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Are ligament-tensioning devices interchangeable? A study of femoral rotation

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ABSTRACT

Background: During total knee arthroplasty (TKA), femoral rotation can be adjusted either in relation to bony landmarks or by tensioning the ligaments with the knee in 90° of flexion. The primary objective of this study was to compare femoral rotations achieved using various ligament-tensioning devices. The secondary objective was to compare these femoral rotations to that indicated by the transepicondylar axis (TEA).
Material and methods: We performed 13 posterior-stabilised TKA procedures using HiFit (Ceraver®) on cadaver knees. Before performing the posterior condyle cut, we used an original method to measure the femoral rotation induced by five different ligament-tensioning devices (2 with a ratchet mechanism, 1 with screws, 1 force-sensing device, and 1 with spacer blocks) and the central tibio-femoral distance (CTFD).
Results: Both ratchet tensioners provided significantly greater mean external rotation values ($P = 0.002$), of 4.94° and 4.46°, respectively, compared to the force-sensing and spacer tensioners. Significant differences were found across devices for CTFD, with a mean difference of about 2 mm between the ratchet and screw tensioners versus the force-sensing and spacer tensioners. The mean differences in rotations obtained using the tensioners versus the TEA were close to 0° but with standard deviations greater than 4°.
Conclusion: Femoral rotation was dependent on the distraction force applied to the joint. Tensioners that did not measure the distraction force were associated with greater distraction force and external rotation values. The TEA criterion did not reliably indicate good ligament balance.
Level of evidence: Experimental study.

1. Introduction

During total knee arthroplasty (TKA), the quality of femoral rotation adjustment influences the functional outcome [1], patellofemoral kinematics [2], laxity of the flexed knee [3], and extent of condylar lift-off during knee flexion [4]. Condylar lift-off is associated with increased polyethylene wear [5] and can cause dislocation of a posterior-stabilised total knee prosthesis [6].

One method for determining the appropriate degree of femoral rotation is the measured resection technique, in which the cuts are performed independently of each other to allow adjustment of femoral rotation based on bony landmarks [7]. These landmarks are challenging to identify, however [8], and a rectangular flexion gap is achieved in only 50% to 80% of cases [7,9]. Another method is the gap balancing technique, which more often produces a rectangular flexion gap [10] but can induce internal rotation in the event of medial laxity [11] or varus tibial resection [12].

Several ligament-tensioning devices (LTDs) based on different mechanisms are available. The tibio-femoral distraction force produced by the device may involve the knee joint compartments individually [11] or simultaneously [13,14] or may be positioned using an intramedullary rod [15].

The primary objective of our study was to compare the rotations obtained using various LTDs. Our hypothesis was that the degree of rotation varied across LTDs. The secondary objective was to compare the rotation obtained using LTDs to the transepicondylar axis (TEA), considered the most reliable bony reference for assessing femoral rotation [7].

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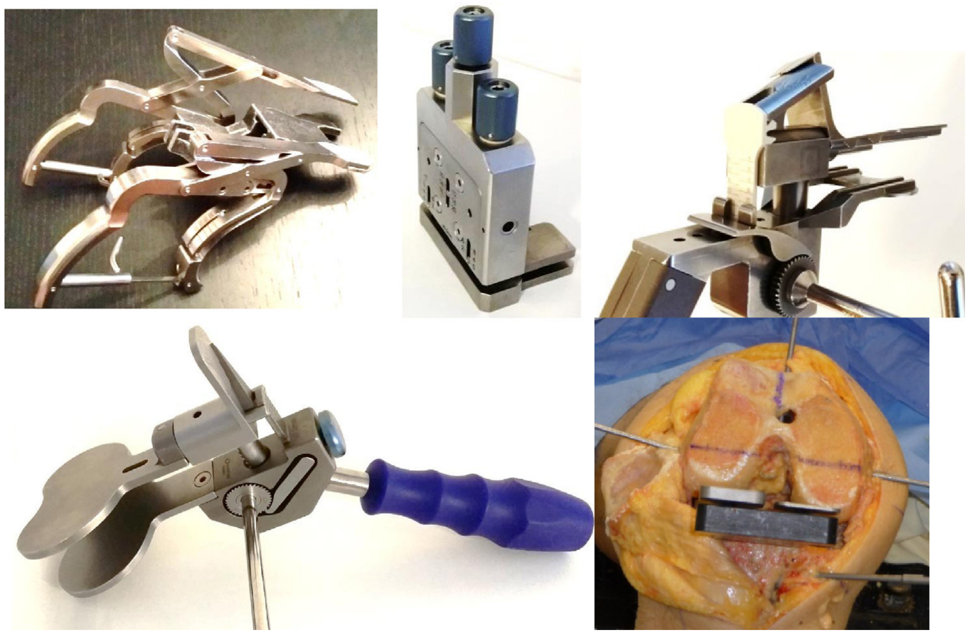

