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Recutting the distal femur to increase maximal knee extension during TKA causes coronal plane laxity in mid-flexion

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ABSTRACT

Background: The aim of this study was to quantify the effects of distal femoral cut height on maximal knee extension and coronal plane knee laxity.
Methods: Seven fresh-frozen cadaver legs from hip-to-toe underwent a posterior stabilized TKA using a measured resection technique with a computer navigation system equipped with a robotic cutting guide. After the initial femoral resections were performed, the posterior joint capsule was sutured until a 10° flexion contracture was obtained with the trial components in place. Two distal femoral recuts of +2 mm each were then subsequently made and the trials were reinserted. The navigation system was used to measure the maximum extension angle achieved and overall coronal plane laxity [in degrees] at maximum extension, 30°, 60° and 90° of flexion, when applying a standardized varus/valgus load of 9.8 [Nm] across the knee.
Results: For a 10 degree flexion contracture, performing the first distal recut of +2 mm increased overall coronal plane laxity by approximately 4.0° at 30° of flexion ($p=0.002$) and 1.9° at 60° of flexion ($p=0.126$). Performing the second +2 mm recut of the distal femur increased mid-flexion laxity by 6.4° ($p<0.0001$) at 30° and 4.0° at 60° of flexion ($p=0.01$), compared to the 9 mm baseline resection (control). Maximum knee extension increased from 10° of flexion to 6.4° (±2.5° SD, $p<0.005$) and to 1.4° (±1.8° SD, $p<0.001$) of flexion with each 2 mm recut of the distal femur.
Conclusions: Recutting the distal femur not only increases the maximum knee extension achieved but also increases coronal plane laxity in midflexion.

1. Introduction

Increasing the amount of distal femoral resection is often required in total knee arthroplasty (TKA) in the presence of a preoperative flexion contracture and/or a tight extension space in order to achieve full knee extension [1]. This is usually accomplished in most total knee systems by cutting the distal femur through the "optional" cutting slot of the jig. However, the quantitative effect of cutting more distal femur on knee extension and coronal knee stability throughout flexion is not well understood.

In the past, part of the difficulty of quantifying the effect of distal femoral cut height was due in part to the limited tools available to obtain accurate measurements. Prior attempts to measure the effect of distal femoral resection height on knee extension used an intraoperative goniometer, accurate only to the nearest 5 degrees, or digital photography [1,2]. With the advent and improvements in computer navigation, one is now able to achieve much more accurate measurements than was possible several years ago [3–5]. Furthermore, currently, there is no standardized method for assessing coronal plane stability. Prior published papers have examined the incidence and magnitude of femoral condylar lift-off by fluoroscopy, tibiofemoral forces using a customised mini-force plate in the tibial tray, and total arc of varus-valgus motion during passive knee flexion to describe coronal plane laxity throughout flexion [6–8]. Further, there is an increased need to develop a standardized method for assessing coronal plane stability given the current debates on whether a measured resection technique or a gap balancing technique is superior in total knee arthroplasty, as well as the current knowledge that laxity leads to early failure following TKA [7,9–11].

Thus, the aims of this study were: 1) to quantitatively analyse the amount of knee extension that is achieved with incremental increases in the amount of distal femoral bone that is resected during posterior stabilized total knee arthroplasty in the setting of a flexion contracture, 2) to quantify the amount of coronal plane laxity that occurs with each 2 mm increase in the amount of distal femur resected, and 3) to describe a reproducible method of assessing coronal plane stability, so that future studies on this topic could be standardized. In the setting of a soft tissue flexion contracture, we hypothesized

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that although resecting more distal femur will reliably improve maximal knee extension, it will ultimately lead to increased varus and/or valgus laxity throughout mid flexion. As a secondary hypothesis, we believed that coronal plane laxity at 0° will improve as the knee is brought closer to full extension, and coronal plane laxity at 90° degrees will not change with each 2 mm recut of the distal femur.

2. Methods

IRB approval was obtained prior to beginning the study. Seven fresh-frozen human cadaveric specimens of the lower extremity, from hip to toe, were used for this study. The average age of the donors was 56 years (range: 41–67 years old). Specimens were excluded if they had gross evidence of anterior-posterior or medial-lateral ligamentous laxity, varus or valgus alignment, previous surgical procedures, or significant osteoarthritis. Prior to formal testing of these specimens, we performed a pilot study utilizing a single fresh-frozen human cadaveric lower limb to test the experimental protocol and determine sample size.

After thawing at room temperature for 24 hours, the subtrochanteric region of the femur was clamped to a vice attached to the operating table with the tibia suspended of the end of the operating table. An anterior midline incision was made, followed by a standard medial parapatellar arthrotomy. Arrays were attached to pins placed in the distal femur and proximal tibia. Bone morphing acquisitions of the femur and tibia were performed, and the mechanical axis of the limb was obtained. Digitization of the transepicondylar axis was performed, which served as our primary femoral rotation reference, whereas the posterior condylar axis served as a secondary femoral rotation reference [12–14]. Morphing of the distal femur and tibia reproduces a 3-dimensional computer replica, accurate to within 1 mm and 1° [3,5]. A stainless steel, threaded hook was inserted through the anterior tibia, 25 cm distal to the joint line [15].

