Mid Inter-Epicondyle Trochlea Intersection (MIELTI): Proposal of a new index for identifying the deepest part of the trochlea

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Abstract

Background:
The tibial tuberosity trochlea groove distance (TT-TG) is an important radiological measurement in patellofemoral instability (PFI). A value ≥20mm is considered an indication for tubercle medialisation. Trochlear dysplasia commonly accompanies PFI, and can make the deepest part of trochlea difficult to identify, which in turn makes the TT-TG difficult or impossible to assess. To address this problem, we propose a new method of identifying the deepest part of trochlea based on the femoral epicondyles. It is named the tibial tuberosity mid inter-epicondyle trochlea intersection distance (TT-MIELTI).

Methods:
The TT-TG and TT-MIELTI of 30 consecutive MRIs of non-dysplastic knees were compared, excluding 96 knees with dysplasia, sulcus angles ≥ 135°, a tibial tuberosity anterior cortex which was not fully demonstrated, artefact, fracture, or Osgood Schlatter's disease. To assess inter-observer reliability three blinded researchers measured the TT-TG and the TT-MIELTI of all 30 knees. To assess intra-observer repeatability one researcher repeated the measurements after 6 weeks.

Results:
The intraclass correlation coefficient (ICC) test demonstrated good to excellent correlation, inter-observer reliability, and intra-observer repeatability of TT-TG and TT-MIELTI.

Conclusions:
We conclude that the mid inter-epicondyle trochlea intersection (MIELTI) accurately identifies the deepest part of trochlea and thus could be used to measure the TT-TG in dysplastic trochlea. TT-MIELTI is a reliable alternative to the TT-TG. Re-assessment in dysplastic knees would be of benefit to establish its usefulness in the clinical setting.

Keywords:
trochlear groove; tibial tuberosity; femoral epicondyles; trochlear dysplasia; patellar instability; tibial tuberosity trochlear groove distance

1. Introduction

Patello-femoral instability (PFI) is one of the most common patellofemoral disorders, and causes significant functional compromise in a young age group [1]. Predisposing factors include trochlear dysplasia, patella alta, an increased tibial tuberosity trochlea groove distance (TT-TG), and femoro-tibial malrotation [2,3]. The acute patella dislocation that can result typically first occurs in the teenage years, with an incidence in the general population of 5.8 per 100,000 [4]. Untreated, PFI predisposes to recurrent dislocations and patellofemoral arthritis.

The tibial tuberosity trochlea groove distance (TT-TG) is an important measurement in the assessment of PFI [5], and can be performed on CT or MRI [6]. It describes the lateral offset of the tibial tuberosity from the deepest part of the trochlear groove in the axial plane (fig 1.), and is therefore a direct measurement of the valgus alignment of the extensor mechanism [1]. A TT-TG exceeding 20mm has been shown to be predictive of PFI, and, in the presence of instability, is an indication for surgery [2]. Accurate TT-TG measurement is important for two reasons. First, to determine whether surgical correction is indicated. Second, to calculate the amount of correction required for stability, with the generally accepted aim being an offset < 10mm [1].

Trochlear dysplasia commonly contributes to PFI [3,7], and can make the TT-TG difficult or impossible to measure. Where the dysplasia consists of an abnormally shallow groove (Dejour type A), conventional pre-operative practice is to make the best assessment of the TT-TG based on the deepest part, though this may be less accurate than in non-dysplastic knees [8]. Where the groove is absent (Dejour types B, C and D) a TT-TG measurement is not possible, potentially leaving an increased lateral offset undiagnosed. The contribution of an increased TT-TG might not become apparent until persisting mal-tracking or dislocation is encountered on-table, or when problems persist post-operatively. Thus, an increased TT-TG which remains undiagnosed or which is inaccurately quantified pre-operatively may be a cause of surgical failure.

