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Proximal tibial morphology and its correlation with osteochondritis dissecans of the knee

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Abstract
Purpose The relationship of proximal tibial morphology to the presence of femoral osteochondritis dissecans (OCD) lesions is unknown. This radiographic study tested the null hypothesis that knees with unilateral medial or lateral OCD lesions would have no difference in the slope of their medial, lateral, or posterior tibial plateau compared with unaffected knees.
Methods There were 72 patients with unilateral OCD lesions of the medial or lateral femoral condyle seen at our institution from 2005 to 2011. On AP and lateral radiographs of the knee, three examiners conducted independent measurements of the tibial plateau posterior slope, as well as medial and lateral slope as measured from the peak of the tibial spine to the edge of the plateau on the side of the corresponding OCD lesion. Measurements were repeated on normal contralateral and matched control knees.
Results Knees with medial femoral condyle OCD lesions had greater medial tibial slope compared with normal contralateral knees ($p = 0.007$) and normal controls ($p < 0.04$). Knees with lateral femoral condyle OCD lesions had no significant difference in lateral tibial slope compared with the contralateral knee or matched controls. Posterior slope was greater in knees with medial OCD lesions than matched controls ($p = 0.007$). Intraclass correlation coefficients demonstrated consistency between observers for all measurements.
Conclusion An assessment of proximal tibial morphology demonstrated greater medial and posterior tibial slope in knees with medial OCD lesions compared with normal knees. The technique for measuring medial and lateral tibial slope was reliable among evaluators. The clinical relevance is that proximal tibial morphology may have a relationship with OCD lesions.
Level of evidence III.

Keywords Osteochondritis dissecans · Knee · Tibial slope

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Introduction

Osteochondritis dissecans (OCD) lesions of the knee have been reported to occur in 20–30 people of every 100,000 [17] and found disproportionately in males [7, 8, 17]. Medial femoral condyle OCD lesions occur up to six times as often as lesions of the lateral femoral condyle [7]. Both medial and lateral condyle lesions occur in weight-bearing regions of the condyle [7, 8, 12]. Medial condyle lesions occur primarily in the non-meniscal portion of the knee joint [7, 12, 17], while lateral condyle lesions occur more often in the central or lateral area of the lateral femoral condyle and are strongly associated with the presence of a discoid lateral meniscus [6].

Various theories exist as to the cause of OCD of the knee. Vascular insults and osteonecrosis have been considered; however, the evidence is unclear [15, 16, 20]. Mechanical stress, either a single acute incident or chronic microtrauma, may play a factor. Green et al. [8], for example, found that 40 % of patients with OCD of the knee reported sustaining an injury to the knee with swelling and pain at the time of the injury. Koch et al. [15] suggested

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a process consistent with osteochondral trauma and subsequent repetitive stress, as evidenced by histological findings of decreased extracellular matrix and new osteoid and osteoblasts. In other studies, rotational malalignment of the tibia [2, 22] as well as the presence of a lateral discoid meniscus [6, 14] were found disproportionately in patients with OCD lesions of the knee, implicating chronic mechanical overload as a risk factor for OCD development [19].

Coronal knee malalignment may also be a cause of mechanical stress in OCD lesions. Jacobi et al. [13] found that medial and lateral femoral condyle OCD occurred more frequently in knees where the mechanical axis passed through the medial and lateral compartments of the knees, respectively. Another study found higher peak pressures in the medial femoral condyle in varus and neutral knees and higher peak pressures in the lateral femoral condyle in valgus knees [4]. No studies, however, have evaluated the relationship of OCD lesions with tibial plateau coronal or sagittal alignment and characteristics that we will generally refer to as "proximal tibial morphology." It is possible that abnormal plateau slope in either the coronal or sagittal plane could lead to focally increased forces on the femoral condyle, thus predisposing to the development of OCD. As an example, a knee with greater slope of the medial tibial plateau in the coronal plane, as measured from the peak of the medial tibial spine to the edge of the medial plateau (Fig. 1), may incur greater force along the lateral aspect of the medial femoral condyle, possibly contributing to OCD development.

