INTRODUCTION: In vitro constraint and laxity measurements of total knee replacements (TKR) give an important insight into the stability characteristics that the device will exhibit when in clinical use. An understanding of these characteristics is essential so that the surgeon is able to choose the appropriate TKR design to suit each patient’s requirements [1]. ASTM has standard specifications for an anteroposterior (AP) translation test, which has been used to test TKR designs currently on the market [1,2]. However, these studies have not considered the effects of varying the medial/lateral (ML) load distribution from the 50:50 equilibrium position. Zhao, et al. [3] have shown that the ML load distribution is not necessarily 50:50 and varies depending on activity. ASTM also specifies an ML translation test to assess ML constraint which has been overlooked by previous studies but has been shown to be significant in certain activities [4]. This work looks at four different TKR designs, their AP stability, tibial rotation during translation, the significance of changing the ML load distribution and also the ML stability of the devices.

METHODS: A specially designed rig was used in conjunction with an Instron materials testing machine allowing six degrees-of-freedom of motion of a TKR; the tibial component is able to move in AP and ML translation and also has the freedom to rotate internally and externally (IE), while the femoral component can move proximodistally (PD) and rotate in both valgus-varus (VV) and flexion-extension (FE). It is unclear from ASTM which coupled motions should be allowed, however, Haider et al. [2] found that anomalous results were obtained if those degrees-of-freedom not being tested were constrained. In the AP translation test, the FE rotation is fixed and the AP drawer is imposed by the Instron. The components are moved into an approximate neutral position and the exact neutral position is then found by applying a 350 N axially compressive load and applying small AP translations (± 2 mm). A 710 N axial load (approximately one body weight) is then applied and the AP limits are found. Firstly, an anterior translation is gradually applied to the tibial component until either dislocation of the TKR is imminent or when the force-displacement graph starts to plateau. This displacement limit is recorded. This process is then repeated with a posterior translation. When the tibial component is moved anteriorly, the posterior limit of the bearing contact is found, and vice versa. The TKR is returned to the neutral position, lubricated with water, reloaded to 710 N and cycled between the anterior and posterior drawer limits found previously. Three “pre-conditioning” cycles are completed and data is collected on the fourth cycle. Four different TKRs were tested for AP stability: 0° and 90° flexion with a 50:50 ML load distribution. Three were of the ‘medial pivot’ type: Finsbury Orthopaedics’ Medial Rotation Knee (MRK), two new medial pivot designs with Fixed Bearing (FB) and Mobile Bearing (MB); and the Stryker Triathlon with symmetrical condylar geometry. AP translation tests were also conducted on the Triathlon at four other ML load distributions, from 70:30 to 30:70, with the IE rotation measured throughout. In addition to the AP tests, the Finsbury Orthopaedics’ implants were subjected to ML translation tests. These are conducted in the same manner as the AP tests, but with both the femoral and tibial components rotated around their central axis by 90°. In this configuration the Instron now imposes an ML translation of the tibial component. It was necessary in this test to fix the IE rotation of the tibial component to prevent unrealistic rotation caused by the centres of contact forces in the medial and lateral compartments not being aligned with the IE rotation axis of the tibial component. Constraint was defined in units of N/mm per N compressive load, mm⁻¹ [2].

RESULTS: AP stability characteristics varied between the four different TKR designs. At 0° flexion the total AP laxity limits ranged from 8.5 mm with the MRK to 15 mm with the Triathlon (Fig. 1) and constraint varied from as little as 0.01 mm⁻¹ with the Triathlon in the posterior direction to a maximum of 0.19 mm⁻¹ with the MRK design in the anterior direction. At the 50:50 ML load distribution there was only a very small amount of 7° of tibial IE rotation with the MRK and both FB and MB medial pivot TKRs. The Triathlon exhibited almost 0° IE rotation at the 50:50 load share but as much as 20° of internal tibial rotation at a load distribution of 30:70 (Fig. 2). Anterior stability did not differ with the ML load share. However, posterior stability did vary and was highest at the 50:50 load share (170 N at 3 mm displacement) and lowest at the 30:70 load share (22 N at a 3 mm displacement). ML translation tests at 0° and 90° flexion were carried out on the three medial pivot TKRs. Laterally, the MRK was slightly more constrained than the FB and MB designs, which may be due to the distinct central ridge on the femoral component, but medially the FB design was the most stable. The MB design had the highest total ML laxity at 0° flexion but the lowest out of the three at 90° flexion.

DISCUSSION: In the AP tests, the highly conforming medial-pivot TKRs were more stable than the more conventionally designed Triathlon (Fig. 1). When normal knee data from the study by Shino, et al. [5] is considered it seems that, while the MRK is the most stable, the new FB and MB implants are more physiologically representative in both directions than either the MRK, which is more constrained than normal, or the Triathlon, which is less constrained. More IE rotation was expected from the medial pivot TKRs given their distinctive geometry, designed to allow rotation around the medial compartment. However, it is thought that if these AP tests are repeated at a more anatomically accurate load share such as 60:40 [3], an increase in IE tibial rotation will occur, consistent with the results from the Triathlon (Fig. 2) and also from in vivo tests conducted by Varadarajan, et al. [4].

FURTHER WORK: As an extension to this work, AP and ML tests on the medial pivot designs will be repeated at a 60:40 load distribution and the effects not only on stability but also on tibial IE rotation will be observed. For a complete assessment of the TKRs’ stability, IE rotation tests will also be carried out, as per ASTM. Of particular interest in these tests will be the effect of the medial pivot design of some of the devices and also how the mobile bearing design behaves in comparison to its fixed bearing counterpart.


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