Varus and Steep Medial Posterior Tibial Slope Are Risk Factors for Degenerative Medial Meniscus Lesions

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Research article

Keywords: Degenerative medial meniscus lesions, Risk factors, Lower limb alignment, Hip-Knee-Ankle angle, Medial posterior tibial slope

Posted Date: August 30th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-829563/v1

Abstract

Purpose: Degenerative medial meniscus lesions(DMMLs) is different from other meniscus injuries, which have a high incidence and easy to miss diagnosis in the middle-aged and elderly. The present study was designed to identify the risk factors for DMMLs among an Asian sample.

Methods: The experimental group included 121 patients（ones partly confirmed during arthroscopic surgery) with DMMLs and the control group included 51 patients with no pathological changes identified by using 3.0-T magnetic resonance imaging (MRI) from January 2017 to January 2021 were analyzed retrospectively. By full-length anteroposterior radiographs of lower limbs in weight-bearing position of the two groups, the Hip-Knee-Ankle (HKA) angle in the coronal plane and the Medial Posterior Tibial Slope(MPTS) in the sagittal plane were measured by the MRI T1 sequence of the knee. The potential risk factors of DMMLs were analyzed by multivariate logistic regression. The independent variables included gender, age, body mass index (BMI), occupational kneeling, Kellgren-Lawrence (K-L) grade, HKA, and MPTS.

Results: T-test analysis between the Experimental Group and the Control Group showed statistically significant differences in age (t=10.718, p<0.001), BMI (t=7.300, p<0.001), HKA (t=8.677, p<0.001), and MPTS (t=5.025, p<0.001). Chi-square test analysis between the two groups showed no statistically significant differences in gender (t=0.183, p=0.669) and occupational kneeling (t=0.339, p=0.560). Non-parametric analysis showed statistically significant differences in K-L (z=5.857, p<0.001) between the two groups. Logistic regression analysis showed that age, BMI, HKA, and MPTS were risk factors for DMMLs among the above-mentioned variables with statistically significant differences.

Conclusions: varus, steep MPTS, advancing age and obesity were risk factors for DMMLs.

Introduction

As an important structure to maintain the normal function of the knee, meniscus guarantees the load distribution, stability, shock absorption, proprioception, and lubrication for the knee[1, 2]. Degenerative meniscus lesions are frequent in the general population, and their prevalence increases with age, ranging from 16% in knees of 50–59 year-old women to over 50% in men aged 70–90 years[3]. The most frequent location of DMMLs is the body and posterior horn of the medial meniscus[4]. They refer to the multi-factor chronic degenerative process of meniscus affected by excessive stress and repeated wear in patients older than 35 with no history of major acute trauma[4, 5].

Studies have shown that degenerative meniscus lesions increased the risk of irreversible degenerative injury to articular cartilage,and which progressed to the development of osteoarthritis. Mesiha et al.[6]have shown that the incidence of degenerative meniscus lesions with Outerbridge grade ≥ 2 cartilage injury was more than 85%. Similarly, Christoforakis et al.[7]found that patients with complex or horizontal meniscus tears were more likely to have Outribridge III and IV grade cartilage pathological changes in a prospective study. Despite knowledge that meniscal lesions can predispose to osteoarthritis, we know little about what predisposes to DMMLs. Efforts to identify modifiable risk factors for disease should focus on risk factors early in disease genesis. Several risk factors for DMMLs have been proposed, including age, BMI, genes and occupational kneeling[4, 8, 9]. However, there are few studies on anatomic and DMMLs.

The purpose of this retrospective observational study was to contribute to the epidemiologic understanding of risk factors (demographic, anatomic, and environmental factors) for DMMLs so as to provide theoretical basis for the study on the injury mechanism and the corresponding selection of treatment strategies.

Materials And Methods

A retrospective design was used to compare demographic, anatomic, and environmental factors among healthy volunteers(ones partly with skin soft tissue trauma and popliteal cyst, but the meniscus with no pathological was confirmed by MRI) and patients with DMMLs. A chart review was conducted using our electronic medical record system to identify 152 volunteers and 421 patients with pain, swelling, locking and clicking of knee at our institution between January 2017 and January 2021.