To date the validity of TT-TG measurement in an abnormally shallow trochlea remains unknown, and only one study has proposed an alternative to the trochlear groove component of the TT-TG where the groove is shallow or absent [9]. The purpose of this study was to address both difficulties by identifying an alternative to the trochlear groove component of the TT-TG. Specifically, the aim was to demonstrate whether:

(1) a perpendicular line drawn from the midpoint of the inter-epicondylar line coincided with the deepest part of the trochlea, at a point we named the ‘mid inter-epicondylar line trochlea intersection’ (MIELTI)

(2) there was a strong correlation between the tibial tubercle mid-inter-epicondylar line trochlea intersection (TT-MIELTI) and TT-TG.

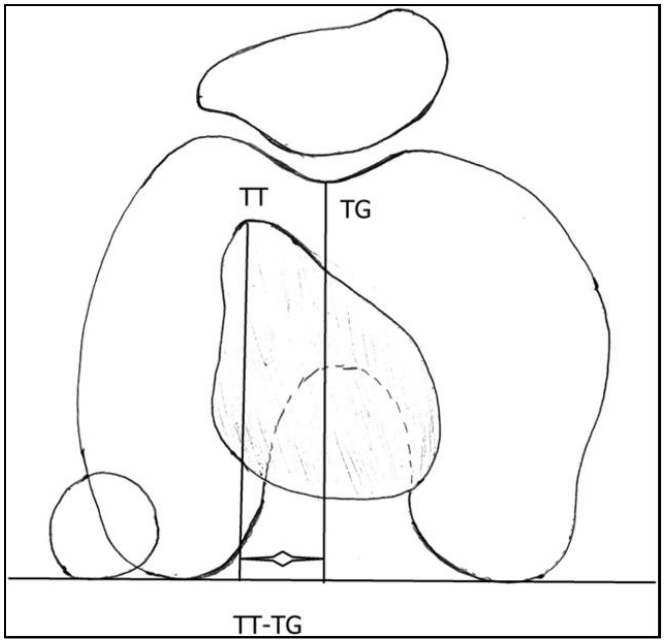


Fig 1. Tibial tuberosity trochlear groove (TT-TG) distance. TT (tibial tuberosity). TG (trochlea groove)

2. Materials and Methods:

2.1 Patients:

We obtained our patient sample from a radiology database which included all knee MRIs performed at our hospital between 1/4/15 and 1/4/16. We reviewed 30 consecutive MRIs after 96 were excluded according to the criteria in table 1. Because a shallow trochlear groove is defined as having a sulcus angle ≥145°, we used an upper threshold of 135° to ensure that dysplastic patients were excluded with a reliable margin of accuracy [10]. The sample patient characteristics are shown in table 2, demonstrating a predominance of female patients. All sulcus angles were in the normal range. The largest group of excluded patients were those with sulcus angles > 135° or other types of dysplasia.

2.2 Methods:

MRIs were performed using a 1.5 Tesla Siemens© Avanto scanner with a receive and transmit dedicated knee coil. Knees were positioned centrally in the coil in full extension. Measurements were made on the proton density fat saturated turbo spin echo (pd fs tse) axial images using the Insignia Medical Systems Insight Analysis and Review© workstation version 8.2.12.1, following a standardised operating procedure (fig 2).

On the axial fat saturated MR images, we selected the section in which the medial and lateral epicondyles were most prominent, and in which a full thickness of articular cartilage covered the trochlea and the posterior condyles (fig 2). For the TT-MIELTI measurements, we identified the deepest part of the trochlear groove on axial MR images by drawing a perpendicular line from the midpoint of the inter-epicondylar line to the bony surface of the trochlea. We named this the ‘mid-inter-epicondylar line trochlea intersection’ (MIELTI) (fig 3). The trochlear groove component of the TT-TG was identified by direct visualisation. The

procedure for identifying the tibial tuberosity was the same for both (fig 4). The standard TT-TG was compared to the TT-MIELTI for each knee.
To assess inter-observer reliability, all 30 knees had the TT-TG and TT-MIELTI measured independently by 3 researchers (RK, AG, RA). To assess intra-observer reliability, one researcher (AG) re-measured the TT-TG and TT-MIELTI for all 30 knees after 6 weeks, without reference to the initial measurements. All the researchers were blinded to the patients' data.

