

# Effects of medial meniscal slope and medial posterior tibial slope on the locations of meniscal tears

## A retrospective observational study

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### Abstract

The aim of this study was to analyze the relationship between medial posterior tibial slope (MPTS) and medial meniscus slope (MMS) with the location of meniscal lesions. We hypothesize that menisci with greater MPTS and MMS are more likely to have lesions in posterior horn.

A total of 292 patients underwent arthroscopic surgery between January 2014 to September 2019 due to knee osteoarthritis (OA) and meniscal lesions were reviewed. Based upon the location of meniscal tears, patients were categorized as group B (tears in posterior horn) and group A (other sites). MPTS and MMS were measured from magnetic resonance imaging (MRI) slices. Osteoarthritis grade was evaluated in anteroposterior radiographs by the criteria defined by Kellgren and Lawrence. Demographic data, OA grade, MPTS, and MMS for the 2 groups were compared and analyzed.

The group A had 29 (39%) male and 45 (61%) female subjects with a mean age of  $57.07 \pm 6.79$  years. Group B consists of 74 (34%) male and 144 (66%) female subjects with a mean age of  $58.90 \pm 7.594$  years. ( $P = .067$  and  $P = .458$  for age and sex, respectively). In group A, 31 knees (42%) were determined to be Kellgren–Lawrence grade one, 32 knees (43%) grade two, and 11 knees (15%) grade three. In group B, 86 knees (39%) were categorized in grade one, 85 knees (39%) in grade two, and 47 knees (26%) in grade three ( $P = .085$ ). The mean MPTS was  $5.06 \pm 2.11$  degree for group A and  $6.15 \pm 2.37$  degree for group B ( $P = .001$ ). The mean MMS for group A was lower than group B ( $1.38 \pm 2.12$  degree vs  $3.14 \pm 2.92$  degree;  $P < .000$ ).

This study demonstrated that increased MPTS and MMS may be considered as the risk factors for medial meniscal posterior horn tears.

**Abbreviations:** ACL = anterior cruciate ligament, ATT = anterior tibial translation, ICC = intraclass correlation coefficient, MMS = medial meniscus slope, MPTS = medial posterior tibial slope, MRI = magnetic resonance imaging, MS = meniscus slope, OA = osteoarthritis, PTS = posterior tibial slope.

**Keywords:** medial meniscal posterior horn, meniscal slope, meniscal tear, osteoarthritis, posterior tibial slope

### 1. Introduction

Meniscal lesions are common among osteoarthritis (OA) patients. Meniscal tears occur in approximately 63% of adult patients with knee osteoarthritis (OA).<sup>[1]</sup> Among the different

meniscus lesions, medial tears are most common.<sup>[2]</sup> The meniscus is involved in multiple significant functions such as load transmission, shock absorption, body stabilization, joint lubrication, proprioception, and dispersion of the body weight.

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The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

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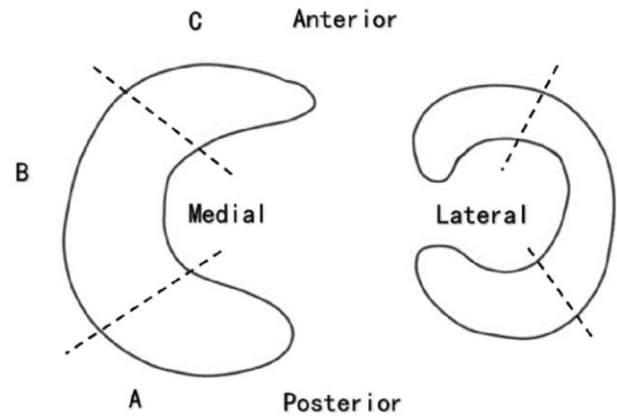
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The geometry of the tibial plateau plays an important role in the injuries of ligament, meniscus, and articular cartilage. Posterior tibial slope (PTS) and meniscal slopes (MS) are considered as the major risk factors affecting knee biomechanism. PTS is defined as the angle between the tangent of the tibial plateau and the tibial anatomical axis.<sup>[3]</sup> Large PTS can cause an increase in the posterior and inferior shear force of the femur, anterior cruciate ligament (ACL) force, and anterior tibial translation and thereby making ACL prone to injuries. Large PTS can cause a series of biomechanical changes in the knee. When the femur and tibia contact PTS, it induces an anterior shear force on the tibia at the sagittal plane. Kevin et al used a 3-dimensional musculoskeletal model of the body and found that with an increase in PTS there is the enhancement of tibial shear force, anterior tibial translation (ATT) and ACL force.<sup>[4]</sup> In a cadaveric study by Agneskirchner et al, an anterior opening wedge HTO was conducted on the tibia and enhancement of ATT with increasing PTS was observed.<sup>[5]</sup> Lee et al<sup>[6]</sup> found that average PTS was higher in patients with ACL graft injury. MS is the angle between the tibial anatomical axis and the tangent of the meniscus. The posterior horn of meniscus is thicker than the anterior horn; as a consequence, a lesser MS might reduce the effect of PTS and an increased MS might improve the effect of PTS as well.