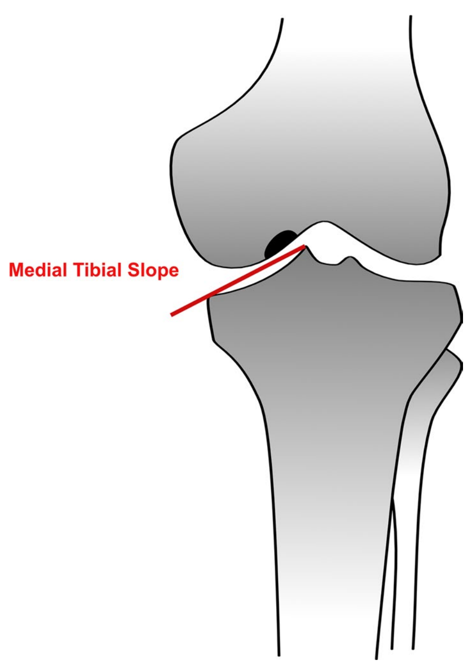

Fig. 1 Tibial slope in the coronal plane was measured from the peak of the tibial spine to the edge of the plateau, on the side corresponding to the femoral OCD lesion

The purpose of this study was to investigate the relationship of OCD lesions to proximal tibial morphology (medial, lateral, and posterior slope). Our null hypothesis was that knees with distal femoral condyle OCD lesions would have no difference in medial, lateral, or posterior slope compared with normal knees.

Materials and methods

All patients who had been seen at our institution between 2005 and 2011 for isolated OCD lesions of the medial or lateral femoral condyle were identified (72 patients). Patients were included in the study if they had a unilateral OCD lesion of the medial or lateral femoral condyle. Patients were excluded from the study if they had concomitant medial and lateral lesions in the same knee (two patients) or lesions in both knees (11 patients). A musculoskeletal radiologist identified 72 patients with normal knee radiographs in our institution's database that were matched for age, gender, height, weight, and BMI. In addition to this information, a retrospective chart review was also carried out to identify duration of patient symptoms and size of the OCD lesion.

Seventy-two knees with OCD lesions of the medial or lateral femoral condyle were identified in our institution. The OCD lesions involved the medial femoral condyle in 61 knees and lateral femoral condyle in 11 knees. There were 33 lesions in right knees and 39 in left knees. Average patient age in the OCD group was 15.4 ± 2.0 years and was comprised of 40 males and 32 females (5:4 ratio), with an average height of 1.72 ± 0.1 m, weight of 63.2 ± 17.2 kg, and BMI of 21.3 ± 3.3. Median female age was 16 (range 10–29), and the median male age was 14.5 (range 9–30). Matched controls were similar with regard to age, gender, height, weight, and BMI. (Table 1) Thirty-eight patients were skeletally immature, and 34 patients were skeletally mature.

Three examiners conducted independent measurements. Medial or lateral tibial slope for knees with respective medial or lateral femoral condyle OCD lesions was measured on the AP radiographs. Posterior slope was measured on the lateral radiograph. Measurements were conducted for three groups: the affected knees, the contralateral normal knees, and the matched control knees. The radiographs were analyzed electronically with use of PACS software [PACSCube (Version 5.0)], with measurement accuracy of greater than one decimal point.

For medial or lateral tibial slope measurements on knee radiographs, the tibial longitudinal axis was estimated using a circle technique described in the literature [1, 3, 10, 11, 18, 23]. Two circles were drawn on the tibial shaft in the AP radiograph, one at the level of the

Table 1 Demographic information

	Medial compartment		Lateral compartment		Overall
	Medial OCD lesions	Normals	Lateral OCD lesions	Normals	
Males/Females	30/31	30/38	10/1	10/1	80/71
Age	15.4	15.8	15.3	15.2	15.4
BMI	21.2	21.4	21.9	22.1	21.3
Weight	62.1	61.5	68.9	68.7	63.2
Height (cm)	170	169	173	176	172

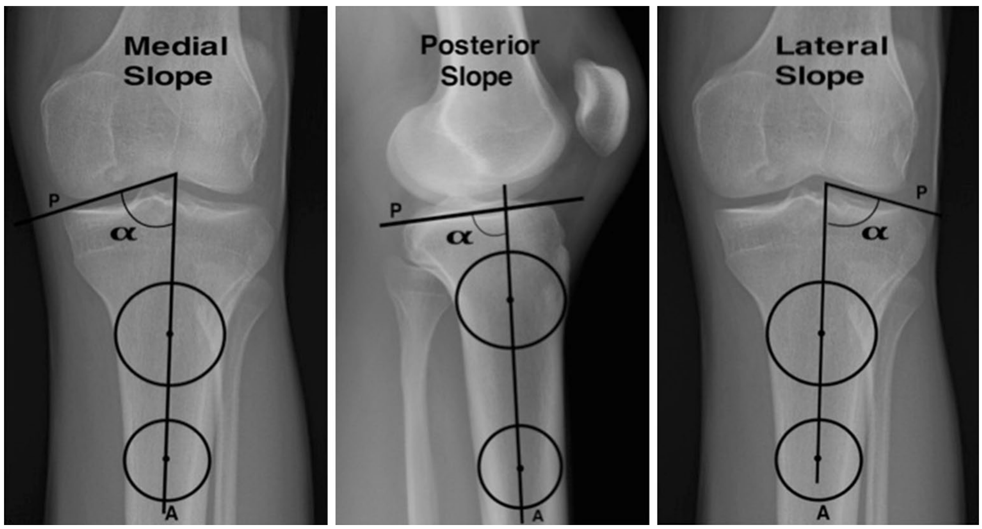

Fig. 2 The angle (α) between the tibial plateau (P) and the tibial axis (A) is subtracted from 90º to yield the medial, posterior, and lateral slope

