Effect of trochlear dysplasia on patellar tracking and patellofemoral contact pressure. A musculoskeletal analysis using an efficient cartilage contact model.

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Introduction

Patellofemoral instability is often seen by orthopedic surgeons. Among its causes, dysplasia of the trochlea plays a major role. The aim of this study was to investigate the effect of trochlear dysplasia on patellar kinematics and patellofemoral contact pressure during voluntary knee extension exercise.

Methods

A specimen-specific musculoskeletal model of a natural knee was developed from computed tomography (CT) and magnetic resonance (MR) images of one cadaver specimen. Images were segmented using Mimics (Materialise NV, Leuven, Belgium) to reconstruct 3-D models of patellar, tibial and femoral bones, tibiofemoral and patellofemoral cartilages, knee ligaments and menisci.

Four additional cases were created by manual editing of the 3-D geometries of the distal femur, to represent four trochlear dysplasia types according to current classification [1] (Fig. 1a).

A 12-degree-of-freedom knee model was implemented using the AnyBody Modeling System (AMS, version 7.0, AnyBody Technology A/S, Aalborg, Denmark) for each case, following an established workflow [2].

An unloaded knee extension exercise was simulated, during which muscle forces, ligaments forces, joint contact forces and knee kinematics were simultaneously estimated using force dependent kinematics (FDK) [3]. Patellofemoral cartilage contact pressures were estimate by means of on an efficient rigid elastic foundation (EF) contact model, based on axis-aligned bounding boxes (AABB) trees for 3-D fast intersection and distance computation implemented in C++ using the Computational Geometry Algorithms Library (CGAL).

Results

Compared to the natural case, trochlear dysplasia type B resulted in 6 mm more lateral patellar translation at about 10 degrees of knee flexion and in the largest medial-lateral translation range during the trial. At knee extension, patellofemoral contact pressures were altered, especially in type B, C, and D, showing pressure concentration in the lowest portion of the patellar cartilage (Fig. 1b).

Discussion

Trochlear dysplasia resulted in altered patellar kinematics and patellofemoral contact pressure in a specimen-specific musculoskeletal knee model. The largest differences with the natural case occurred when the knee approached extension, in agreement with clinical findings on patellar dislocation. An efficient discrete cartilage contact model effectively complemented a specimen-specific knee model, without adding extra computational cost. Future research will aim at implementing real patient data from dynamic CT and formulating optimized surgical strategies for the treatment of patellofemoral instability.

Acknowledgements

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References

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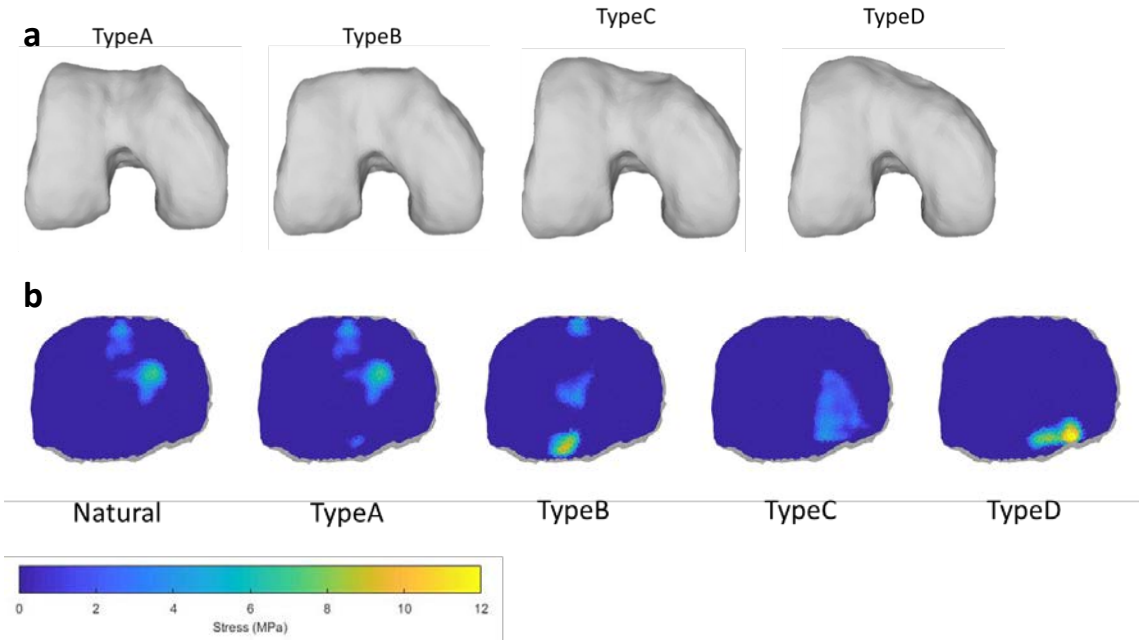

Fig. 1: a) The four cases of trochlear dysplasia models created according to Dejour classification; b) The effect of trochlear dysplasia on patellofemoral cartilage contact pressures at knee extension.