Case inclusion criteria: Experimental Group: (1) No any history of significant acute trauma in a patient older than 35 years[4]. (2) A degenerative meniscus lesion was usually characterised by linear intrameniscus MRI signal (including a component with horizontal pattern) communicating with the inferior meniscus surface on at least two image slices, and lesion was the body and (or) posterior horn of the medial meniscus(Fig. 1abc). (3) Arthroscopic knee surgery confirmed DMMLs(Fig. 1d). (4) No or mild degenerative osteoarthritis (K-L $\leq$ 2 grade). Congenital lesions, traumatic meniscus tears, severe osteoarthritis (K-L > 3 grade), MMPRT, lateral meniscus tear and degenerative lesions occurring in young patients, especially in athletes, were excluded.

Thus, the final sample sizes were 121 patients and 51 volunteers in groups, respectively, which demonstrated adequate power to detect a significant difference between each pair of groups. This study was approved by the Ethics Committee of Our hospital with informed consent of all subjects.

Research and measurement methods

Gender, age, BMI, and occupational kneeling of all patients in the two groups were recorded. By full-length anteroposterior radiographs of lower limbs in weight-bearing position, the HKA was measured in the coronal plane, and the MPTS was measured in the sagittal plane by the MRI T1 sequence of the knee. The measurement method was as follows, the full-length anteroposterior radiographs of lower limbs in weight-bearing position: The patient stood upright before the camera frame, with his/her back firmly attached to the camera frame, hands hanging down naturally, knees as straight as possible, feet about the same width as shoulders, and patella facing straight ahead (Namely toes parallel forward). (1) Lower limb alignment: If the line between the center of the femoral head and the center of the ankle passes medially through the center of the knee, then it is called the genu varum, and laterally the genu valgum. (2) HKA: If the included angle by the connection between the center of the femoral head, the center of the knee and the center of the ankle was less than 180°, then it is called varus, and greater than 180° the valgus(Fig. 2a). (3) MPTS: Measurements were made in three steps on MRI. The first step was to make a circle through the posterior cruciate ligament tibial attachment point, the intercondylar eminence, the concave sagittal plane of the anterior and posterior tibial cortex and the highest point of the tibia. The second step was to center a circle on the first circumference and passing through the anterior and posterior bone cortex. In the third step, the straight line connecting the first center and the second center was the longitudinal axis of the tibia. On the sagittal plane of the center of the medial tibial plateau, the included angle between the tangent line formed by connecting the anterior and posterior margin of the tibial plateau and the vertical line of the longitudinal axis of the tibia was formed, namely, MPTS[10](Fig. 2b,c). Imaging diagnosis and angular parameters related to lower limb alignment of all patients were measured by an experienced musculoskeletal radiologist in our hospital.

Statistical analysis

The data were analyzed using the SPSS 24.0 statistical software package. The continuous data were taken as mean ± standard deviation (x ± SD). The group design data t-test was utilized to compare the measurement data between the Experimental Group and the Control Group. Chi-square test was used to compare the classification data between groups. Non-parametric tests were used for non-normal distributions. For the independent variables with statistical significance between the two groups, the risk factors of DMMLs were explored by Logistic regression analysis, and the specific influence of each independent risk factor on DMMLs was analyzed. When the two-tailed α value was less than 0.05, the difference was considered statistically significant.

Results

The age of the Experimental Group was 52.87 ± 7.02, and that of the Control Group was 42.43 ± 5.25, showing statistically significant difference. There were 55 males and 66 females in the Experimental Group and 25 males and 26 females in the Control Group, showing no statistically significant difference in sex distribution. The mean BMI of the Experimental Group (24.93 ± 2.48) was significantly higher than that of the Control Group (22.04 ± 2.07), showing statistically significant difference. There was no statistical difference in occupational kneeling between the two groups. The mean HKA and MPTS of the Experimental Group were (176.43 ± 1.90) ° and (6.54 ± 2.18), which were (179.04 ± 1.55) ° and (4.98 ± 1.70) in the Control Group, respectively, showing statistically significant difference. Radiological grade of knee osteoarthritis in the Experimental Group was higher than that in the Control Group, showing statistically significant difference (Table 1).

