ARTICLE IN PRESS
THEKNE-02408; No of Pages 9
The Knee xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
The Knee

Femoral articular geometry and patellofemoral stability

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ARTICLE INFO

Article history:
Received 22 February 2016
Received in revised form 14 January 2017
Accepted 24 January 2017
Available online xxxx

Keywords:
Patellofemoral joint
Patellofemoral stability
Femoral articular geometry
Biomechanics test

ABSTRACT

Background: Patellofemoral instability is a major cause of anterior knee pain. The aim of this study was to examine how the medial and lateral stability of the patellofemoral joint in the normal knee changes with knee flexion and measure its relationship to differences in femoral trochlear geometry.
Methods: Twelve fresh-frozen cadaveric knees were used. Five components of the quadriceps and the iliotibial band were loaded physiologically with 175 N and 30 N, respectively. The force required to displace the patella 10 mm laterally and medially at 0°, 20°, 30°, 60° and 90° knee flexion was measured. Patellofemoral contact points at these knee flexion angles were marked. The trochlea cartilage geometry at these flexion angles was visualized by Computed Tomography imaging of the femora in air with no overlying tissue. The sulcus, medial and lateral facet angles were measured. The facet angles were measured relative to the posterior condylar datum.
Results: The lateral facet slope decreased progressively with flexion from 23° ± 3° (mean ± S.D.) at 0° to 17 ± 5° at 90°. While the medial facet angle increased progressively from 8° ± 8° to 36° ± 9° between 0° and 90°. Patellar lateral stability varied from 96 ± 22 N at 0°, to 77 ± 23 N at 20°, then to 101 ± 27 N at 90° knee flexion. Medial stability varied from 74 ± 20 N at 0° to 170 ± 21 N at 90°. There were significant correlations between the sulcus angle and the medial facet angle with medial stability ($r = 0.78$, $p < 0.0001$).
Conclusions: These results provide objective evidence relating the changes of femoral profile geometry with knee flexion to patellofemoral stability.

1. Introduction

Patellar "stability" has been quantified according to classical mechanical principles by measuring the magnitude of force that opposes its displacement from its initial position of equilibrium [1,2]. This is stability as an objective mechanical measurement and, although it may be related, it is different from the spectrum of subjective "instability" that presents as a clinical problem. A reduction in objective stability as a result of injury or pathology and the changing stability with flexion may result in clinical patellofemoral instability in a particular part of the flexion cycle. In order to avoid confusion, the reader should note that this paper is concerned solely with objective measurement of mechanical "stability" in-vitro; the clinical usage to describe subjective sensation in-vivo is not the subject of this paper.

Objective data that characterises the factors which govern the stability of the patellofemoral joint helps us understand the behaviour of this joint. The patellofemoral joint relies on both its geometry and its soft tissue stabilisers working in concert so that it

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http://dx.doi.org/10.1016/j.knee.2017.01.011

can function with optimal mobility and stability. The difficulty in understanding this is reflected in the radiographic indices, the various surgical techniques and variable results for correction of patellar instability [3–11].

The stability of the patellofemoral joint at different flexion angles has been described [2] and it is known that the 'skyline' profile of the patellar contact area on the femoral groove changes with knee flexion [12]. It has been suggested that the increased stability of the patellofemoral joint with increasing knee flexion is as a result of a deepening sulcus with knee flexion [13]. It has been shown that surgically flattening the lateral condyle can reduce the lateral stability of the patellofemoral joint [14]. Similarly, flattening the anterior trochlea and subsequently deepening it with a trochleoplasty caused decreases and then increases of patellar lateral stability, respectively [15]. A review of clinical data found that the trochlear sulcus angle was related to clinical instability [16]. This evidence suggested the hypothesis that the force needed to displace the patella away from its stable articulation in the trochlear groove would correlate to the slope of the lateral or medial trochlear facet on which it is moving. Thus, the aim of this study was to examine how the medial and lateral stability of the patellofemoral joint in the normal knee changes with knee flexion and to measure its relationship to changes in femoral trochlear geometry.

2. Methods

Twelve fresh-frozen cadaveric knees with no prior history of knee surgery or disease were used in this study (mean age 64 Standard Deviation (S.D. = 15). These were obtained from the International Institute for the Advancement of Medicine (Jessup, PA, USA). The Institute undertook screening and consent for the use of the knees for research. Ethical permission for the study was obtained from the Riverside Research Ethics Committee. The knees were stored at −20 °C and thawed a day prior to experimentation.