2.3 Statistical analysis:
To compare TT-MIELTI and TT-TG, we used the intraclass correlation coefficient (ICC). This is a univariate test of the relationship between multiple observations of a single variable using analysis of variance. Coefficient values between 0.75 and 0.90 are considered to demonstrate 'good' to 'excellent' reliability [11].

Fig 2. MRI axial section with prominent epicondyles and full thickness cartilage covering trochlea and posterior condyles.

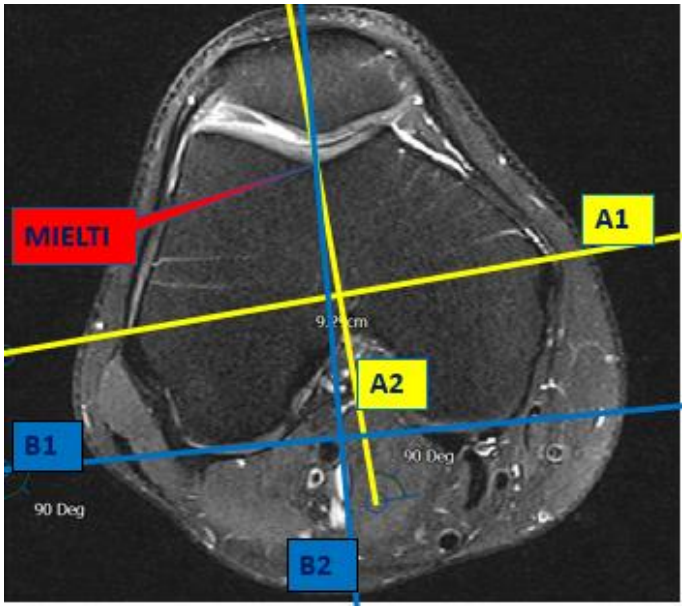
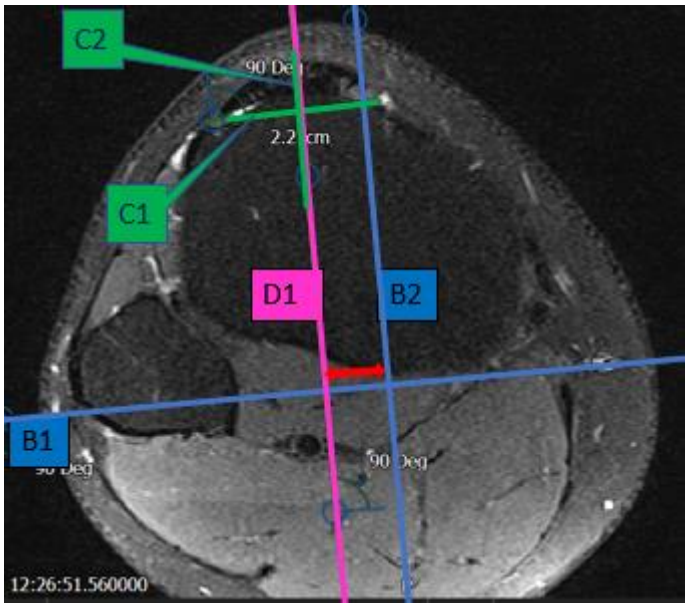


Fig. 3 Identifying the MIELTI
1. Draw an inter-epicondylar measuring line (A1) between the most prominent extents of the medial and lateral epicondyles, ensuring that only bone is included. Identify the mid-point of this line.
2. Draw a line (A2) from the mid-point of this inter-epicondylar measuring line to the trochlear surface. This point is the MIELTI.
3. Draw a line (B1) tangential to bony posterior femoral condyles. Draw a line (B2) at 90° and align it to the point where A2 crosses the bony trochlear groove.