Table 1
Patients demographics (mean ± standard deviation)

	Control Group(n = 51)	**Experimental Group(n = 121)**	***t/z/x²***	***p***
Mean age (years)	42.43 ± 5.25	52.87 ± 7.02	10.718	< 0.001*
BMI(kg/m^2)	22.04 ± 2.07	24.93 ± 2.48	7.300	< 0.001*
Gender			0.183	0.669
Male	25(49.0)	55(45.5)		
Female	26(51.0)	66(54.5)		
occupational kneeling			0.339	0.560
No	47(92.2)	108(89.3)		
Yes	4(7.8)	13(10.7)		
HKA(°)§	179.04 ± 1.55	176.43 ± 1.90	8.677	< 0.001*
MPTS(°)	4.98 ± 1.70	6.54 ± 2.18	5.025	< 0.001*
K-L	0.00(0.00,1.00)	1.00(1.00,2.00)	5.857	< 0.001*
§HKA was less than 180°, then it is called varus, and greater than 180° the valgus				
*Significant results				

Single factor analysis showed that there were statistically significant differences in age, BMI, HKA, MPTS and K-L grades between the two groups. On the basis of single factor analysis, multivariate logistic regression analysis was performed with DMMLs as dependent variable to evaluate the factors related to DMMLs, such as age, BMI, HKA, MPTS and K-L grade. The results showed that age, BMI, and K-L grade were the risk factors for DMMLs (Table 2).

Table 2
Logistic regression analysis of study on related risk factors of degenerative medial meniscus lesions

	b	S_b	Waldχ^2	*P*	*OR*	95% Confidence interval
Age	0.128	0.044	8.677	0.003	1.137	1.044–1.238
BMI	0.477	0.138	11.867	0.001	1.611	1.228–2.114
HKA	− .0739	0.182	16.472	0.000	0.478	0.334–0.682
MPTS	0.378	0.151	6.262	0.012	1.459	1.085–1.962
constant	112.824	32.053	12.390	0.000	9.971E + 48	

OR, Odds ratio

Discussion

In this study, we confirmed that higher BMI is an important risk factor for DMMLs. Advancing age and radiographic factors (varus, steep MPTS) also contributed as risk factors for DMMLs. DMMLs is the result of a combination of systemic and local biomechanical factors. Thus, the predominant risk factors for DMMLs (varus, older age, and higher BMI) are consistent with those for development of osteoarthritis. Most importantly, the identification of relevant controllable risk factors other than age can be used to modify risk factors through conservative or surgical treatment, thereby reducing the risk of DMMLs and delaying the development of bone and joint.

Degenerative meniscus lesions is a slow degeneration process of meniscus biomechanics disturbed by repeated wear and heavy load in the knee. Most of the lesions are asymptomatic horizontal tears[4]. The most common lesions site is the posterior horn or body of the medial meniscus with the highest percentage of the overall load, especially when the knee is flexed and the backward shear force is applied[4, 5]. Biomechanical studies showed that the medial meniscus plays an important role in the transfer of shear force and longitudinal loads[11]. The percentage of total load carried by the posterior horn of the medial meniscus is the highest, especially in knee flexion and backward shear force[12]. In clinical practice, the posterior horn of medial meniscus is also the most frequently injured site, which is consistent with our clinical data[13]. Among the biomechanical risk factors that we evaluated, lower limb malalignment and overweight may be important influencing factors, which were important risk factors for the progression of osteoarthritis, which also associated with degenerative meniscus lesions[14]. The results of this study showed that the average HKA of the Experimental Group was significantly lower than that of the Control Group, and the average BMI was significantly higher than that of the Control Group. In the varus patients with lower limb malalignment, the pressure load of the medial compartment was increased, and the risk of DMMLs was increased about 1.3-fold with each degree increase of varus. This finding has been confirmed by arthroscopy that there is a higher incidence of medial meniscus lesions in varus patients[15].

This study further confirmed the development process of meniscus injury osteoarthritis through which lower limb malalignment and obesity can lead to chronic overload. This overload increased the medial compartment load and pressure, and the increase in the medial meniscus load can easily lead to the tear of the medial meniscus (especially the tear of the posterior horn)[16]. Once the meniscus lost its key function in the knee, the increased biomechanical load on the articular cartilage may lead to cartilage loss, reduced joint space, and increased joint-line convergence angle, which afterwards exacerbated the lower limb malalignment. This was a process of mutual causality and vicious circle, but it was difficult to make clear the causal relationship among the lower limb malalignment, meniscus injury, and cartilage wear. During this degenerative change process of the knee, abnormality of the lower limb alignment may be basic role, more likely to cause DMMLs and was an early sign of knee osteoarthritis. Understanding the influence of these modifiable risk factors on meniscus injury and osteoarthritis can produce better prevention and treatment.

