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The role of the patellar tendon angle and patellar flexion angle in the interpretation of sagittal plane kinematics of the knee after knee arthroplasty: A modelling analysis

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Background: Many different measures have been used to describe knee kinematics. This study investigated the changes of two measures, the patellar tendon angle and the patellar flexion angle, in response to variations in the geometry of the knee due to surgical technique or implant design.
Methods: A mathematical model was developed to calculate the equilibrium position of the extensor mechanism for a particular tibiofemoral position. Calculating the position of the extensor mechanism allowed for the determination of the patellar tendon angle and patellar flexion angle relationships to the knee flexion angle. The model was used to investigate the effect of anterior–posterior position of the femur, change in joint line, patellar thickness (overstuffing, understuffing), and patellar tendon length; these parameters were varied to determine the effect on the patellar tendon angle/knee flexion angle and patellar flexion angle/knee flexion angle relationships.
Results: The patellar tendon angle was a good indicator of anterior–posterior femoral position and change in patellar thickness, and the patellar flexion angle a good indicator of change in joint line, and patellar tendon length.
Conclusions: The patellar tendon angle/knee flexion angle relationship was found to be an effective means of identifying abnormal kinematics post-knee arthroplasty. However, the use of both the patellar tendon angle and patellar flexion angle together provided a more informative overview of the sagittal plane kinematics of the knee.

1. Introduction

Knee arthroplasty is considered an effective procedure however a significant proportion of patients experience pain after the procedure [1–3]. The kinematics of the knee can be altered by both surgical technique and implant design. Undergoing total knee arthroplasty may affect the anterior–posterior position of the femur, the joint line, the patellar thickness (overstuffing/understuffing of the patellofemoral joint) and the patellar tendon shortening post-surgery [4–6]. Knee component designs also play an important part in controlling the kinematics of the knee joint due to their geometry as well as the addition of constraints such as a cam-post mechanism [7–9]. As such kinematic measures of the knee joint are regularly used to assess whether knee arthroplasty designs [9–16] achieve their intended design aims or restore native knee kinematics.

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Many techniques have been used to investigate the kinematics of the knee using gait analysis, mechanical measurement, magnetic resonance imaging (MRI), fluoroscopy, and radiostereomatographic imaging [11,17–21]. A well-recognized method used to assess the kinematics of total knee arthroplasty is two dimensional (2D) to three dimensional (3D) reconstruction of fluoroscopic imaging [11,14,15] which has also been used to study kinematics of native knees [22]. More recently the use of MRI has allowed for improved studies of native knee kinematics [19–21]. These methods are complex, time consuming, and resource demanding. Additionally the descriptors most commonly used are tibiofemoral contact points and relative tibiofemoral motion. It may be more appropriate to consider both tibiofemoral and patellofemoral joint interaction when assessing the kinematics of the knee. The motion of the patella relative to the tibia is dependent on both the tibiofemoral and patellofemoral joint interactions. The patellar tendon angle (PTA) is a simplified measure of sagittal plane kinematics of the knee [23–29] and can be measured using conventional fluoroscopy [24,30]. The PTA is the angle subtended between the axis of the patella tendon and the tibial axis as illustrated in Figure 1. The PTA has been shown to be effective in differentiating the kinematics of normal and prosthetic knees [9,16,31] however the interpretation of the PTA is not straightforward [24]. The PTA is often interpreted as an indicator of relative anterior–posterior motion of the femur on the tibia which Stagni et al. [24] conclude is not entirely correct. In addition to the PTA, other studies looking at sagittal plane kinematics have made the additional use of the patellar flexion angle (PFA) to describe patellofemoral kinematics [9,16,25,32]. The PFA is the angle subtended between the femoral axis and the axis through the midline of the patella in the sagittal plane (Figure 1). It is felt that the use of both PTA and PFA gives a more complete picture of the overall sagittal kinematics of the knee [9,16,25,32].

Both the PTA and PFA are influenced by multiple parameters. In this study a computational sagittal plane model of the knee was used to determine PTA versus knee flexion angle (KFA) and PFA versus KFA relationships to determine their response to alterations in parameters representing changes of interest in a clinical context such as the: 1) anterior-posterior (AP) position of the femur relative to the tibia, 2) distal-proximal (DP) position of the femur relative to the tibia leading to an altered joint line, 3) change in patellar thickness causing overstuffing or understuffing of the patellofemoral joint and 4) alteration in patellar tendon length leading to patella baja or alta. This study postulated that the synchronous use of both PTA/KFA and PFA/KFA relationships can provide clinically relevant information of sagittal plane knee kinematics over the use of the PTA alone.

2. Methods

2.1. Sagittal plane model

A two-dimensional mathematical sagittal plane model of the knee was developed, similar to previously described models [26,33,34], to calculate the equilibrium position of the extensor mechanism for a specified position of the femur relative to the

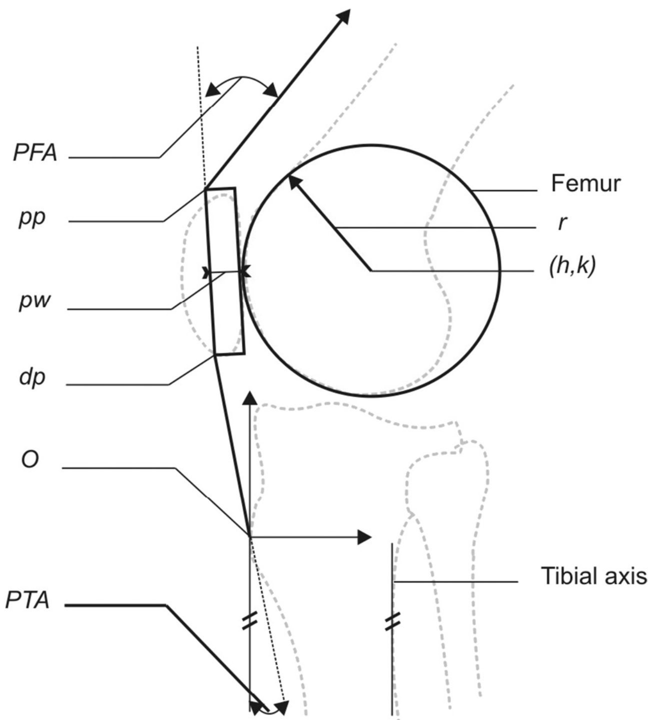

Figure 1. Illustration of the model setup overlaying the sagittal representation of the knee showing the parameter descriptions: tibial tubercle (O), distal pole of the patella (dp), patellar thickness/width (pw), proximal pole patella (pp), femur origin (h,k), radius of femur (r), patellar tendon angle (PTA), and patellar flexion/femoral angle (PFA).

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