Kinematics of an anatomically designed cruciate retaining total knee arthroplasty implanted using a spacer guided PCL balancing technique.

Introduction
Many fluoroscopic kinematic studies describe paradoxical roll-forward of the femur in flexion in PCL-retaining total knee arthroplasty (CR TKA), indicating an incorrect PCL tension. The variation of the contact point in CR TKA is larger than in PS TKA, which demonstrates that correct balancing of the PCL is difficult [1]. An important observation explaining the difficulty of flexion gap balancing in CR TKA was reported by Christens et al. [2]. They found a strong relation between distraction of the flexion gap and anterior translation of the tibia. This anterior translation is caused by the oblique orientation of the PCL in the knee joint. A 2 mm increase in spacer thickness could cause an anterior translation of the tibia relative to the femur up to 4 mm. This indicates that relatively small variations in gap size can change the tibia position considerably with respect to the femur. This relative translation indirectly determines the contact point of the TKA after implantation of the components.

Theoretically, one would expect a correct PCL tension with a precise measured resection technique in which the resected bone of femur and tibia is replaced with prosthetic material, thereby restoring the joint surfaces. This would not change distances between ligament insertions and the ligament tensions will remain the same before and after replacement. But it can be challenging to make the precise bone cuts within the range of 1-2 mm. Implant designs have their specific contact point which is determined by the deepest part of the bearing insert at a certain position measured at the antero-posterior distance of the tibial plateau for instance at 60%. The concern during surgery is to control this contact point since the position of the femur on the tibia cannot easily be measured at the back of the knee joint. We therefore developed a simple technique to check the contact point in 90 degrees of flexion by indirectly measuring the step off between the distal cut of the femur and the anterior edge of the tibia with a spacer in place after all the bone cuts are made.

During laboratory tests of an anatomically-designed cruciate retaining knee implant the above described spacer technique was used to check the correct PCL balancing during placement of the knee implant. To this end, knee kinematics were measured in an Oxford rig simulating a weight bearing squat before and after replacement of the knee.

Materials and Methods
For this study, eight fresh frozen full leg cadaver specimens were used. The methodology followed for the experiments was largely similar to the detailed description given by Victor et al. [3] Prior to the experiment, with the legs still frozen, two bone pins were inserted unicortically in both femur and tibia and frames with four reflective spherical markers were fixed to the pins. A CT scan of the full leg was then made with the frames in place. Coordinate systems for femur and tibia could be defined to describe the relative femoro-tibial kinematics during the tests, based on the tracked marker trajectories. Twenty-four hours before the experiment, the legs were taken from the freezer to thaw overnight. Both bones were cleaned and embedded in aluminum fixtures with PMMA. Afterwards, the quadriceps tendon was dissected, stripped from all muscle tissue and secured in a clamp. Also the medial and lateral hamstrings tendons were dissected and suture wires were attached to be able to load the hamstrings during the experiment.

Finally, prototype components of a new Journey CR implant (Smith & Nephew, Memphis, TN) were implanted using navigation. With the computer assisted system the knee prosthesis was implanted using a measured resection technique cutting an amount of bone equal to the prosthesis thickness in extension and flexion. A three degrees external rotation jig was used to determine the femoral rotation. A bony island around the PCL was preserved and all ligaments were intact after finishing the bone cuts.

The surgical PCL balancing technique was based on the preferred contact point in the insert of the knee implant. After finishing the bone cuts of tibia and femur, the spacer was inserted in flexion and positioned on the anterior edge of the bony surface which simulates the anterior edge of the chosen size of the tibial baseplate. If the distance from distal femur to anterior tibia edge is correct the contact point and PCL balancing is correct.

The specimen was mounted on the knee kinematics rig and a loaded squat with a constant vertical ankle force of 130 N and constant medial and lateral hamstrings forces of 50 N was performed between an estimated 30° and 130° of knee flexion. The trajectories of the reflective spherical markers on tibia and femur were continuously recorded using six infrared cameras (Vicon, Oxford, UK) at 100 Hz. Kinematics were analysed and the projections of the femoral condylar centres on the horizontal plane of the tibia were calculated. In two specimens with osteoporotic bone a femur fracture occurred during the loaded squat, these were treated with osteosynthesis. All PCLs remained intact during the tests.

Results
Of the 8 specimens implanted the calculated step-off was correct in 6 after finishing the bone cuts and in 2 specimens an additional tibia cut with 2-3 degrees more slope was sufficient to achieve the correct step-off. No lift off of the tibial tray occurred during the tests. Statistical calculations were not available at the time of writing, but comparing the patterns of the kinematics of the native knee with the Journey CR knee implant showed a considerable similarity in the weight bearing tests (fig 1). The projected condylar centres on the medial side of the Journey CR knee implant are at the same position as the projected condylar centres of the native knee. No paradoxical roll forward is seen in the knee implants. All but one specimen had projected condylar centres around the desired 60 % of the AP diameter of the tibia plateau showing that both femur and tibia are aligned appropriately to work quite well. The contact points on the lateral side of the knee have a similar pattern in flexion. The knee implant shows near extension a slightly more anterior contact point but this is only marginal.

Discussion
The kinematics of the Journey CR knee implant are on average comparable to the kinematic pattern of the native knee in these tests. Apparently the joint surfaces of the anatomic knee design with a dished medial insert surface and a convex lateral insert surface and a 3 degrees varus of the joint line is guiding the motion towards that of a normal knee joint. We feel that correct balancing of the PCL during implantation is of major importance in achieving these results. The step-off guided spacer technique to balance the PCL seems to work well in this experiment, no lift off of the tibias inserts occurred during trial implantation. The preparation of the PCL with preservation of the bony insertion was also safe since no ligament ruptures occurred during the tests.

References

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