metadiaphyseal junction and the other within the diaphysis as distal as the radiograph would allow, with a circle diameter equal to that of the tibial shaft. A line was drawn between the centers of these two circles, which intersected with a line drawn from the apex of the tibial eminence to the edge of the corresponding tibial plateau on the side of the knee containing the OCD lesion. Posterior slope was measured on the lateral radiograph in a similar manner with a line through two circles on the tibial shaft that intersected with a line parallel to the tibial plateau. By convention, the angle between the lines for all measurements was subtracted from 90 degrees to yield the slope (Fig. 2).

Institutional Review Board approval (ID # 1204E13363) was obtained from our institution, the University of Minnesota, prior to initiating this study.

Statistical analysis

Student's *t* test was employed to compare medial, lateral, and posterior slope between the OCD knees, the normal contralateral, and control knees for both medial and lateral OCD lesions. When the comparisons were between OCD knees and the normal contralateral knee, a paired Student's *t* test was used. For patients with medial OCD lesions, the Student's *t* test was also used to compare medial and posterior slope measurements for groups based on patient age and skeletal maturity. For patients with medial OCD lesions, logistic regression analysis was performed to assess the relationship between medial tibial slope and size of lesion, as well as slope and length of time from presentation to treatment. Due to low numbers of patients with lateral-sided lesions, these additional analyses were not performed on lateral lesions. Inter-observer correlation coefficients (ICCs) were calculated for all measurements. Height, weight, and BMI were matched to controls with normal knee radiographs and were correlated with medial, lateral, and posterior tibial slope for both normal knees and affected knees. Using means for the patients' affected side and contralateral control, as well as a common standard deviation, to calculate for an alpha value of 0.05 and a power of 0.8, the required sample size for each group was 60 patients in each group.

Results

Medial lesions

For medial femoral condyle OCD lesions, the average medial tibial slope on the affected side was greater than the normal contralateral knees ($p < 0.01$) as well as the matched controls ($p = 0.04$). The average difference between OCD knees and the normal contralateral knees was 1.6 ± 0.3°. The average posterior tibial slope for knees with OCD lesions of the medial femoral condyle was greater than the matched controls ($p = 0.01$) but not significantly different from the contralateral knees (n.s.). (Table 2).

There were significant differences in medial slope when comparing affected knees to control knees (21.3 ± 5.8°) for skeletally immature (22.2 ± 2.9°) and skeletally mature (22.1 ± 3.1°) OCD patients ($p < 0.01$). There was no difference between skeletally immature and skeletally mature OCD patients for medial slope (n.s.). There were also significant differences in posterior slope when comparing affected knees to control knees (8.9 ± 2.9°) for skeletally immature (10.0 ± 3.9°) and skeletally mature (9.9 ± 3.7°) OCD patients ($p < 0.01$). There was no difference between skeletally immature and skeletally mature OCD patients for posterior slope (n.s.).

There was a poor correlation between medial tibial slope and duration of symptoms ($R = 0.11$). There was also a poor correlation between medial tibial slope and size of the lesion ($R = 0.11$).

Table 2 Knees with medial femoral condyle OCD lesions are compared to contralateral knees and normal controls with regard to medial and posterior slope

	Medial slope	Post slope
Medial OCD knees ($n = 61$)	22.2 ± 2.9° *,# (ICC(2,1) = 0.77, $p < 0.01$	10.0 ± 3.9° **,## (ICC(2,1) = 0.78, $p < 0.01$)
Contralateral knees	20.6 ± 3.6° * (ICC(2,1) = 0.79, $p < 0.01$	10.4 ± 4.4° ** (ICC(2,1) = 0.84, $p < 0.01$
Normal control knees	21.3° ± 5.8° # (ICC(2,1) = 0.73, $p < 0.01$	8.9° ± 2.9° ## (ICC(2,1) = 0.80, $p < 0.01$

ICC Inter-observer correlation coefficients

* $p = 0.007$ (OCD vs. contralateral)—medial slope

** $p = 0.19$ (OCD vs. contralateral)—posterior slope

$p = 0.043$ (OCD vs. normal)—medial slope

$p = 0.007$ (OCD vs. normal)—posterior slope

Table 3 Knees with lateral femoral condyle OCD lesions are compared to contralateral knees and normal controls with regard to lateral and posterior slope