Fig. 4. Identifying the TT-MIELTI
1. Select the axial section displaying the anterior-most part of the tibial tuberosity.
2. Identify the base of the tibial tuberosity where it becomes continuous with the anterior cortex of the tibia. Extend a measuring line (C1) between the medial and lateral sides of the base.
3. Identify the mid-point of the measuring line (C1).
4. Draw a line (C2) from the midpoint of C1 to the anterior surface of the tibial tuberosity.
5. Draw a line (D1) at 90° to B1 and align it to the point where C2 crosses the anterior surface of the tibial tuberosity.
6. Measure the distance between D1 and B2. This is the TT-MIELTI.



3. Results:

The intraclass correlation coefficient demonstrated good to excellent correlation of TT-TG and TT-MIELTI distances for all 4 measurement series. We also demonstrated good to excellent inter-observer reliability and intra-observer repeatability of TT-TG and TT-MIELTI (Table 3).

Table 1.
Exclusion criteria

Exclusion criteria	**n=**
Sulcus angle > 135°/ dysplastic trochlea	64
Anterior prominence of tibia tuberosity at level of patella tendon attachment not demonstrated	17
Artefact (metalwork/movement)	10
Cruciate injury	3
Osgood Schlatter's disease	1
Fracture	1

Table 2.
Patient characteristics

Mean age	42.9	(range 16 – 77)
Gender: female	20	(66.7%)
male	10	(33.3%)
Mean sulcus angle	125.5°	(range 109° - 133°)

Table 3.
Comparison of TT-TG and TT-MIELTI using the intraclass correlation coefficient (ICC)

TT-TG measurement	**Reliability between 3 observers** *95% confidence interval*	ICC = 0.85 0.75 – 0.92	p<0.001
	Repeatability, one observer *95% confidence interval*	ICC = 0.90 0.76 – 0.95	p<0.001
TT-MIELTI measurement	**Reliability between 3 observers** *95% confidence interval*	ICC = 0.86 0.76 – 0.92	p<0.001
	Repeatability, one observer *95% confidence interval*	ICC = 0.89 0.78 – 0.94	p<0.001
TT-TG compared with TT-MIELTI	**Observer 1** *95% confidence interval*	ICC = 0.96 0.97 – 0.99	p<0.001
	Observer 2 *95% confidence interval*	ICC = 0.97 0.94 – 0.99	p<0.001
	Observer 3, time 1 *95% confidence interval*	ICC = 0.96 0.92 – 0.98	p<0.001
	Observer 3, time 2 *95% confidence interval*	ICC = 0.94 0.87 – 0.97	p<0.001

4. Discussion:

On MRIs of non-dysplastic knees, we identified a landmark based on the epicondyles as a potential alternative to the trochlear groove component of the TT-TG (fig 3). We have demonstrated that it is quick and easy to locate on a standard MRI system, that it accurately and consistently predicts the position of the deepest part of the trochlear groove, and that it has good to excellent inter and intra-observer reliability, even though one of the researchers was a medical student with minimal MRI experience.

An increased TT-TG is one of the principle risk factors for PFI, present in 56% of patients with instability in a series by Dejour [2]. It is also a common finding in trochlear dysplasia. Surgical correction consists of distal re-alignment procedures such as medialisation osteotomy of the tibial tubercle for mild dysplasia (types A + B), and trochleoplasty for advanced trochlear dysplasia (types C + D) [7]. Additional soft tissue corrections might also be necessary depending on the patient specific contributing factors. Identification of an increased lateral offset is therefore essential in the comprehensive assessment of PFI and for effective pre-operative planning. This is particularly the case for distal re-alignment procedures, but might also usefully contribute in the planning of trochleoplasty.

