder of the subchondral bone that results from osseous resorption, followed possibly by collapse, sequestrum formation, and articular cartilage delamination.[1,2]

It is one of the most common causes of knee pain in children and adolescents,[3] with a prevalence of 15 to 29 per 100,000,[4] an average age of onset of 11 to 13 years,[5] and a sex predilection of 5:3 (M:F).[4] Although the majority of lesions will heal either spontaneously or after surgical intervention with good results, a small number of patients will suffer long-term limitation of activities and early degenerative osteoarthritis.

The etiology of OCD is unknown. Although many factors have been investigated, including ischemia, inflammation, and genetics, current theories favor the role of repetitive microtrauma. Initial bouts of microtrauma induce a stress fracture in the subchondral bone, and continued microtrauma overwhelms the capacity of the bone to heal, resulting in necrosis and OCD lesion formation.[4] This theory is supported both by animal studies[6] and by epidemiologic studies that show that patients are commonly involved in regular athletic activities and that the disease incidence is increasing as youth and adolescent sports participation increases.[4]

Symptoms and signs of OCD are often vague but may include poorly localized knee pain and intermittent swelling early in the disease, mechanical symptoms in advanced disease, an antalgic gait, and tenderness over the anteromedial aspect of the knee.[2,4] In 1967, Wilson described a test to diagnose OCD lesions of the medial femoral condyle (MFC) in which the tibia is internally rotated while the knee is extended from 90 to 30 degrees. He believed that pain created by this maneuver but relieved by external rotation of the tibia occurred because of impingement of the tibial eminence on a MFC OCD lesion.[1] Conrad and Stanitski[1] showed that this sign lacked sensitivity; however, in the 8 patients who did have a positive sign, conversion of the sign to negative correlated with lesion resolution. This suggests that tibial

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eminence impingement may play a role in MFC OCD lesion symptomatology and, further, may produce the microtrauma that contributes to lesion creation. This being so, certain anatomic factors, including a tall tibial eminence and/or a narrow femoral notch, may predispose to MFC OCD lesions.

The purpose of this study was to evaluate the tibial eminence height (TEH) and femoral notch width (FNW) on magnetic resonance imaging (MRI) scans of patients with juvenile OCD lesions of the MFC and to compare these values to normal knees. Our hypothesis was that patients with MFC OCD lesions would have taller tibial eminences and narrower femoral notches than normal knees.

METHODS

A retrospective, case-control study was performed at the Children's Hospital at Westmead in New South Wales, Australia. The electronic radiology database was searched from July 1, 2009 to February 28, 2014 to identify patients with MFC OCD lesions. For each patient, the earliest available MRI showing disease was selected for inclusion; in patients with bilateral disease, 1 knee was randomly selected for inclusion. For each OCD patient, a matched control patient (matched for age, sex, and available MRI sequences) was also located. Control MRIs demonstrated either no or only minimal pathology such as osteomyelitis, benign bone lesions, or sequelae of minor trauma. MRIs with pathology potentially associated with altered preexisting knee anatomy, such as anterior cruciate ligament (ACL) ruptures or lateral discoid menisci, were excluded. A power calculation performed using notch width data in skeletally immature patients[7] showed that a sample size of at least 18 patients was required to ensure 80% power and a significance level of 5%.

For each MRI, proton density-weighted sequences were selected for review; if they were unavailable, short tau inversion recovery or spectral attenuated inversion recovery sequences were used for each matched pair. Measurements were performed on coronal images and were performed first using underlying bony margins to define each landmark and then repeated using the extent of the overlying cartilage to define each landmark (Figs. 1, 2, respectively).

Measurement of TEH was based on work by Hashemi et al[8] (ORS 2013 Annual Meeting, Poster 0892). Measurements were performed on multiple coronal images to determine the maximal possible TEH. On each MRI image, the base of the tibial eminence was defined by a line connecting the lowest aspect of the medial and lateral tibial plateaus (Fig. 1, line a). The TEH was measured from this line perpendicularly to the most proximal aspect of the tibial eminence (line b). The TEH was then normalized to the size of the knee by dividing by the maximal tibial plateau width, TPW (measured parallel to the physis, line c), producing the TEH normalized (TEH-N).