	Lateral slope	Post slope
Lateral OCD knees (11)	10.5 ± 4.6° *,# (ICC(2,1) = 0.81, $p < 0.01$	9.0 ± 3.6° **,## (ICC(2,1) = 0.63, $p < 0.01$)
Contralateral knees	10.0 ± 3.5° * (ICC(2,1) = 0.55, $p < 0.01$	10.9 ± 4.3° ** (ICC(2,1) = 0.61, $p < 0.01$
Normal control knees	9.6° ± 2.6° # (ICC(2,1) = 0.79, $p < 0.01$	8.8° ± 2.8° ## (ICC(2,1) = 0.61, $p < 0.01$

ICC Inter-observer correlation coefficients

* $p = 0.378$ (OCD vs. contralateral)—lateral slope

** $p = 0.49$ (OCD vs. contralateral)—post slope

$p = 0.461$ (OCD vs. normal)—lateral slope

$p = 0.52$ (OCD vs. normal)—post slope

Lateral lesions

Knees with lateral femoral condyle OCD lesions had lateral tibial slope that was not significantly different from the normal contralateral knees (n.s.) or the matched controls (n.s.). Knees with lateral femoral condyle OCD lesions had an average posterior tibial slope that was not significantly different from the contralateral knees (n.s.) or matched control knees (n.s.). (Table 3).

Inter-observer reliability

Inter-observer correlation coefficients (ICCs) showed significant agreement between the three authors ($p < 0.01$) for all measurements. (Tables 2, 3).

Discussion

The most important finding in this study population was that knees with medial femoral condyle OCD lesions had greater medial tibial slope than normal contralateral and control knees. Posterior slope was also found to be greater in knees with medial OCD lesions compared with controls. Knees with lateral femoral condyle OCD lesions had no difference from normal contralateral or control knees in terms of lateral or posterior tibial slope. The ICC values showed low inter-observer variability for all measurements.

Despite the statistical significance, the clinical significance of greater medial and posterior tibial slope in patients with medial OCD lesions is unclear. It is possible that greater slope of the plateau could contribute to concentration of mechanical stress, and therefore, it could be a risk factor for OCD, but at this point, it unclear how much of a difference in slope is clinically significant (Fig. 1). Interestingly, based on our data, there were no correlations between slope and duration of symptoms or size of lesion; however, abnormalities in slope could contribute to the severity of the disease, such as increased pain or lesions more likely to progress. Future studies to evaluate the clinical relevance of these findings may, therefore, be important.

It is important to remember that treatment for OCD lesions often depends on whether the patient has reached skeletal maturity. Therefore, slope in light of skeletal maturity is important to consider. Our data for patients with medial sided lesions did demonstrate differences between control and OCD skeletal maturity groups, but not between skeletally mature and immature OCD patients, for both medial and posterior slope. Despite the fact that slope does not appear to change dramatically with the transition from skeletal immaturity to maturity, the clinic relevance of the comparison between OCD patients and controls is that if proximal tibial morphology can further be shown to have a relationship with OCD, then it could be used as an additional prognosticator for evaluating success with different treatment modalities. It is also possible that in the future, corrections of proximal tibial morphology could be included in the treatment algorithm for OCD lesions; however, much more study is necessary prior to incorporation into the surgical armamentarium.

Measuring tibial slope in the coronal plane through our technique is a novel approach. Previously described techniques to measure coronal slope looked at the medial and lateral tibial plateau as a whole, placing a line joining the highest points of the medial and lateral tibial plateaus [1, 5, 9, 21]. Coronal slope was then either calculated relative to the corresponding condyle or to the tibial axis. The technique used in our study has the advantage of measuring medial and lateral plateau coronal slope separately, allowing separate comparisons for medial and lateral OCD lesions. In addition, the tibial spine and the corner of the plateau proved to be easily identifiable reference points, as indicated by our ICC values, which showed low interobserver variability for all measurements. This technique, especially for measuring slope in the coronal plane, may be used in other applications evaluating proximal tibial morphology.

Limitations include the number of affected knees, particularly on the lateral side, which may mean the analysis of lateral lesions was underpowered. These numbers, however, are similar to previously reported incidences [7] since we had over five times as many medial as lateral femoral condyle OCD lesions. A limitation of using radiographs to analyze posterior tibial slope is that the medial and lateral tibial plateaus may not be overlapping or there may be some rotational malalignment; the accuracy of the measurements can be affected. In this study, we attempted to place the measurement line between the plateaus to average this effect and indeed there was noted to be good interobserver agreement.

Conclusion

An assessment of proximal tibial morphology demonstrated greater medial and posterior tibial slope in knees with medial OCD lesions. The technique for measuring medial and lateral tibial slope was reliable among evaluators.

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