At this stage, a computer navigated posterior stabilized (PS) total knee arthroplasty (TKA) using the Genesis II® total knee system (Smith and Nephew, Memphis, TN) was performed, which served as our control group. All bony resections were performed using the Praxim Nanostation knee navigation software for total knee arthroplasty (Praxim, La Tronche, France) with an anatomic measured resection technique. Femoral resections were performed using the iBlock® automated robotic femoral cutting guide [4], and tibial resections were performed using conventional computer navigation cutting guides. The initial distal femoral cut height was set at 9 mm off the medial femoral condyle on all specimens. Femoral component rotation, tibial slope, and the amount of distal femoral valgus were standardized and equivalent in all specimens.

The patella was reduced in the trochlea of the trial femoral component prior to coronal plane stress testing, but the arthrotomy was not closed. Varus and valgus stress testing was then performed following TKR at maximum extension, 30°, 60°, and 90° of flexion, applying a standardized moment of 9.8 Nm (4 kg applied 25 cm distal to the knee joint), utilizing a spring gauge scale pulling on a cable tie through the hook [15]. The cable tie was used to prevent the lower limb from rotating, which would have influenced our results. The exact flexion angle (maximum extension, 30, 60 and 90 degrees) and mechanical axis (varus/valgus) angles between the tibia and femur were measured in utilizing the navigation software (Fig. 1).

At this point, the femoral and tibial components were removed. With the femur in the vice, direct visualization of the posterior capsule was obtained. Using a 0 Prolene suture, the posterior capsule was imbricated to create a 10 degree flexion contracture (i.e. maximum passive extension of 10 degrees), with the total knee components in place, as confirmed using computer navigation software. With the proximal femur of the specimen held securely in a vice, the knee was maximally extended while holding the foot at the heel with the toes pointing perpendicular to the floor/ceiling and the exact flexion at maximal extension was recorded.

The trial components were again removed, and using a robotic cutting guide, 2 mm of bone was resected from the distal femur (i.e. 11 mm total off the medial femoral condyle) (Fig. 2a,b). The remaining anterior and posterior champfer cuts were also made, and the trial components were again securely impacted in to position. The above testing was again performed, assessing maximal extension achieved with each 2 mm cut on the distal femur and coronal plane laxity at maximal extension, 30, 60, and 90 degrees. Finally, the trial components were removed, and a second 2 mm recut (i.e. 13 mm total) of the distal femur was made. The above testing protocol was then repeated.

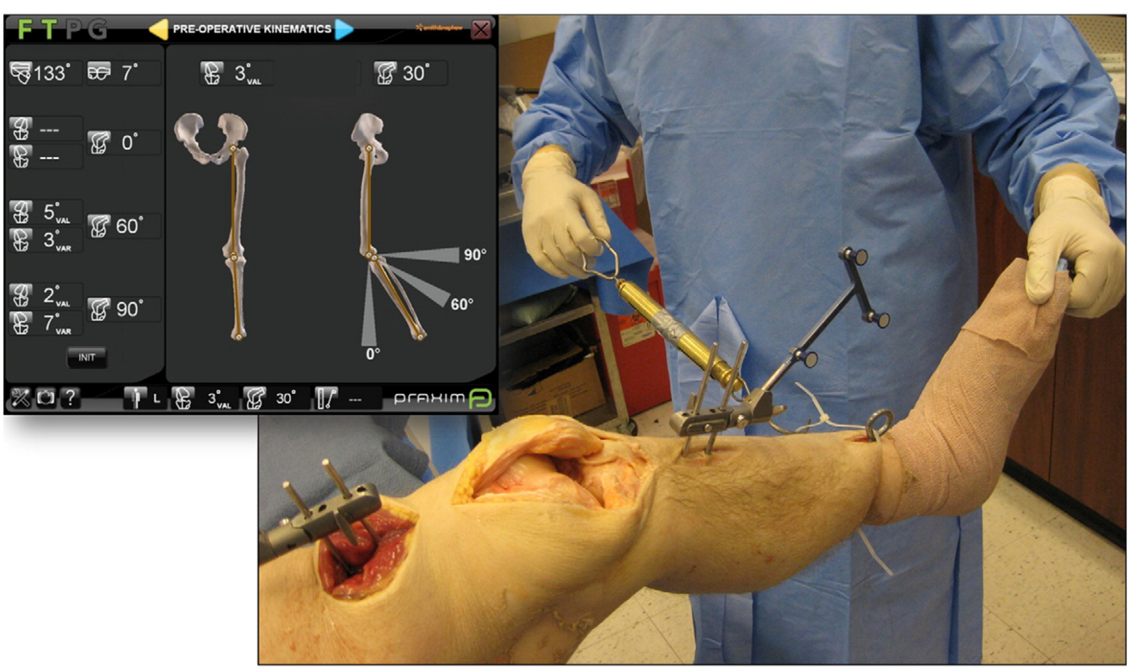

Fig. 1. A standardized varus/valgus moment of 9.8 Nm was applied and the Praxim total knee navigation system was used to measure the varus and valgus mechanical alignment angle of the knee at maximum extension, 30, 60 and 90 degrees of flexion.