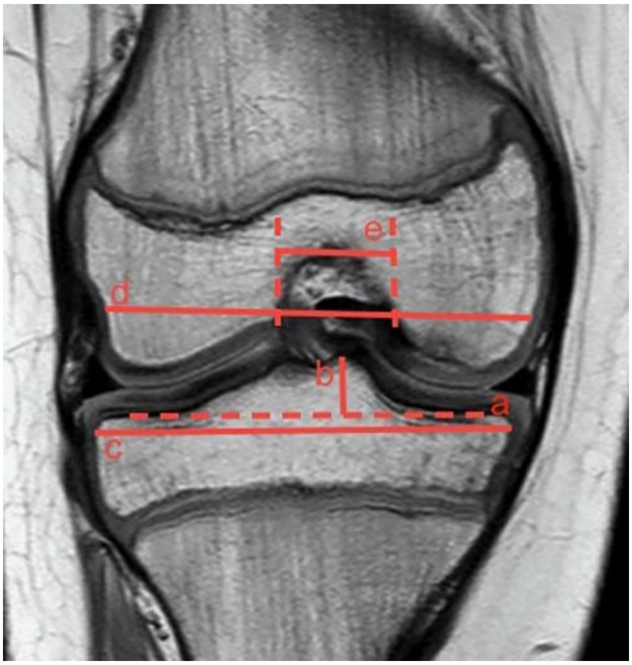

FIGURE 1. Measurements using bony margins. Line defining the tibial eminence base (a);tibial eminence height (b); tibial plateau width (c); femoral condyle width (d); femoral notch width (e).

Measurement of the FNW and calculation of a normalized value, the notch width index (NWI), was based on methods described by Souryal and Freeman[9]

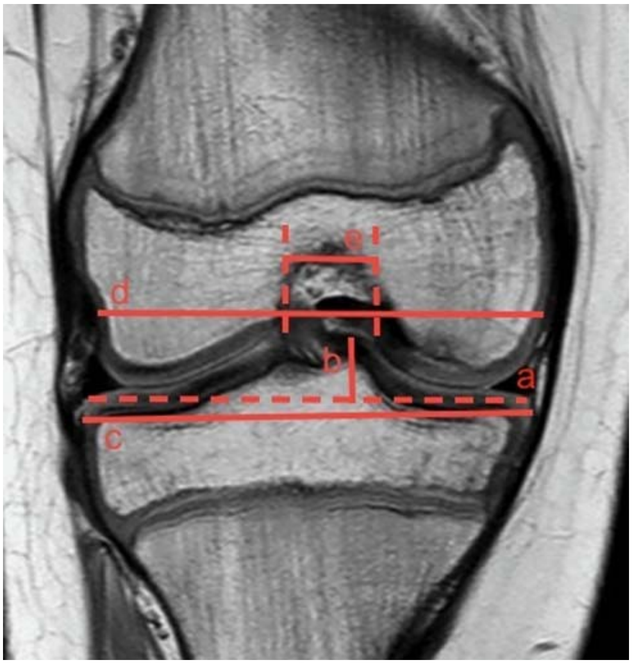

FIGURE 2. Measurements using cartilaginous margins. Line defining the tibial eminence base (a); tibial eminence height (b); tibial plateau width (c); femoral condyle width (d); femoral notch width (e).

and Domzalski et al.[7] FNW was measured on the MRI image closest to the mid-substance of the ACL and to the decussation of the ACL and posterior cruciate ligament. First, the angle of the joint line was defined by a line connecting the most distal aspects of the medial and lateral femoral condyles. Parallel to this and at the level of the popliteal groove, the width of the femoral condyles (FCW) from their outermost margins was measured (Fig. 1, line d). Along this line, the FNW was measured as the distance between the innermost borders of the intercondylar notch (line e). The ratio of FNW to FCW produced NWI.

All measurements were performed by a single investigator and then, for a randomly chosen subgroup consisting of half of the patients, measurements were repeated by both the first investigator and a second investigator to calculate intrarater and interrater reliability, respectively. TEH-N and NWI were compared between MFC OCD and control knees using Student *t* test. A value of $P < 0.05$ was considered significant. Intrarater and interrater reliability were calculated using intraclass correlation coefficients (ICCs).

Clinical records of the MFC OCD patients were reviewed to determine treatment regimes (nonsurgical vs. surgical). All MFC OCD patients who were managed with activity modification alone and who demonstrated healing of their MFC OCD lesions on subsequent MRIs were included in the nonsurgical group. All patients who required surgery either for failure of nonsurgical management (6 mo of activity modification without MRI evidence of lesion healing) or for unstable lesions demonstrated on MRI were included in the surgical group. A comparison of TEH-N and NWI between the nonsurgical and surgical groups was performed using the Mann-Whitney *U* test.

Finally, a comparison of TEH-N and NWI between patients with bilateral disease and those with unilateral disease was performed with the Mann-Whitney *U* test.

