Introduction: During the majority of total knee arthroplasty (TKA) implantations, it is necessary to sacrifice the anterior cruciate ligament (ACL). With this resection and the implantation of the prosthesis, the tension of the retained posterior cruciate ligament (PCL) may be increased and increase the tibiofemoral stress on the polyethylene inlay due to the presence of abnormal knee kinematics and imbalances of the retained soft tissue[1]. To prevent this excessive PCL tension, some knee prosthesis systems offer the option of creating a posterior tibiofemoral slope of the tibial component[2,3]. The objective of this study was to investigate the effect of the amount of tibiofemoral slope on PCL tension after TKA under dynamic in vitro conditions. The tibial component of one common knee prosthesis system was thus implanted in cadaver knee specimens, both normally as well as with increased tibiofemoral slope, and PCL tension, quadriceps force as well as tibiofemoral stress were measured during simulated isokinetic flexion motion of the knees.

Methods: Five fresh frozen knee specimen were tested in isokinetic extension in an in vitro simulation. After implantation of the Interax I.S.A.(Stryker/Howmedica®, Ireland) knee prosthesis-system with a mobile bearing inlay, a bow shaped strain transducer was fixed in the medial fibers of the PCL, with care being taken to minimally disrupt the soft tissues of the knee during insertion. A pressure sensitive film (Tekscan®; Boston, USA) was fixed on the femoral inlay surface. The test cycle simulated an isokinetic extension cycle from 120 degrees of flexion to full extension, a hydraulic cylinder thereby applied sufficient force to the quadriceps tendon in a closed-loop control cycle to produce a constant extension moment of 31 Nm about the knee. During simulation, the force applied by this cylinder changed depending of flexion angle of the knee. A second hydraulic cylinder simulated the co-contraction of the hamstrings muscle with a constant co-contraction flexion force of the hamstrings of 200 N. First, PCL strain and tibiofemoral stress were measured with the tibial component implanted with a neutral tibial slope and a mobile bearing inlay with 6 mm height, and then with 10 degrees posterior slope. With this posterior slope the inlay height was changed to 8mm to restore the same knee joint line. The difference between the loading on the PCL and tibiofemoral stress before and after simulated co-contraction were analyzed using a nonparametric Wilcoxon test.

Results: During the knee extension cycle, quadriceps muscle forces reached a maximum of 1390 N (SD 247 N) at 85.4 degrees of knee flexion to generate a constant extension moment of 31 Nm. After implantation of the tibial component without tibial slope, PCL tension reached a maximum tension of 34.7 N (SD 38.8 N) at 100 degrees, and decreased to 3.1 N (SD 4.7 N) at 8.8 degrees of knee flexion (Fig. 1). Tibiofemoral stress reached a maximum of 11.6 MPa (SD 5.5 MPa) at 4.8 degrees and decreased to 2.0 MPa (SD 1.8 MPa) at 112.2 MPa. With a tibial slope of 10 degrees, PCL tension was reduced, reaching a maximum of only 17.9 N (SD 10.4 N, p=0.22) at 100 degrees, thereafter decreasing to 5.5 N (SD 7.9 N, p=0.11) at 4.2 degrees. With tibial slope, maximum tibiofemoral stress differed lower than 1 MPa up to 20 degrees of knee flexion, but increased thereafter to a maximum of 16.0 MPa (SD 6.0 MPa, p=0.28) at 8.9 degrees (Fig. 2).

Discussion: This test setup enabled direct in vitro measurement of PCL tension and tibiofemoral stress during an isokinetic extension cycle under different conditions of tibial slope after TKA. Maximum PCL tension was observed at high knee flexion angles, decreasing to full extension, which showed an equal tension pattern like traction of cruciate ligaments in physiologic knees[4,5]. The implantation of the tibial component with 10 degrees dorsal slope reduced tension in the PCL by 90% (SD 24%), correlating to findings of other investigators[2,3]. This decreasing tension allowed an implantation of a higher inlay without any effect on tibiofemoral stress at high knee flexion angles. Reaching nearly full extension tibiofemoral stress was affected by different parts of the surrounding soft tissue showing an increasing tibiofemoral stress than without tibial slope and a thinner inlay[3-5]. Therefore a posterior tibial slope prevents an exceeding tension on the PCL particular in knee flexion, without having little effect on tibiofemoral stress in knee extension.

REFERENCES:


Figure 1: PCL tension with (TSH) and without (TKH) tibial slope

Figure 2: Tibiofemoral stress with (TSH) and without tibial slope (TKH)