Fig. 1. Five ligament-tensioning devices, from left to right and top to bottom: BalanSys (Mathys®), TIPI (Amplitude®), Xcelerate (Stryker-Howmedica®), Balanceur (Amplitude®), and Spacer blocks (Ceraver®).

2. Materials and methods

2.1. Ligament balancing procedures

The following were available to us: trial prostheses and the tool kit of the HiFit TKA (Ceraver®), which included a LTD made of spacers of different thicknesses (Fig. 1); and four other LTDs: TIPI (Amplitude®, Valence, France), which is a replica of the CORES device (Stryker-Howmedica®, Kalamazoo, MI, USA), BalanSys (Mathys®, Bettlach, Switzerland), both of which provide separate distraction of the two tibio-femoral compartments; and Xcelerate (Stryker-Howmedica®) and Balanceur (Amplitude®), which distract both tibio-femoral compartments simultaneously.

All procedures were done by the same operator. This operator and another observer performed all the study measurements.

We studied 13 fresh cadaver knees from 7 individuals (4 males and 3 females aged 67 to 83 years). None had clinically detectable misalignment, scars from previous surgical procedures, or stiffness (no fixed flexion or flexion limitation). A medial para-patellar incision was made and the posterior cruciate ligament was excised. The tibia was cut perpendicularly to the mechanical axis of the tibia (intramedullary guide then verification using an extramedullary guide) and the distal femur was cut in 5° of valgus (intramedullary guide). The patella was everted during the approach but was subluxated during the measurements to avoid excessive lateral tension. Then, ligament release was performed as needed using the pie-crusting technique (multilevel tiny incisions into the tightest fibres using a 15 blade) to ensure gap balancing in extension with a spacer. Medial ligament release (moderate) was performed in 3 cases.

The knee was then fixed in 90° of flexion. Then, the surgical TEA was traced after careful identification of the epicondyles using pins (Fig. 2). A pin was inserted perpendicularly to the anterior aspect of the femoral metaphysis (F pin) (Fig. 2). Finally, a drill bit was inserted into the medial aspect of the tibial metaphysis, parallel to the tibial cut.

The five LTDs were used in random order to distract the flexed knee. With the spacer system (Ceraver®), a rectangular block was inserted into the tibio-femoral space. Then, blocks of increasing thickness (1-mm increments) were added under each condyle until residual laxity in each compartment was 1 mm, as shown by the ability to introduce an additional 1-mm thick block. With the BalanSys device, a force of 150 Newtons was applied as advocated by Asano et al. [14]. With Xcelerate and Balanceur, distraction was achieved using a central ratchet handle; the upper platform rotated freely around a longitudinal axis. Distraction was applied until each compartment showed 1 mm of residual laxity as evaluated by inducing varus and valgus movements using the handle of the device (under visual control). Both LTDs displayed the induced rotation (with 1° precision). Finally, with the TIPI device, the gap in extension (determined using a central screw that simultaneously separated both condyles) was replicated with the knee flexed. Each compartment was then distracted in flexion using the two lateral screws. Distraction was applied until residual laxity in each compartment was 1 mm, as described above.

Fig. 2. Bony landmarks: transepicondylar axis (TEA) and F pin aligned on Whiteside's line.

2.2. Assessment methods

2.2.1. Measuring femoral rotation

We developed a measurement method that allowed us to compare the LTDs. A camera (with a resolution of 10 megapixels and a digital zoom) was placed on a tripod in front of the knee. Camera position was considered correct when the intramedullary rod was