All calculations were performed using Microsoft Excel (version 14.3) and SPSS (version 21). This study received approval from the Human Research Ethics Committee of the Sydney Children's Hospital Network.

RESULTS

Thirty-five patients and matched controls were identified (Table 1). The average age of the cohort was 12.0 ± 1.7 years (6.9 to 14.4 y).

TABLE 1. Patient Demographics

	MFC OCD (n = 35)	Control (n = 35)
Sex (M:F)	24:11	24:11
Age (y)	11.6 ± 1.9	12.2 ± 1.6
Male	12.2 ± 1.6	12.3 ± 1.6
Female	11.6 ± 1.9	11.7 ± 2.0

Data reported as mean ± SD.
MFC indicates medial femoral condyle; OCD, osteochondritis dissecans.

TABLE 2. Anatomic Measurements Using Bony Margins

	OCD (n = 35)	Control (n = 35)	*P*
TEH	0.95 ± 0.13	0.96 ± 0.12	0.86
TPW	6.89 ± 0.68	6.71 ± 0.74	0.31
TEH-N	0.1387 ± 0.0161	0.1428 ± 0.0108	0.21
FNW	1.82 ± 0.28	1.94 ± 0.34	0.10
FCW	6.93 ± 0.64	6.71 ± 0.72	0.19
NWI	0.2620 ± 0.0248	0.2886 ± 0.0323	**0.0003**

Data reported as mean ± SD.
Bold values indicate statistically significant.
FCW indicates femoral condyle width; FNW, femoral notch width; NWI, notch width index; OCD, osteochondritis dissecans; TEH, tibial eminence height; TEH-N, tibial eminence height normalized; TPW, tibial plateau width.

Values for TEH, TPW, TEH-N, FNW, FCW, and NWI when measured using bony and cartilaginous margins are shown in Tables 2 and 3, respectively. The NWI was significantly less in the MFC OCD group compared with the control group when measured using both bony and cartilaginous margins ($P < 0.05$). The TEH-N was not significantly different.

The NWI was also significantly larger in male patients compared with female patients when grouped irrespective of their OCD status and measured using bony margins (0.2811 ± 0.0312 vs. 0.2628 ± 0.0292, $P = 0.02$). Within male and female subgroups, the finding of a smaller NWI in OCD patients compared with controls, measured using bony margins, remained significant [0.2672 ± 0.0235 vs. 0.2949 ± 0.0322, in males ($P = 0.001$), and 0.2507 ± 0.0249 vs. 0.2748 ± 0.0291, in females ($P = 0.05$)].

ICC values for intrarater reliability were between 0.90 and 1.00 for bony measurements and between 0.79 and 0.98 for cartilaginous measurements. ICC values for interrater reliability were between 0.81 and 0.99 for bony measurements and 0.58 and 0.98 for cartilaginous measurements. The intrarater and interreliability were excellent when measurements were made using bony margins and were fair to good when cartilaginous margins were used.[10]

Clinical records were available for 31 of 35 patients with MFC OCD lesions. Of these, 28 patients had

TABLE 3. Anatomic Measurements Using Cartilaginous Margins

	OCD (n = 35)	Control (n = 35)	*P*
TEH	0.92 ± 0.12	0.89 ± 0.15	0.28
TPW	7.29 ± 0.67	7.02 ± 0.68	0.09
TEH-N	0.1270 ± 0.0175	0.1267 ± 0.0207	0.96
FNW	1.39 ± 0.34	1.59 ± 0.39	**0.03**
FCW	7.07 ± 0.62	6.85 ± 0.66	0.15
NWI	0.1963 ± 0.0427	0.2304 ± 0.0436	**0.002**

Data reported as mean ± SD.
Bold values indicate statistically significant.
FCW indicates femoral condyle width; FNW, femoral notch width; NWI, notch width index; OCD, osteochondritis dissecans; TEH, tibial eminence height; TEH-N, tibial eminence height normalized; TPW, tibial plateau width.

adequate follow-up. Nineteen patients underwent surgery; 9 patients healed with nonsurgical management. There was no statistically significant difference in TEH-N or NWI between surgically and nonsurgically treated patients.

Finally, 7 patients had bilateral disease. There was no statistically significant difference in TEH-N or NWI between patients with bilateral and unilateral disease.