Multiple studies as mentioned above focused upon analyzing the connection between PTS, MS, and ACL. However, any study focused upon the relationship between PTS or MS and the location of meniscal lesions is not available in the literature. If PTS or MS does affect the location of meniscal lesions of patients with knee OA, this may contribute to determining the origin of symptoms and the proper treatment method. This study aims to perform a measurement of PTS and MS, to evaluate the relation between them and the locations of meniscal lesions. We hypothesized that the locations of meniscus lesions may be more posterior in knees with greater PTS and that MS would not be associated with locations of meniscal lesions.

## 2. Materials and methods

All patients underwent arthroscopic surgery for medial meniscal tears at our institution, between January 2014 and September 2019 were included in the study. Indications for surgery were joint line tenderness along with medial meniscal lesions confirmed by magnetic resonance imaging (MRI). Disease symptoms were not relieved by a  $\geq 3$ -month long conservative treatment. The surgical procedure on these patients was consist of clearing of the hyperplasia synovium, the free edge of the tearing meniscus, chondral flaps, suturing the tears in the red and red-white zone. The locations were divided into the anterior horn tear, middle body tear, and posterior horn tear (including posterior root) (Fig. 1). This method was described by Cooper et al.<sup>[7]</sup> The surgeries and evaluation of the locations of lesions were performed by Dr. Jiushan Yang. Patients were categorized as group B and group A according to the locations of tears (tears in posterior horn and sites other than posterior horn respectively). Inclusion criteria were as following, mild to moderate medial OA (Kellgren-Lawrence grade of one-three), tears limited to the medial meniscus. Patients with a history of previous surgery at the index knee, trauma at the same knee, rheumatoid arthritis, discoid meniscus, knee instability, varus or valgus knee (the distance between center of knee to lower limb alignment  $> 5$  mm), severe OA (Kellgren Lawrence level=4) or tears involving



**Figure 1.** Cooper zone classification of the meniscus. Radial zones of medial meniscus are classified as posterior horn (A), middle body (B) and anterior horn (C) from posterior to anterior.

$> 1$  area (anterior horn, middle body, posterior horn) were excluded from the study. A total of 324 patients were included. Thirty-two patients were excluded because of lack of MRI data. Two hundred ninety-two patients were included eventually.

The Ethics Committee of Affiliated Hospital of Shandong University of Traditional Chinese Medicine approved this study and patient consent was waived.

### 2.1. Clinical evaluation.

Demographic data were collected from the medical history of all the patients. MRI scans were obtained at least 3 months before the surgery. MRI scans were performed in a relaxed state with a fully extended knee. The image slices were used to measure PTS in picture archiving and communication system. Two independent certified orthopedic surgeons performed all the measurements. To determine the interobserver and intraobserver reproducibility, the reviewers repeated the measurements after two weeks in 50 randomly selected MRI slices. In the end, PTS and MS were averaged by both sets of data measured by the 2 surgeons.

We applied a method described by Hudek et al to measure the PTS on sagittal T1 sequences. First, the central slice of the sagittal plane was selected. In this slice, the visibility of posterior cruciate ligament and intercondylar eminence was clear. Also, the anterior cortex and posterior tibial cortex were in a concave shape. After this, the proximal anatomical axis was defined. Two circles were drawn in the proximal tibia. The proximal circle was tangent to all 3 proximal, anterior, and posterior cortices. The center of the distal circle was located at the perimeter of the proximal circle. A line across the centers of both circles was considered as the proximal anatomical axis (Fig. 2). The medial PTS was measured in a slice with the mediolateral center of the medial plateau. Line A tangent to the anterior and posterior edges of the tibial plateau and a line B vertical to the proximal anatomical axis were drawn. The angle between line A and line B was considered as medial PTS. A tangent line to the anterior horn and posterior horn of meniscus was also drawn. The angle between this line and line B was the medial MS (Fig. 3).

