The Knee 25 (2018) 367–373

Contents lists available at ScienceDirect

The Knee

Variation in tibial tuberosity lateralization and distance from the tibiofemoral joint line: An anatomic study☆

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ARTICLE INFO

Article history:
Received 4 May 2017
Received in revised form 27 February 2018
Accepted 11 March 2018

Keywords:
Tibial tuberosity
Three-dimensional modeling
Lateralization

ABSTRACT

Background: To describe variation in tibial tuberosity position in a normal adult population and inter-rater reliability of measurements of tibial tuberosity position.

Methods: Surface models of 161 proximal tibia specimens (83 female, 78 male; 80 black, 81 white; age 28.7 years, SD 7.5) were created with a three-dimensional laser scanner. Percent lateralization, tuberosity–eminence angle, and distance from joint surface were measured for each specimen. Variation in tuberosity position by sex, race, age, height, and BMI was calculated. Multivariate regression was used to assess for demographic factors independently associated with tuberosity positioning.

Results: Mean percent lateralization was 57.9% (SD 2.4, range 52.4–64.9%). Tuberosity–eminence angle mean was 11.03° (SD 2.8, range 0–18.7°). Percent lateralization and tuberosity–eminence angle were not influenced by sex, race, age, height or, BMI ($p > 0.05$). Mean tuberosity distance from joint surface was 29.2 mm (SD 3.5, range 16.6–38.6 mm) and larger in males than females (30.7 mm (SD 2.9), 27.6 mm (SD 3.3); $p < 0.001$). Tuberosity distance from joint surface increased 0.18 mm on average per 1.0 cm increase in height ($p < 0.001$). Inter-rater reliability was high for distance from joint surface (Cronbach alpha = 0.99) and percent lateralization.

Conclusions: Tibial tuberosity percent lateralization falls in a narrow range for individuals, whereas tuberosity–eminence angle and distance from joint line are more variable. Inter-rater reliability is high for percent lateralization and distance for the joint surface. Distance of tibial tuberosity from joint surface is associated with sex and height.

1. Introduction

The location of the tibial tuberosity is known to play an important role in patellofemoral joint kinematics, contact mechanics, and stability [1]. As such, the tibial tuberosity is understood to be an important landmark to use in measurements involved in clinical decision-making. In particular, the lateralization of the tibial tuberosity is considered to be an essential part of working up a patient with patellofemoral pain or instability [2] and rotational alignment for total knee arthroplasty [3–7].

☆ Disclosures: The authors received no funding for this study and report no conflicts of interest.

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https://doi.org/10.1016/j.knee.2018.03.006
0968-0160/

The most well described method for measuring the amount of tibial tuberosity lateralization in patients with patellofemoral instability is the tibial tuberosity–trochlear groove (TT–TG) distance, defined mediolateral distance between the anterior tibial tuberosity and the deepest point of the trochlear groove [8,9]. Therefore, it measures tibial tuberosity lateralization relative to the femoral groove and does not evaluate anatomical deformity of the tibia [2,10]. The TT–TG distance is an imperfect measure of lateralization and will vary with degree of trochlear dysplasia and degree of flexion due to the external rotational translation of the tibia relative to the femur as the knee moves from flexion into full extension [11,12]. Active flexion may be more representative of the degree of correction required in surgery to establish patellofemoral congruence than passive flexion, which is how the TT–TG distance is measured [13,14]. Additionally, TT–TG cannot be determined intraoperatively as it is measured off of magnetic resonance imaging (MRI) or computed tomography (CT) imaging.

The tibial tuberosity–posterior cruciate ligament (TT–PCL) distance is a reliable means of evaluating the true lateralization of the tibial tuberosity [15]. Unlike the TT–TG measurement, the TT–PCL measurement is not susceptible to changing with degree of flexion or trochlear dysplasia and therefore may be better at identifying the patients who could benefit from a tibial tuberosity repositioning procedure. However, TT–PCL distance requires magnetic resonance imaging and cannot be determined based on clinical exam or intra-operative assessment, and there is limited data regarding variation in tuberosity position in normal population.

