Comparison of Natural and Unresurfaced Patellofemoral Mechanics

INTRODUCTION
The decision to resurface the patella during total knee arthroplasty (TKA) remains controversial, as recent clinical results for unresurfaced patellae have been on par with resurfaced [1]. Differences in congruency between the natural patella and the femoral component affect kinematics and contact mechanics, and may alter contact stresses on the articular surface of the patellar cartilage [2], potentially leading to early degeneration or eventual resurfacing.

A femoral component with perfectly anatomic geometry may aid in restoring natural kinematics to the joint, but contact mechanics are affected not just by geometry, but also by the material properties of the contacting surfaces. The purpose of this study was to compare mechanics of the natural patella articulating against five femoral representations; natural femoral cartilage, three current Co-Cr femoral component designs (LCS, Sigma, and Attune posterior-stabilized components, DePuy, Warsaw, IN), and an idealized natural Co-Cr component, in order to assess the influence of geometry and material properties on patellofemoral (PF) mechanics.

METHODS
A population of 10 subject-specific explicit finite-element models of the PF joint were developed from MR scans of normal knees. Hexahedral meshes of the femoral and patellar cartilage were created using an automated custom-scripted algorithm and morphing approach and represented as deformable (E = 12 MPa, ν = 0.45). The analysis was performed using Abaqus/Explicit (Simulia, Providence, RI) five times for each subject with the patella articulating against: deformable femoral cartilage, LCS, Sigma, and Attune Co-Cr components, and a ‘natural’ Co-Cr component. The natural component was modeled as femoral cartilage geometry with femoral component material properties (Figure 1). Due to the greater stiffness of CoCr relative to cartilage, each femoral component was modeled as a rigid body. The extensor mechanism and retinacula of the knee were represented by 2D fiber-reinforced membranes with a 1000 N ramped load distributed among the quadriceps (vasti and rectus femoris) as the knee was flexed from full extension to 120° [3]. Six-degree-of-freedom kinematics and contact mechanics were evaluated.

RESULTS
Predicted PF kinematics and contact mechanics illustrated differences between the femoral representations. Kinematics for the natural cartilage and the natural component were identical, while differences were present between the natural knee and the femoral components, particularly in internal-external (I-E) rotation (Figure 2). I-E tracking of the patella when articulating against the dome and anatomic components was opposite to the natural knee.

The Sigma component resulted in the highest peak contact pressure throughout flexion (Figure 3). The LCS and Attune components maintained better contact in early flexion than the natural component, as the trochlear grooves of these two components extended further superior, providing a larger contact surface. Once the patella left the conforming trochlear groove, differences between implant components decreased. Contact area as a function of flexion was similar for each of the implants. Contact pressure and area patterns were similar between the natural knee and the natural Co-Cr component; however, contact pressure was consistently 1 MPa higher and contact area 20% lower for the natural Co-Cr component than with the natural knee for each subject throughout flexion (Figure 4).

DISCUSSION
Using a relatively small population of subject-specific models, unresurfaced joint mechanics were impacted by congruency of the femoral representation. In early and mid flexion, conformity between the LCS and Attune components and the unresurfaced patella resulted in lower peak contact pressure compared to the less conforming Sigma design. In deeper flexion, the differences were less. The natural Co-Cr component maintained a larger contact area and lower pressure with the patella in deeper flexion.

Despite kinematic agreement, there were substantial and consistent differences in contact mechanics between the natural femur and natural Co-Cr component, attributable to material property differences between metal and cartilage surfaces. Component designs with a more anatomic distal and posterior geometry may improve contact mechanics in later flexion; however, material property differences and the constraints of a PS design limit the available improvement.

SIGNIFICANCE
Implant design does influence unresurfaced patellofemoral mechanics in early and mid flexion, but the soft-hard bearing surface increases patellar contact pressures compared with the natural, even with perfectly anatomic geometry.

REFERENCES

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