Experimental Investigation of Patellofemoral Overstuffing Kinematics and Its Relationship to Flexion and Tilt after Total Knee Arthroplasty

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Abstract
Patellar instability is viewed as a source of pain. Wear of the knee cap is a critical and important outcome variable after total knee arthroplasty. Various factors can lead to patellar instability and imbalance among which tight outer ligaments and loose inner ligaments. The objective of this paper is to track kinematically the patella during knee flexion after resurfacing and overstuffing, using a sensory device based on Optotrack system. Resurfacing of the patella during TKA requires matching the bone resections with an exact patella button to prevent loss of knee motion. It is also important to note that, given limited implant sizes and patient-specific inherent structure knee geometry, resection of these portions of the femur may affect the trochlear groove height in the anterior compartment of the knee. Overstuffing of the patella is viewed as an option to preserve normal kinematics and patella tracking. We examined varying amounts of patella overstuffing in eight cadaver knee models to observe the effects of the patella on knee flexion-extension. A 0-8mm buildup by an increment of 2mm resulted in flexion loss of less than 1.5 degrees for all eight knees while the patella tilt loss was 5 degrees. The change in patella thickness may have small clinical effects on flexion but the patella tilt raises some concerns.

Methods
Knee motion during flexion is recorded with an Optotrak Certus® motion capture system composed of three cameras and several markers. A marker has three infrared light-emitting diodes, so that each marker corresponds to one three-dimensional coordinates system. We fixed one marker to each rigid body, namely the femur, the patella and the tibia. Virtual points were added and digitized on each bone. This allowed for additional points to be monitored without adding additional markers. The NDI software displays the three translations and the three rotations of each digitized point. The angles between any two lines during knee motion can be calculated. We applied a load to a cable that was sewed to the quadriceps tendon and passed through a pulley system mounted on a stable frame to control the force vector producing the flexion-extension.

Results
We examined the effects of the thickness of patella overstuffing during TKA on both magnitude and fluctuation of the patellar angles, more precisely the tilt (Ωy) and the patella-femoral flexion angle (Ωx). We performed a TKA on eight knees, resurfaced the patella and examined the correlation of the different patella button thicknesses on each knee. Figure 2 is an example of the correlation study of the tilt for knee 1. This study aims to assess potential patellar instabilities due to incorrect prostheses sizes, and whether overstuffing is a correct option. Moreover, we focused on each prosthesis size in the height knees in motion in order to estimate the average evolution of the angles for one specific overstuffing. Figure 4 corresponds to both flexion and tilt average angles (Ωx or Ωy) during knee flexion for different augmentation heights of the patella button. It enables us to observe an overall progression of angles.

Discussion and conclusion.
The results show that patella flexion angle was clinically insignificant and was not affected by the thickness overstuffing. Indeed, almost all the flexion angles Ωx curves in figure 4 overlap. Our study shows that the size of the prosthesis thickness has a stronger influence on the tilt. The tilt correlation coefficient in figure 2 varies between 0.81 (0mm/8mm) and 0.998 (2mm/4mm) whereas the minimum patella-femoral flexion correlation coefficient is 0.99. Various conclusions can be made from the curves representing the patellar angles function of the flexion angle (fig.3 is one example). First, the patella-femoral curves are almost linear for each knee and each prosthesis. Secondly, the tilt remained constant around 20°. These two remarks are summarized in Figure 4. A third general conclusion is seen when the overstuffing is above 6mm: the patella instability is significant (see Fig.3) when there is a sudden drop in tilting.

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Reference