Effect Of Vastus Medialis Obliquus Deficiency On Patellar Bone Strain After Total Knee Arthroplasty

Adeliya V. Latypova¹, Francesc Levrero Florencio¹, Dominique Pioletti², Brigitte Jolles², Alexandre Terrier, PhD¹.
¹EPFL, Lausanne, Switzerland, ²CHUV, Lausanne, Switzerland.

Disclosures:

Introduction: Patients undergoing Total Knee Arthroplasty (TKA) may still face postoperative complications related to the patellar resurfacing, such as osteonecrosis, patellar bone fracture, anterior knee pain (AKP), and implant failure [1]. Specially, AKP problem in non-resurfaced case remains the most disputed as the causes and mechanisms of its development are still unclear. Weakness of Vastus Medialis Obliquus (VMO) has been frequently associated with patellofemoral pain (PFP) syndrome. It has been shown that VMO weakness may lead to patella lateral shift [2], and that patients with PFP exhibit atrophy of the VMO [3]. However, there is a limited knowledge of the influence of VMO weakness on the strain state of the patellar bone. Bone strain is associated with bone damage. Furthermore, changes in the strain state can influence the metabolic activity of the bone cells that are known to be mechano-sensitive. The remodeling has been indeed linked with AKP [4]. The goal of this study was to build a model of the TKA with the non-resurfaced patella in order to assess the influence of VMO deficiency on the strain state of the patellar bone.

Methods: A subject-specific finite element model of the knee after TKA with the non-resurfaced patella was developed in Abaqus (Simulia, Providence, RI). The model included the femur, the tibia, the patella and the four heads of the quadriceps. Geometry of the bones and the cartilage was reconstructed from a cadaveric CT. Insertion and direction of muscle forces were estimated from literature [5] and CT. An ultra-congruent mobile-bearing knee prosthesis (FIRST, Symbios, Switzerland) was inserted according to manufacturer recommendations. The femur, the tibia and the metallic components of the prosthesis were assumed rigid. Cartilage was assumed Neo-Hookean hyperelastic (C10 = 2 MPa, k = 40 MPa). The polyethylene components (E = 572 MPa, ν = 0.4) and the patellar bone were considered as linear elastic materials. Density-elasticity relationship was used to assign non-homogeneous mechanical properties to the patellar bone [6]. Mapped apparent density was extracted from CT data. The surfaces on the patellar bone representing the sites of tendon attachments were coupled with the insertion points of the quadriceps and the patellar tendon to provide a proper transmission and distribution of the forces from the tendons to the patella. Quadriceps tendon was modelled as four linear trusses [7]. Patellar tendon was modelled as non-linear springs with force-displacement behaviour extracted from the experiments in the literature [8]. A loaded squat movement (bodyweight = 800 N) controlled by quadriceps muscle elongation was simulated from full extension to 90° of flexion. The active part of the muscles was controlled by a user-defined element. At each time increment, a subroutine synchronized the muscles of the knee through a feedback mechanism, where the lengthening and reaction force in the Vastus Intermedius controlled the forces of the other muscles. Mechanical equilibrium was reached by assigning forces proportional to their corresponding ratios. Ratios were estimated from physiological cross-section area of muscles [9]. Two cases were compared: normal and deficient VMO. Deficiency of VMO was simulated by reducing its ratio by 50%. In the posterior-superior quarter of the patella, two regions of interest (ROI) were defined: medial and lateral (Fig. 1). Bone volume of octahedral shear strain were predicted and compared in these 2 ROI through the flexion cycle, for the normal and deficient VMO.
Results: Since bone strain did not exceed 0.4% below 70° of flexion, the comparison was performed from 70 to 90° (Fig. 2, Fig. 3). The volume of highly strained bone in the lateral part of the patella was 2-fold larger in the case of VMO deficiency than for normal VMO. Conversely, it was twice smaller in the medial part for deficient VMO than for normal VMO. The medial side of the patella experienced higher strains than the lateral side, in both cases.

Discussion: In this work, we proposed a numerical model of TKA with non-resurfaced patella to assess influence of VMO deficiency on patellar bone strain. Results showed that VMO deficiency increased bone strain in the lateral part and decreased strain in the medial part of the patella. Since octahedral shear strain exceeding 0.5% may be associated with bone micro-damage [10], these results suggest that VMO deficiency could be also associated with change in metabolic activity. Thus, VMO deficiency might indeed lead to AKP development. However, further investigations are needed to assess a critical level of bone strain and volume leading to AKP. Finally, because of inter-individual variations, this hypothesis should be verified on different groups of patients.

Significance: Knowing how quadriceps muscle imbalance influences patellar bone strain in TKA can help in understanding and predicting possible complication development after surgery, such as anterior knee pain.
Figure 2: Strain volume in medial and lateral ROI for normal and deficient VMO.

Acknowledgments: This study was supported by the Inter-Institutional Center for Translational Biomechanics (EPFL-CHUV-DAL), and Symbios for providing the geometry of the prosthesis. The cadaveric CT was provided by the University of Bern.


ORS 2014 Annual Meeting
Poster No: 0970