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Ratio of the tibial tuberosity–trochlear groove distance to the tibial maximal mediolateral axis: A more reliable and standardized way to measure the tibial tuberosity–trochlear groove distance

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ABSTRACT

Background: Tibial tuberosity–trochlear groove distance(TT-TG) is a measurement to assist in the diagnosis and treatment of patellar instability, however it still has some limitations. Our study was to modify the accepted measurement method and seek a more reliable and standardized method.

Methods: The data of 65 healthy controls and 49 patients with bilateral patellar instability from 2010 to 2016 were collected and analyzed by CT. The TT-TG, tibial maximal mediolateral axis (MML), and their ratio [i.e., the modified-TT-TG (M-TT-TG)] were compared between the two groups.

Results: The MML (71.9 ± 12.0 vs. 71.3 ± 10.9) was not significantly different between the two groups ($P > 0.05$). However, the TT-TG(18.1 ± 6.0 vs. 13.1 ± 2.9) and M-TT-TG (0.25 ± 0.08 vs. 0.19 ± 0.04) were significantly different between the two groups ($P < 0.05$). A TT-TG of >15 mm was found in 24.5% of healthy controls and 71.5% of patients. The healthy controls with a TT-TG of >15 mm were compared with the patients; although no significant difference was found in the TT-TG (16.8 ± 1.5 vs. 18.1 ± 6.0), the healthy controls had a significantly larger MML (76.9 ± 12.7 vs. 71.9 ± 10.9) and significantly smaller M-TT-TG (0.22 ± 0.04 vs. 0.25 ± 0.08). A total of 53.1% of patients but only 6.9% of healthy controls had an M-TT-TG of >0.25.

Conclusion: The M-TT-TG is a more reliable and standardized way to measure the effect of the TT-TG with the goal of reducing the false-positive rate associated with the standard measurement technique. The normal M-TT-TG ranges from 0.11 to 0.25, with an M-TT-TG of >0.25 being associated with patellofemoral malalignment.

Level of evidence: III.

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1. Introduction

An increased tibial tuberosity–trochlear groove (TT–TG) distance has been defined as an isolated predisposing factor for patellofemoral instability, and one of the gold standard diagnostic measurements [1–5] which may affect 56% of patellar dislocation patients [3]. A normal TT–TG distance is commonly accepted as 10–15 mm [6], and an increased TT–TG distance is an indication for medial tibial tuberosity transfer to correct patellofemoral malalignment [7].

Whether an increased TT–TG distance should be an indication for surgical intervention and if so, what threshold should be used remain topics of debate [8,9]. Dejour et al. [3] recommended that a distance of 20 mm be considered pathologic and thus an indication for surgery in symptomatic patients, whereas Koëter et al. [10] performed medialization of the tibial tubercle when a threshold of 15 mm was exceeded. The lack of consensus may be related to differences in the joint sizes of patients with patellofemoral instability, and many of these patients are active young adolescents [1,11], the joint sizes of whom might be significantly different. Therefore, the same TT–TG distance may have different clinical significance for various joint sizes. Some studies have shown that a TT–TG distance of <20 mm or even <15 mm may predispose to patellofemoral misalignment [12–14]. Therefore, a cut-off of 20 or 15 mm for all patients is obviously inappropriate; instead, personal morphological factors should be taken into consideration when measuring the TT–TG distance.

Moreover, the TT–TG distance is not only a diagnostic index but also a reference for treatment. Medial displacement of the tibial tuberosity may aggravate the average contact pressure of the medial tibiofemoral compartment and cause imbalance in tibiofemoral joint loading [15], which may exacerbate degenerative arthritis in the long term. The current consensus is that the postoperative position of the tubercle should be 10–12 mm lateral to the trochlear groove [10]. Some scientists have stated that medial transfer of the tibial tuberosity and the TT–TG distance should be interpreted depending on the knee size [3,10,16]. However, no specific or realistic quantitative indicators based on individual factors are yet available.

In the present study, we modified the measurement method of the TT–TG distance to establish a new measurement index, namely the modified TT–TG distance (M-TT–TG). This was accomplished by performing measurements in both healthy subjects and patients with patellar instability of different ages and sexes, thus providing relevant evidence for the appropriate diagnosis and treatment of patellar instability.

2. Materials and methods

This study was approved by the ethics committee of the Third Hospital of HeBei Medical University (Z-2016-157-1). In total, 65 healthy volunteers without joint symptoms such as pain, swelling, or dislocation; joint hypermobility syndrome; joint hyperextension, or a history of knee surgery or trauma were included in the study. After all participants had provided written informed consent, bilaterally axial computed tomography (CT) scans of the knees were taken.

Additionally, the data of 49 patients with bilateral patellar instability at the Third Hospital of Hebei Medical University from 2010 to 2016 were collected and retrospectively analyzed. Patient selection was based on the following inclusion criteria. (1) The patients had a >1-year history of recurrent episodes of pain in the knees often accompanied by swelling and giving way. (2) The patients had physical findings such as a lateral position of the patella or passive subluxation of the patella (lateral translation greater than three-fourths the patellar width when a direct lateral force was placed on the patella) or a positive apprehension sign in response to a lateral thrust to the patella. (3) Radiologic evidence was present to confirm the dislocation or subluxation, including X-ray, CT, or magnetic resonance imaging findings. (4) No history of knee surgery or tumors was present. (5) No periarticular scar tissues that may impact the patellar location were present.

To take the individual patients' knee sizes other than the TT–TG distance (Figure 1(a)) into account, the tibial maximal mediolateral axis (MML) was measured (Figure 1(b)). We chose the MML rather than other parameters because many femoral anatomic variations exist, including trochlear dysplasia, femoral anteversion, and posterior femur [3,17,18], while tibial plateau does not have too many anatomic variations [19,20]. We subsequently calculated the TT–TG distance/MML ratio [modified TT–TG (M-TT–TG)] to further optimize the use of the TT–TG distance.

While in the supine position, all subjects underwent examination of their bilateral knees at 0° of flexion using the same CT scanner and imaging program. All measurements were performed twice in a blinded manner by two persons separately (the first and second authors), and the averages were used for further analysis.

The TT–TG distance was measured by superimposing the axial section depicting the deepest part of the trochlear groove upon the center of the tibial tuberosity, ensuring that the measurement was parallel to the posterior condylar axis of the femur (Figure 1(a)), as described by Dejour et al. [3].

The MML was measured in the tibia platform slice in which the posterior condylar notch was clearly recognized. It was defined as the distance between two lines perpendicular to the posterior tibial condyle line, which was indicated by the line connecting the centers of medial and lateral circles (Figure 2(b)).

2.1. Statistical analysis

The data were analyzed using SPSS 22.0 software (IBM Corp., Armonk, NY, USA). Statistical significance was defined a *P*-value of <0.05. All measurements are expressed as mean ± standard deviation. The data were checked for a normal distribution using

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