Weight-bearing anteroposterior radiographs were used to evaluate the degree of OA. Radiographs were graded from zero to four based upon the criteria defined by Kellgren and Lawrence: 0 suggests absence of degenerative changes, 1 indicates doubtful

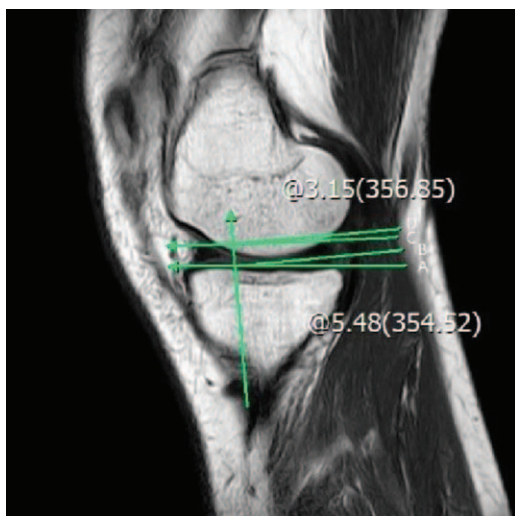


**Figure 2.** The image demonstrates the proximal anatomical axis of tibia determined by two circles.

osteophytes without joint space narrowing; 2 contains certain osteophytes with slight joint space narrowing; 3 has clearly narrowed joint space with moderate osteophytes and sclerosis; and 4 has severely narrowed joint space with distinct cysts, osteophytes, and sclerosis.<sup>[8]</sup>

**2.2. Statistical analysis**

Statistical analysis was carried out using SPSS Statistics (version 23.0; IBM, Chicago, IL). A student *t* test was performed to evaluate the difference of medial posterior tibial slope (MPTS) and medial meniscus slope (MMS) between the 2 groups. A  $\chi^2$  test was used to compare sex. Kellgren and Lawrence levels were analyzed by Mann–Whitney *U* test. *P* value <.05 was considered



**Figure 3.** The image demonstrates the MMS and MPTS. A tangent line (A) is drawn to the anterior and posterior edges of the tibial plateau. Another tangent line (C) is drawn to the anterior and posterior horn of medial meniscus. Two lines (B and D) vertical to the proximal anatomical axis are drawn. MMS = medial meniscus slope, MPTS = medial posterior tibial slope.

**Table 1**

**Comparison of demographics, KL grade, MPTS and MMS by groups.**

	Group A (n=74)	Group B (n=218)	<i>P</i>
Age, y	57.07 ± 6.79	58.90 ± 7.59	.067
Male/female	29/45	75/143	.458
Kellgren-Lawrence grade (1/2/3)	31/32/11	86/85/47	.085
Medial PTS, degree	5.06 ± 2.11	6.15 ± 2.37	.001
Medial MS, degree	1.38 ± 2.12	3.14 ± 2.92	.000

MS = meniscus slope, PTS = posterior tibial slope.

as statistically significant. Interobserver intraclass correlation coefficient (ICC) and intraobserver ICC were calculated using SPSS (SPSS Inc, Chicago, IL). ICC values >0.9 were considered excellent while values between 0.8 and 0.9 were counted as good.

**3. Results**

Group A was consisting of 29 (39%) male and 45 (61%) female participants. The mean age of these subjects was 57.07 ± 6.79 years. A total of 74 (34%) males and 144 (66%) females with an average age of 58.90 ± 7.594 year constituted group B. No significant difference in age (*P* = .067) or sex (*P* = .458) between both groups was observed (Table 1).

In the group A, 31 knees (42%) were found to be Kellgren–Lawrence grade one, 32 knees (43%) in grade two, and 11 knees (15%) in grade three. In group B, these numbers were 86 (39%), 85 (39%), and 47 (26%), respectively. No statistically significant difference in Kellgren–Lawrence grade was observed (*P* = .085) (Table 1).

The mean medial posterior slope was 5.12 ± 2.09 degree for group A and 6.10 ± 2.25 degree for group B (*P* = .001). The mean MS was 1.38 ± 2.12 degree and 3.14 ± 2.92 degree for group A and group B, respectively (*P* < .000) (Table 1).

The interobserver ICCs for PTS and MS were 0.838 and 0.812, indicating a high degree of agreement between observers. The intraobserver ICCs for the 2 observers ranged from 0.820 to 0.902, suggesting reliable findings.

