Retropatellar pressure distribution during 3D-patellar-tracking under muscular loading – dynamic measurements with an industrial robot to evaluate the influence of ligament instabilities

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Introduction: The medial patellofemoral ligament (MPFL) has been recognized as the most important medial structure preventing lateral dislocation or subluxation of the patella (LeGrand 2007). After MPFL rupture the patella deviates from the optimal path resulting in an altered retropatellar pressure distribution. This may lead to an early degeneration with loss of function and need for endoprosthetic joint replacement. The below described method was developed and evaluated by the authors in 2011 (CAOS, London 2011). The goal of this study was to obtain first data about retropatellar pressure distribution under simulation of physiological quadriceps muscle loading and evaluate the influence of ligament instabilities.

Materials and Methods: On ten fresh-frozen cadaveric knees the quadriceps muscle was divided into 5 parts along their anatomic fiber orientation analogous to Farahmand 1998. Muscular loading was achieved by applying weights to each of the five components in proportion to the cross sectional muscle area. A total of 175 N was connected to the muscles using modified industrial cable connecting systems [Lancier Cable, Drensteinfurt / Germany].

A custom made sensor was introduced between patella and femur [Pliance, Novel / Germany]. The sensor consists of 85 single pressure measuring cells. The robot-control-unit is linked to a force-torque sensor (hybrid method). The force free knee-flexion-path from 0° to 90° was calculated during three “passive path” measurements using this hybrid robotic method. The actual measurements followed with identical parameters. At first, the retropatellar pressure distribution was recorded with intact ligaments (“native”). After cutting the MPFL the test was repeated. Then double bundle MPFL reconstruction (Schoettle 2009) was performed and the pressure distribution was obtained again. A CT-scan of the cadaver knees was performed after all tests to calculate the retropatellar 3D surface of the patella. The surface was then divided in 4 quadrants (proximal, distal, medial, lateral) and matched to the corresponding single measuring cells. Minimum, mean and maximum pressures and forces were statistically compared [IBM SPSS 21] for the complete retropatellar surface and
the 4 above described areas in each of the three tested conditions (native Patella with intact MPFL, cut and reconstructed MPFL). We followed the hypothesis that MPFL reconstruction can restore native retropatellar pressure distribution.

**Results:** Mean retropatellar force measured in all conditions of the MPFL was 64.29 N [Fmin 0.06, Fmax 194.91, SD 66.99] N. Mean retropatellar pressure was 285.69 [Pmin 0.00, Pmax 923.64, SD 303.73] kPa. The mean retropatellar force increased with knee flexion from 35 N [0° flexion] to 75 N [90° flexion]. After cutting the MPFL mean force decreased in all degrees of flexion compared to the native state but mean pressure increased for the first 50° of flexion. Reconstruction of the MPFL did not restore native conditions. The mean pressure was only 3 N above the one of the cut MPFL. Regarding the entire retropatellar surface, maximum pressure decreased with increasing degrees of flexion from 330 kPa to 275 KPa. After cutting the MPFL, maximum pressure decreased about 60 kPa. MPFL reconstruction resulted in an increased maximum pressure (+ 10 kPa) in all degrees of flexion, but the values of the native state could not be achieved.

The mean force at the medial facet of the patella decreased about 25 N after cutting the MPFL – reconstruction of the MPFL did not restore native conditions but resulted in another decrease of about 3 N. Pressure at the medial facet increased from 0°-30° flexion to a maximum of 500 kPa and decreased from 30°-90° of flexion. After cutting the MPFL, maximum pressure dropped to 400 kPa. Reconstruction resulted in an even lower maximum pressure of 300 kPa.

At the lateral facet of the patella, mean force increased with knee flexion from 5° / 43 N to 90° / 60 N. Cutting the MPFL resulted in a decreased mean force of 20 N. Reconstruction of the ligament increased the mean force about 10 N.

Maximum pressure decreased at the lateral facet with increasing knee flexion from 450 kPa at 0° to 350 kPa at 90°. Cutting the MPFL resulted in a decrease of 100 kPa and reconstruction increased the maximum pressure about 50 kPa.

At the distal facet of the patella, mean force increased up to 35° of knee flexion to 65 N and decreased from 35°-90° to 30 N. Cutting the MPFL resulted in a decrease in mean force of 10 N. Reconstruction decreased the mean force another 20 N.

Maximum pressure decreased at the distal facet with increasing knee flexion from 300 kPa to 200 kPa. Cutting the MPFL did not change the pressure and reconstruction resulted in a decrease of 100 kPa.

At the proximal facet of the patella, mean force increased from 10 N at 0° to 80 N at 90° of flexion. There were no changes through cutting or reconstruction of the MPFL.

Maximum pressure also increased from 0° 50 kPa to 90° 400 kPa. There were no changes after cutting the MPFL. Reconstruction of the ligament resulted in a slight decrease of max. pressure during the first 35° of flexion of 10 kPa.

**Conclusion:** To our knowledge this is the first experimental data of dynamic retropatellar pressure measurements on human cadaver knees in which a force free knee flexion is performed by an industrial robot under muscular quadriceps loading. There were no significant changes in retropatellar pressures after cutting the MPFL.

In contrast to our hypothesis, MPFL reconstruction does not restore native conditions at this experimental setting. It even results in lower pressures compared to the ligament free flexion, especially at the medial and distal facet. A possible explanation could be the applied surgical method which might tend to alter the 3D position of the patella during 3D-tracking.