The skin and subcutaneous tissue were removed. The deep fascia, retinaculae and iliotibial band (ITB) were preserved. The femur and tibia were cut approximately 20 and 15 cm above and below the knee, respectively. The head of the fibula was transfixed to the tibia by two bone screws to maintain its anatomical position and then the distal part excised. Using polymethylmethacrylate and after preparation of the medullary cavity, an intramedullary sleeve and a rod were cemented into the femur and tibia respectively. The sleeve in the femur was aligned to the central femoral axis by use of rubber spacers and an outrigger alignment rod. A polyethylene socket was cemented into the patella, centred over the median ridge and 10-mm deep to the anterior (superficial) surface. This was taken to be the geometric centre of the patella. The quadriceps was separated into six components: rectus femoris (RF), vastus intermedius (VI), vastus lateralis longus (VLL), vastus lateralis obliquus (VLO), vastus medialis longus (VML), and vastus medialis obliquus (VMO).

The stability rig was composed of two parts. The fixed part was attached to the base of an Instron materials testing machine (Instron Ltd., Buckinghamshire, England) and the moving part was a three-degree of freedom mounting attached to the Instron load cell (Figure 1). The knee was mounted sideways (lateral aspect upwards) in the fixed part of the stability rig by locating the cemented femoral sleeve onto a rod on a femoral mounting device. The knee was aligned such that the anatomic axis of the femur was perpendicular to the load cell axis. The femoral sleeve allowed the rotation of the femur to be adjusted until the most posterior parts of the femoral condyles were aligned vertically in a distal–proximal view; when this was achieved it

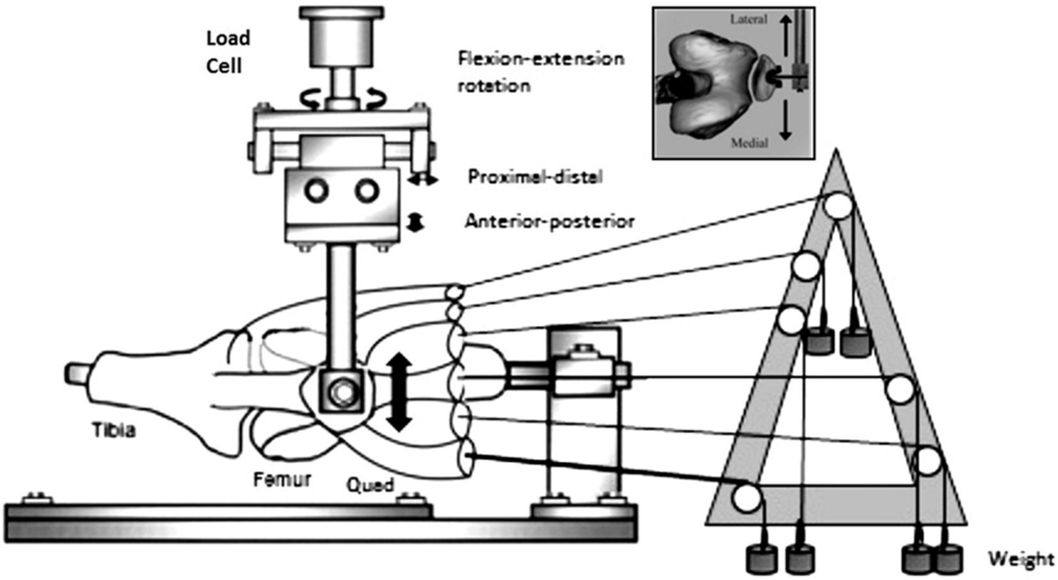

Figure 1. The experimental setup. The figure shows a right knee mounted in a rig secured to the Instron base plate with its lateral aspect upwards. The components of the quadriceps were loaded with cables passed over pulleys and attached to weights. The three-degree of freedom mounting is attached to the load cell of the Instron machine at the top and is coupled to the patella by snap fit into a polyethylene patellar socket cemented into the patella. The knee was flexed to the desired angle and a rod was placed anterior to the tibial rod to maintain this position but allow for the tibia to rotate during testing. The femur was rigidly fixed and the load cell moves up and down by 10 mm from the neutral position to test for lateral and medial stability (see inset).

Please cite this article as: Iranpour F, et al, Femoral articular geometry and patellofemoral stability, Knee (2017), http://dx.doi.org/10.1016/j.knee.2017.01.011