Understanding the tibial tuberosity position is also considered important for establishing the proper rotational alignment of the tibial component in total knee arthroplasty (TKA) surgery. The most anterior point of the tibial tuberosity, the medial 1/3 of the tibial tuberosity, and the medial border of the tibial tuberosity have all been described as intraoperative reference points; however, none are universally adopted and there is limited intra-rater and inter-rater reliability data [3–7]. The mediolateral location of tibial tuberosity has been shown to be variable in knee arthroplasty patients, [16] but there is limited data on the degree of variability expected in a general patient population.

The purpose of this anthropometric study is 1) to describe variation in tibial tuberosity position in a normal adult population and 2) to describe inter-rater and test–retest reliability of measurements of tibial tuberosity position that could be performed intra-operatively. We seek to utilize measures of tibial tuberosity position that are unrelated to distal femur morphology and can be obtained with CT or MRI imaging. We hypothesize that 1) there is significant individual variation with respect to tuberosity lateralization and distance from the proximal tibial joint surface, and 2) there is high reliability of measurements of tuberosity position. Knowledge of normal values for tibial tuberosity position will aid in further investigation of its role in disease processes such patellofemoral disorders and use as an intraoperative landmark for tibial tubercle osteotomy or positioning of tibial components in TKA.

2. Methods

2.1. Sample selection and surface model creation

Ipsilateral tibiae and femora from 161 skeletons (one knee per skeleton) with known demographic information at death (83 female, 78 male; 80 black, 81 white, age 28.7 years Standard deviation (SD) 7.5) were examined at the Hamann-Todd Osteological Collection in Cleveland, Ohio (Figure 1). Specimens were selected to have equal numbers of each demographic group, but Caucasian women (N = 32) and African-American men (N = 34) are underrepresented due to the smaller number of available specimens in those categories. This represents a convenience sample as there is no prior reported data regarding sex or race specific variation in tibial tuberosity positioning to allow for an a priori power analysis.

All proximal tibiae were free of osteoarthritic changes such as osteophyte formation or gross deformation of the subchondral surface. Specimens 40 years or older at death were excluded due to the increased likelihood of early-stage osteoarthritis (OA) and accompanying changes in surface morphology. Specimens were also excluded if there was evidence of prior fracture, limb length discrepancy, hip arthritis, or abnormal bowing of the tibial or femoral diaphysis. Digital models of the proximal tibial surfaces (Figure 1) were created with a three-dimensional laser scanner with 0.127 mm resolution (NextEngine Inc., Santa Monica, CA).

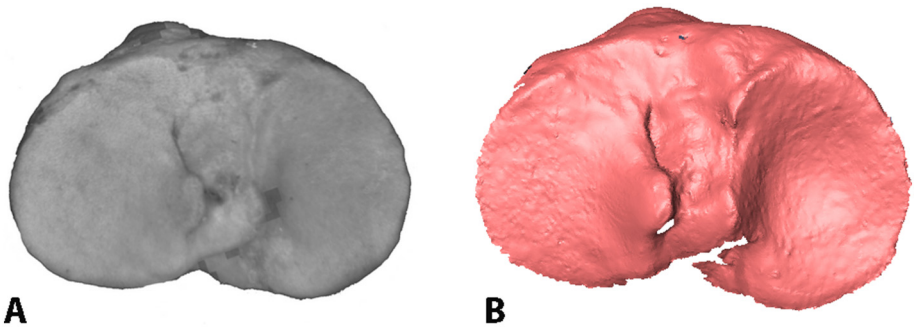

Figure 1. A: Representative black & white photograph of a disarticulated proximal tibia. B: Laser scanner generated surface model (axial view) of the same proximal tibia. The tibial tuberosity is easily visualized as a bony anterior prominence (top of both images).