DISCUSSION

This study demonstrated a significantly narrower NWI in knees with MFC OCD lesions compared with controls when measurements are made using bony margins (0.2620 vs. 0.2886) and cartilaginous margins (0.1963 vs. 0.2304). No significant difference was found in TEH-N between MFC OCD and control knees. To the best of our knowledge, no previous studies have looked at anatomic risk factors predisposing to MFC OCD lesions. Furthermore, no previous studies have calculated NWI using cartilaginous margins. Although the measurement technique for TEH-N was based on work by Hashemi et al[8] (ORS 2013 Annual Meeting, Poster 0892), no data for TEH-N are reported in their work to allow for comparison.

NWI as a risk factor for ACL rupture has been extensively debated in the literature. Recently, a meta-analysis by Zeng et al[11] showed a significantly smaller NWI (by 0.02) in ACL ruptured knees compared with controls. This meta-analysis included studies using radiographs and MRIs (using bony margins) for calculation of NWI. The magnitude of this difference is comparable to that found in our study. Zeng and colleagues did not comment on a normal value for NWI.

Three previous studies have used the same technique as in our study for calculation of NWI in ACL ruptured patients and controls. They reported values of between 0.263 and 0.27 for NWI in controls.[7,12,13] Specifically, Domzalski et al[7] reported a value of 0.2691 in controls who were skeletally immature (mean age 14.7 y), which is the study population most closely approximating ours. The NWI in our control group was greater than this at 0.2886. This may be due to the younger mean age of our study cohort, as we did find a trend towards larger NWIs in younger patients. This trend is support by studies, such as that by Shelbourne et al,[14] that have demonstrated decreases in NWI with increasing patient height. This occurs as a result of the FCW increasing disproportionately more than FNW as patient height increases. We did not collect data on patient height; however, it is possible that as the patients in our study cohort age and grow that their NWIs may decrease to more closely reflect the values in the older adolescent and adult literature.

Our study also found that the NWI was significantly smaller in female compared with male patients. Again, referring to ACL-related literature, this finding is supported by Souryal and Freeman[9] but is in contrast to studies by Anderson et al[15] and Harner et al.[16] In ACL studies, a smaller NWI in female patients may help to explain the higher incidence of female compared with male ligament ruptures; however, in MFC OCD, there is a well-documented higher incidence of disease in male patients (5M:3F). This emphasizes that although a smaller NWI may be a risk factor for OCD lesion formation, many other factors are also involved.

The intrarater and interrater reliabilities in our study were excellent when using bony margins for measurement but were slightly less robust when using cartilaginous margins. We performed the measurements using bony margins first, as this replicated the described technique and allowed for comparison with existing literature. The measurements were then repeated using cartilaginous margins given that the majority of the patients were skeletally immature and some still had large cartilaginous components contributing to the overall anatomy of the knee. The reliability of the cartilaginous measurements decreased, however, due to difficulty differentiating cartilage from ACL fibers when measuring TEH and cartilage from posterior cruciate ligament fibers when measuring FNW. As both methods of measurement showed a significantly smaller NWI in MFC OCD knees compared with controls, we recommend that future studies use bony margins for measurement given the increased reliability.

In this study, we did not find that NWI correlated with the need for surgical intervention or with the presence of bilateral disease. The number of patients available, however, for these subgroup analyses was small, and this area requires further study. If a correlation is found in future studies, the information would be useful in counseling patients and families regarding the likelihood of needing surgical intervention or of developing contralateral disease.

Future studies should also focus on lower extremity alignment and movement patterns of children with MFC OCD lesions. If tibial spine impingement, caused by internal rotation of the tibia in a flexed knee position and made more likely by a smaller NWI, is a risk factor for MFC OCD lesion formation, then, perhaps, specific pathologic movement patterns can be identified and prevention programs implemented.

This study does have limitations. The number of patients included was small; however, despite this, the key finding of a smaller NWI in MFC OCD knees compared with control knees did reach statistical significance. This study was also only performed at a single center on a single population of patients. Although we believe that the results are generalizable, we do acknowledge that this study requires replication at other centers on other populations. One of the strengths of the study is its use of a previously described technique for measurement of NWI (using bony margins), a technique that showed excellent intrarater and interrater reliabilities. This will allow for easy replication of the study and comparison of results. Finally, the study is limited by its retrospective design and by its unavoidable lack of blinding of observers. This may have introduced bias and error.

Wilson proposed that internal rotation of the tibial while extending the knee from 90 to 30 degrees caused pain because of impingement of the tibial spine on MFC OCD lesions. We postulate that this impingement may also induce microtrauma and contribute to lesion formation. In this study, we have shown a significantly smaller NWI in knees with MFC OCD lesions compared with normal knees, which increases the likelihood of tibial spine impingement. Further study is required to address the clinical implications of this finding.

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