**4. Discussion**

The main finding of this study is that knees with greater MPTS or MMS are prone to injury in posterior horn. Degenerative meniscal lesions are common in patients suffering from OA.<sup>[9]</sup> These are related to many factors like age, previous knee injury, over-weight, among others.<sup>[10]</sup> The relationship between meniscal tears and OA is very complex. Meniscus tear could be a result or the cause of OA.

There has been no consensus on the method of PTS measurement. It can be obtained from MRI, lateral knee x-ray, computed tomography, and 3-dimensional reconstruction. Anatomical reference for the tibial axis is of great importance for all the measurements. Values of PTS within 1 tibia change with the selection of different tibial axes, as those axes are not parallel to others. In this study, we used a method described by Hudek et al,<sup>[11]</sup> which has been reported to be the most repeatable method to measure PTS on MRI as it is independent of the tibial length.<sup>[12,13]</sup>

The present study suggests that regenerative meniscal lesions in the posterior horn had a higher medial PTS and medial MS with respect to those in other parts of the medial meniscus. Very few

studies have analyzed the relationship between PTS, MS, and meniscal tears in patients suffering from OA. Alici et al studied the correlation between PTS and location of meniscal tears, medial or lateral, and found that lateral posterior tibial slope of knees with lateral meniscal tears was larger than the medial meniscal tears. Increased PTS of the lateral tibial plateau may be a factor causing injury to the lateral meniscus.<sup>[14]</sup> In a retrospective study performed by Song et al, mean medial MS was found to be significantly larger in patients with noncontact ACL injuries and ramp lesion, which is defined as the peripheral lesions in the meniscocapsular zone of the posterior horn of the medial meniscus, than in patients with isolated ACL injuries, especially for those with longer time from injury to surgery ( $\geq 6$  months). However, medial PTS is not reported to be associated with the appearance of ramp lesions.<sup>[15]</sup> Relative biomechanics study is rare. Craig M. Rodner analyzed 9 fresh-frozen cadaveric knees. The knees were loaded to 500N along the tibial anatomic axis at 0 degree and 30 degree flexion before and after a medial opening wedge high tibial osteotomy. PTS increased from 7 degree to 13.6 degree, location of peak pressure moved by 5% posteriorly in ACL-intact knees and 24% in ACL-deficient knees.<sup>[16]</sup> This may help to understand that lesions in the posterior horn had a higher medial PTS.

The posterior meniscal horn is like a wedge between the femoral condyle and the tibial plateau. As the posterior meniscal horn is thicker than the anterior horn, the MS is nearly vertical to the tibial anatomical axis and might counteract the posterior inclination of the PTS.<sup>[17]</sup> The MS increases and the anterior-posterior transmission of the femoral condyle might become greater. Therefore, the posterior horn of medial meniscus is more prone to injury in knees with larger MMS.

The present study also revealed that posterior horn lesions (74.66%) were most common among all the lesions. Posterior horn tears, especially root tears, have been reported to be specific in aged knee OA patients.<sup>[18]</sup> The posterior horn has little mobility due to its strong attachment to the tibial plateau, and as a result, it is prone to injury.<sup>[19,20]</sup>

The present study had several limitations. First, the patients enrolled in this study underwent an arthroscopic surgery, which might cause a biased selection, so it may not be suitable to translate the present findings into meniscal tears with nonoperative management or severe OA patients. Second, due to most of the regenerative meniscal tears occur in medial meniscal horn, the sample size of the middle body and anterior horn is relatively small.

In conclusion, location of regenerative meniscal tears is associated with MPTS and MMS, increased PTS and MMS may be risk factors of medial meniscal posterior horn tears. It is more likely that patients with higher PTS complain medial posterior pain, as the location of pain usually echoes the location of meniscal lesion. Orthopedic surgeons should consider reinforce posterior horn when PTS or MS is great.

## Author contributions

**Conceptualization:** Xiaotan Wang.

**Data curation:** Xiaotan Wang, Lizhong Jing.

**Formal analysis:** Xiaotan Wang, Lizhong Jing, Zhuang Li.

**Investigation:** Lizhong Jing, Xiaole Wang, Zhiwei Zhang.

**Methodology:** Xiaotan Wang, Xiaole Wang, Zhuang Li, Jiushan Yang.

**Project administration:** Jiushan Yang.

**Resources:** Xiaole Wang, Zhen Li.

**Software:** Xiaotan Wang, Zhen Li, Zhiwei Zhang.

**Supervision:** Jiushan Yang.

**Writing – original draft:** Xiaotan Wang.

**Writing – review & editing:** Xiaole Wang.

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