Though the difficulties of TT-TG measurement in trochlear dysplasia are acknowledged in the literature [8,12], to our knowledge only one publication, by Julliard et al, has proposed an alternative measurement [9]. They suggested a technique in which they used centre of patellar tendon attachment and estimated the deepest part of trochlear groove by overlying images of the trochlea [9]. Two studies have proposed additional radiographic measurements to be used in conjunction with the TT-TG, which assess the lateral offset of the tibial tuberosity or patella tendon from the tibial attachment of the posterior cruciate ligament (PCL), but without reference to the femur [13,14].

The first is Seitlinger's 2012 study which described an increased TT-TG distance as a combination of a medialised trochlear groove and/or a lateralised tibial tubercle in which either might predominate [13]. On axial MRI they examined the lateral offset of the tibial tuberosity from the medial border of the PCL's tibial attachment in order to calculate a 'TT-PCL' distance. This was shown to be significantly greater in patients with previous patella dislocations than in controls. Used together with the TT-TG, it was proposed as a potentially more precise indication for tubercle medialisation than the TT-TG alone. It is reasonable to postulate that the TT-MIELTI and TT-PCL used together might help quantify the relative contributions of a medialised trochlear groove and lateralised tibial tubercle to an increased TT-TG.

The second is a more recent study by Pozzi which used the middle of the patella tendon instead of the tibial tuberosity itself as the point from which the lateral offset was calculated, also in relation to the medial border of the tibial attachment of the PCL [14]. This study further proposed expressing the offset as a ratio which incorporates the maximum width of the tibia, to allow for differences in the size of the tibia between patients.

The primary advantage of the TT-MIELTI is that it can be used irrespective of the degree of trochlear dysplasia, while still incorporating the contribution of the femoral component to the lateral offset. Our results indicate that it is an accurate and consistent alternative to the TT-TG in non-dysplastic knees. This will potentially facilitate surgical planning in trochlear dysplasia, particularly for tibial tubercle realignment procedures in Dejour types A and B. Further research is however required to determine its clinical usefulness in the presence of dysplasia.

Strengths of this study were that all MRIs were performed according to a standard radiology positioning protocol, with the knee extended. This helped ensure consistency of data, as well as accuracy of TT-TG measurement, especially given that the TT-TG is known to reduce with increasing flexion [12,15]. We did not formally measure the flexion angles as they did not differ between the TT-TG and TT-MIELTI measurements, given that each were performed on the same scan.

We considered the use of MRI rather than CT to be of pragmatic benefit, given the advantages of MRI as a single imaging modality, such as the ability to visualise ligamentous and cartilaginous integrity. These are likely to outweigh any disadvantages compared to undertaking an additional CT, which the literature would suggest are slight [6]. Our use of bony rather than cartilaginous or soft tissue landmarks is likely to have ensured more reproducible measurements and to have helped reduce inter and intra-observer error.

Weaknesses of this study include its relatively small sample size, and female gender predominance. While the sample size has been sufficient to demonstrate statistical significance, it would be beneficial to confirm the findings with a more balanced gender distribution. The necessary exclusion of MRIs which did not extend sufficiently distally to demonstrate the anterior prominence of tibial tuberosity at the level of the patella tendon attachment might have introduced selection bias. A further potential weakness is that it is not known whether dysplasia might affect epicondyle anatomy, thereby potentially invalidating the TT-MIELTI as a useful assessment in the setting of dysplasia.

To our knowledge we are the first to describe this method, which may improve assessment in patients with trochlear dysplasia, facilitate surgical planning, and improve post-operative patello-femoral tracking and stability.

5. Conclusions:

Our results demonstrate that MIELTI accurately identified the deepest pat of trochlea and the measurement of the TT-MIELTI was consistent with the measurement of the TT-TG in a series of MRIs of non-dysplastic knees. We conclude that the TT-MIELTI is a reliable alternative to the TT-TG. Assessment of this landmark in patients with trochlear dysplasia would be of benefit to establish its usefulness in the clinical assessment of PFI, in surgical planning, and in optimising post-operative patello-femoral tracking and stability.

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Conflict of interest

None.

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