It is well known that the geometry of the tibial plateau has a direct influence on the biomechanics of the tibiofemoral joint[12]. In load-bearing buckling motion, the longitudinal load and horizontal shear force component of the tibial platform were related to and positively correlated with the posterior tibial slope[12, 17]. PTS was a geometric factor with influences on the biomechanics of the knee. Relevant studies have proved that the increase of PTS would lead to the relative physiological forward shift of the tibia and the corresponding increase in the contact stress between the posterior horn of the medial meniscus and the posterior medial condyle of the femur, especially the degeneration and damage of the knee during rotation and flexion[18]. After the anterior cruciate ligament was deficient or ruptured, the wedge shape form of the posterior horn of the meniscus may limit the tibia displaced forward and increase the stress on the posterior horn of the medial meniscus[19, 20]. For patients with posterior root tear of the medial meniscus, the posterior edge of the medial meniscus moved 8.56 ± 2.00mm backward on average when the knee flexed from 10° to 90°, which was significantly greater than the distance of posterior movement of the medial meniscus during flexion of the normal knee[21]. If there were no injury to the posterior root of the medial meniscus, the posterior edge of the medial meniscus, which does not excessively move backwards, would generate contact stress with the posterior condyle of the femur when the knee flexion angle increases. The overload stress may be the potential factor for the high incidence of injury to the posterior horn of the medial meniscus. In conclusion, the high incidence of degenerative medial meniscus injury (especially the posterior horn) may be associated with the highest percentage of overall load carried by this site, especially in patients with increased longitudinal medial stress caused by varus and increased stress at posterior Angle of medial meniscus caused by MPTS. This was basically consistent with the results of this study, namely, the increase in MPTS was closely related to the increase in the incidence of degenerative medial meniscus injury. If we take these findings into account, we would expect an increase in MPTS to affect the shear force exerted on the posterior horn of the medial meniscus. Therefore, it was reasonable to assume that if the MPTS was increased, the risk of tearing the posterior horn of the medial meniscus would also be increased due to the relatively high shear force exerted on the meniscus. MPTS can be used as a potential radiological parameter to evaluate the possibility of DMMLs (especially the posterior horn) in patients with knee pain[22]. The most important finding of this study was that the Experimental Group had steeper MPTS, and greater angle of the varus compared with the Control Group.

Rytter et al.[8], in a retrospective case control study, found that patients with occupational kneeling had a higher incidence of degenerative meniscus lesions, and degenerative lesions were most common in the middle and posterior 1/3 of the medial meniscus, and the tear layer mostly involved the tibial side. According to the previous theoretical study, patients who squat frequently bear steep longitudinal loads and shear forces in the middle and posterior parts of the medial meniscus, and may be more prone to degeneration and damage. However, the results of this study showed that there was no statistical difference in the occupational kneeling between the two groups, which may have selection bias or limited number of cases.

Degenerative meniscus lesions, which can be considered as a process of aging or degeneration, was the most common form of meniscus injury in the middle and the old, and its incidence increased with age: the morbidity of women aged 50–59 was 16%, and that of men aged 70–79 was 50%[3]. MRI usually showed linear high signal shadow in the meniscus. This high signal was the result of persistent mucinous degeneration, usually affected the articular surface[23]. Therefore, surgery should not be the first choice for the treatment of degenerative meniscus lesions. The injury should be regarded as the degeneration that occurs with the growth of age. More attention should be paid to modifiable risk factors to minimize degeneration of meniscus and osteoarthritis.

The study may have the following limitations. First, this was a retrospective case-control study, and there may be some selection bias. The Control Group was not entirely volunteers without knee pain and discomfort, and included patients with knee pain or mass (such as skin soft tissue trauma, popliteal cyst). Secondly, patients included in this study were basically from Central China, and patients from other regions may differ.

Conclusions

This study demonstrates that advancing age, higher BMI, increased K-L, varus mechanical axis angle, and steep MPTS are all associated with DMMLs. This suggests that intrinsic risk factors (similar to those that predispose to osteoarthritis) predispose to DMMLs. Whether it is the conservative and surgical treatment of DMMLs, the risk factors that can be changed should be modified early to further reduce the occurrence and development of osteoarthritis.

