Dynamic analysis of knee biomechanics on cadaveric specimens

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INTRODUCTION

The knee is a very complex joint with multidegrees of freedom. The biomechanics of such joints is rather difficult to test. For the measuring of the patello-femoral contact pressures, several test rigs already exists but they test knees in a static way. A new test rig is designed for dynamically testing post-mortem human knees, with inclusion of a dynamic analysis of the patello-femoral contact pressure.

METHODS

For this test a new test rig was developed, based on the Oxford Knee rig [1]. This test rig makes it possible to measure forces (quadriceps and tibia) and rotations (knee flexion, tibia) during flexion and extension. The main overview of the test rig is presented in [2]. For measuring the contact area of the patello-femoral joint a thin film is used. This film (I-scan, Tekscan, Inc.) is a flat and thin (<1mm) polymer film, with cupper lines in it. The sensor is square-shaped and has a total contact area of 1600mm². The sensor was inserted in the knee joints by a lateral incision, and stitching the knee afterwards. After opening of the knee, the patella was freed so the gluing of the sensor could be done easily. Due to the thin nature of the sensor, the film could be glued perfectly on the patella. This for keeping the sensor in position during motion. After that the patella is placed in position again, and the knee is laterally stitched.

A new post-mortem human knee is first treated and cleaned, tibia and femur were prepared for further imbedding, and the quadriceps muscle/tendon was released. The clamping makes it possible to transfer forces of more than 3000N from the steel cable to the tendon.

The tibia and femur were then cemented with polyester in two aluminium cylinders. These are constructed to be placed on the test rig, and aluminium was used for later removal of the polyester(heating of the samples). Once placed in the test rig, the motor was correctly positioned. Due to the modular setup the motor can be placed on the right and on the left of the 'hip' construction, so right and left knees can be tested without problems.

By pulling on the quadriceps tendon, the knee will extend, and flex after extension. Forces and rotations are continuously measured, due to the thin film in the knee joint also contact pressures and the contact area can be measured during flexion and extension.
Tests were performed by using a linear motor speed of 1 or 2 mm/s, resulting in a flexion-extension time of 80 to 100 seconds.

RESULTS AND DISCUSSION

Figure 1 gives a graph of the relation between the quadriceps force and the tibia force. This graph is for clinicians rather strange due to the mechanical construction of the test rig and test set up. The test starts with a certain flexion angle (A). After that the force on the quadriceps is loaded(1), until movement starts (B). Then an extension (2) of the knee joint takes place with lowering of the Fq and a rise in the force along the tibia (Ft). Once fully extended (C) the total body weight is resting on the tibia. During flexion (3) the force in the quadriceps tendon rises again, and lowers (4) to an Fq of 0 when the simulated body weight rests on two safety blocks.

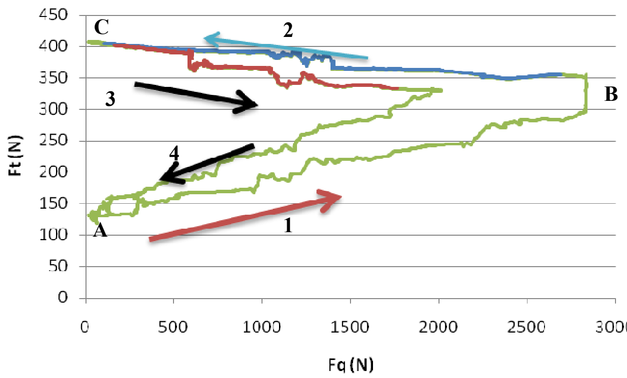

Figure 1: Flexion-extension force graph.

The differences between flexion and extension are due to the fact that the patella does not follow the same traject during flexion and extension as measured with a Zebris (zebris Medical GmbH). Also the contact area and pressure distribution (Figure 2) shows this behaviour.

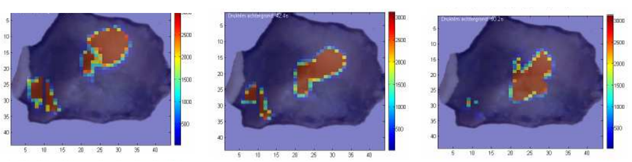

Figure 2: Contact area, position and pressure distribution during extension at different flexion angles (55°; 45° 35° flexion angle)

CONCLUSIONS

The designed test rig offers great potential in research of post-mortem human knees. The results of the different sensors (force, rotation, Zebris, pressure films) show the same results. The influence of the thin films on the biomechanics of the knee joint does not cause any difference in the knees behavior.

REFERENCES

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