Introduction
Several kinematic studies have described a paradoxical movement of the tibiofemoral contact point from posterior to anterior during knee flexion after TKA. Such a motion would decrease the distance between the tibial insertion of the patella tendon ligament and the tibiofemoral contact point, especially in positions of knee flexion, resulting in a decrease in the lever arm of the extensor mechanism. A higher quadriceps muscle force would thus be required to produce the same extension moment [1]. An increase in tibial slope has been postulated to lead to posterior displacement of the femur which results in an increase of the quadriceps lever arm [2]. In order to investigate this hypothesis, we measured the quadriceps extension force, the movement of a mobile bearing inlay, and tibiofemoral position after TKA with and without ten degrees of tibial baseplate angulation (ten degrees posterior slope).

Methods
Human knee specimens (n=7, mean age=65 SD 7 years, all males) were tested in a kinematic knee simulator after TKA with a mobile bearing inlay prosthesis (Interax®, Stryker/Howmedica) (Fig. 1). During simulation, a hydraulic cylinder applied sufficient force to the quadriceps tendon to produce an extension moment of 31 Nm about the knee, while a second cylinder simulated a 100 N cocontraction of the hamstrings. Quadriceps load was measured using a load cell attached to the quadriceps tendon, anteroposterior displacement of the mobile bearing inlay as well as the relative tibiofemoral position was measured using an ultrasound base motion analysis system (CMS 1000®, Zebris). Quadriceps load and inlay and tibial displacement were first investigated with a neutral tibial base plate orientation, and subsequently after a ten degree posterior angulation.

Results
After TKA with neutral slope, the shape of the quadriceps force curve was typically sinusoidal, reaching a maximum value of 1390 N (SD see Fig. 2) and a minimum value of 742 N. After applying a posterior slope of ten degrees, maximum quadriceps force was measured to be up to 1300 N (p=0.04), with a minimum force of 681 N. The mobile bearing inlay was observed to move up to 0.11 mm (SD see Fig. 3) anteriorly relative to the tibial base plate with neutral tibial slope, and up to 1.04 mm (p=0.47) with tibial slope. The maximum posterior displacement relative to the tibial base plate was observed to be 1.83 mm without and 1.07 mm with tibial slope at maximum knee extension. Femoral position relative to the tibia moved from a posterior position of 13.1 mm anteriorly up to 0.5 mm (SD see Fig. 4), with a ten degrees tibial slope from 16.0 mm (p=0.67) to 9.54 mm (p=0.33).

Discussion
In this study quadriceps muscle force needed to produce a constant extension moment was observed to change with angulation of the tibial component after TKA. Posterior slope of the inlay resulted in a more physiologic inlay movement at higher flexion angles with a more posterior position of the femur and reduced quadriceps force. Generally, quadriceps muscle force changes during extension in a sinusoidal shape due to the changing lever arm of the patella [3]. In this study, after implantation of TKA with a ten degrees posterior slope, the femoral position relative to the tibia shifted anteriorly. With this, quadriceps lever arm increased and quadriceps extension force was reduced to extend the same extension moment. Interestingly, inlay movement shows a different movement pattern as well: with ten degrees tibial slope the inlay moved anteriorly during extension at higher degrees of knee flexion, which tends to be a more physiologic movement pattern. The results of this study thus suggest that changing the tibial slope of the tibia base plate alters the movement of the tibiofemoral contact point, resulting in an improvement of the quadriceps lever arm at flexion angles from 100 to 30 degrees of knee flexion.

Literature:
1. Dennis et al., 1998, Orthopedics Today