Abbreviations

DMMLs: Degenerative medial meniscus lesions; MRI: Magnetic resonance imaging; HKA: Hip-Knee-Ankle; MPTS: Medial posterior tibial slope; BMI: Body mass index; K-L: Kellgren-Lawrence

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board (IRB) of Affiliated Renhe Hospital of China Three Gorges University. The volunteer involved in the study consent to participate in the study. And the written consent has been obtained from the volunteer.

Consent for publication

All individual person's data consent to publish.

Availability of data and materials

Please contact author for data requests

Competing interests

The authors declare that they have no competing interests.

Funding

None

Authors' contributions

Tao Xu and You Zhou conceived and designed the experiments. Tao Xu wrote a draft of the manuscript. Liuhai Xu contributed to the data and produced the figures. You Zhou performed the surgical procedure. You Zhou and Xinzhi Li analyzed and interpreted the results of the experiments and revised the manuscript. All authors read and approved the final manuscript.

Acknowledgements

None

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Figures

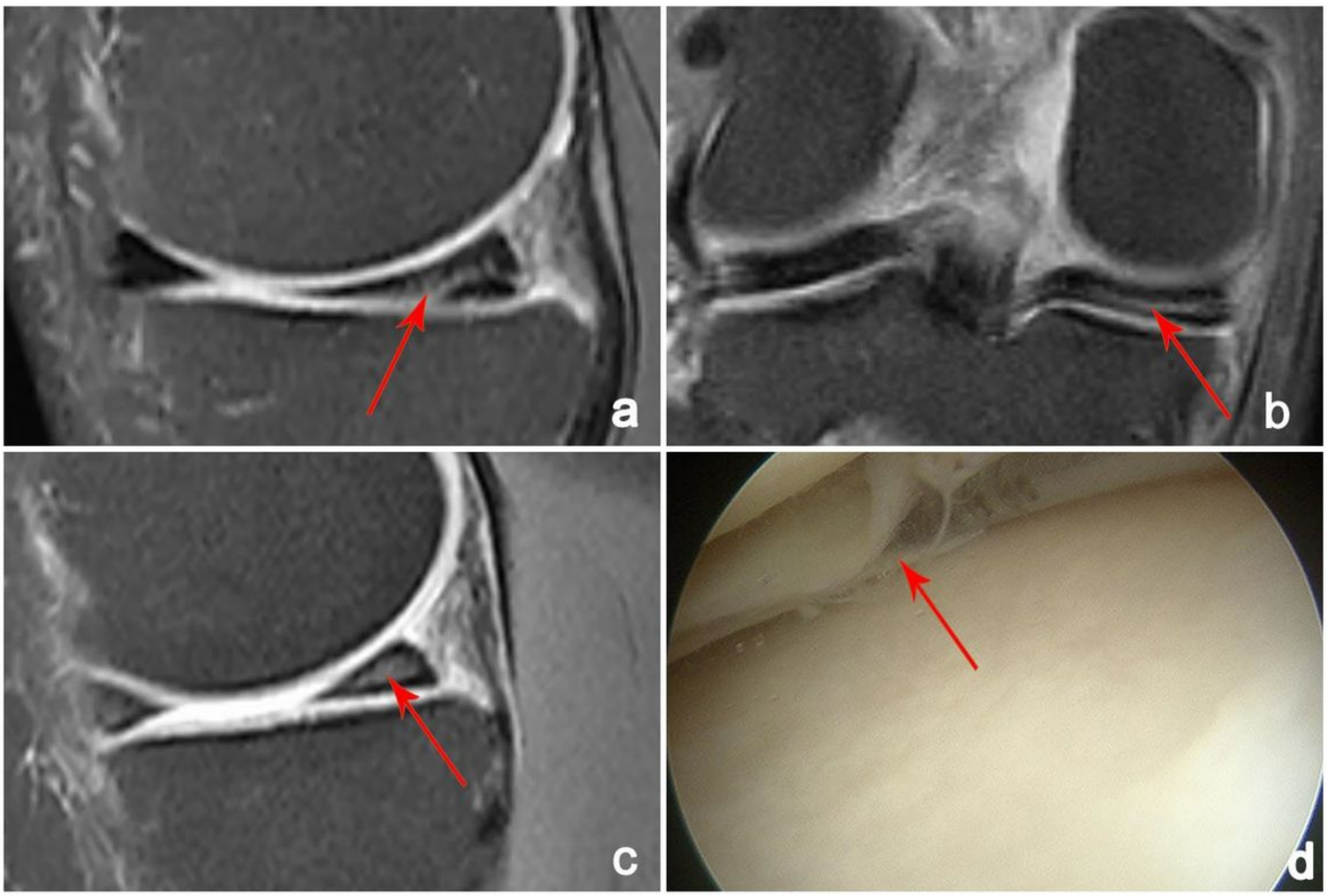

Figure 1

Imaging and arthroscopy of the degenerative meniscus lesions a, b and c: Degenerative lesions of the posterior horn of medial meniscus; d: The hierarchical tear of the posterior horn of the medial meniscus under arthroscope.

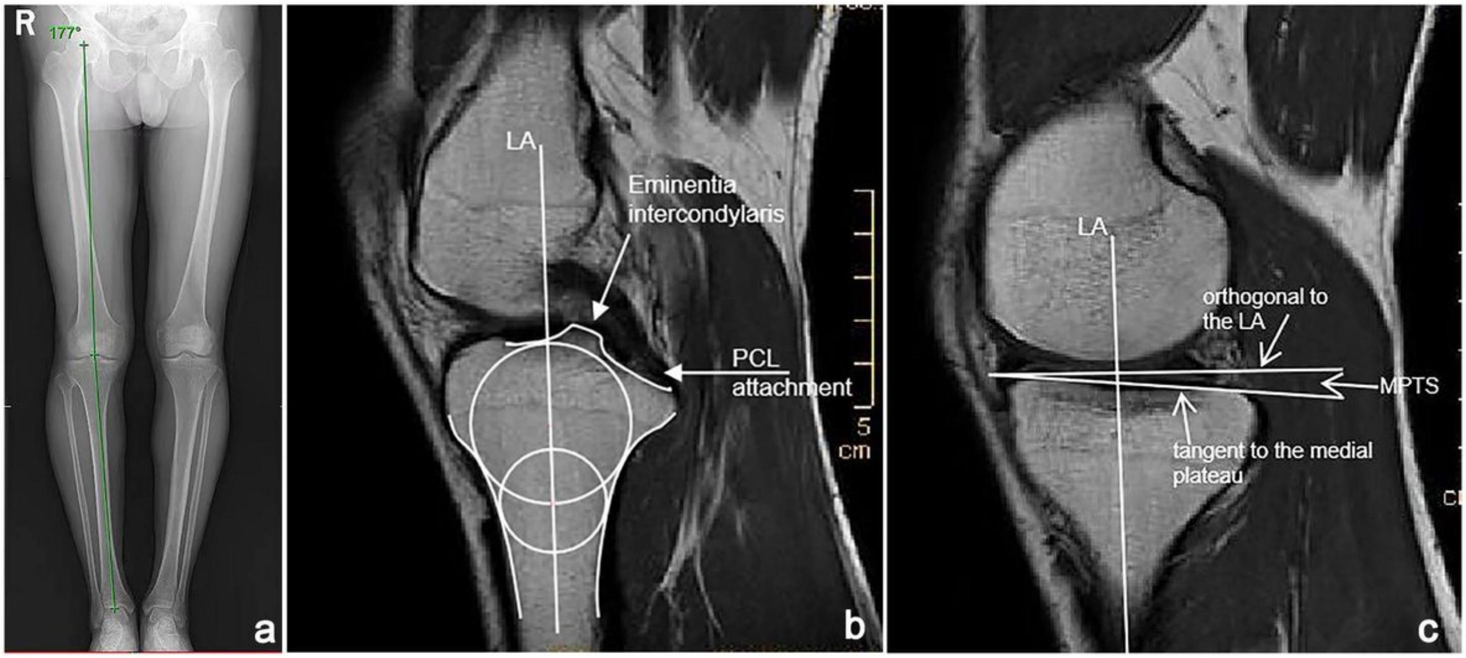

Figure 2

Measuring method of HKA and MPTS a: HKA; b: The line connecting the first and second center of the circles was the longitudinal axis of the tibia in the sagittal plane of the knee MRI T1 sequence; c: The included angle formed by the connection between the vertical line of the longitudinal axis of the tibia and the highest point of the anterior and posterior edge of the widest sagittal plane of the medial tibial plateau is the MPTS.