INTRODUCTION:
Femoroacetabular impingement (FAI) is a recently proposed etiology of hip pain and early osteoarthritis (OA) of the hip, especially in young and active patients [1, 2]. Nowadays the pathomechanism of FAI is confirmed by a variety of observations from clinical centers and research studies [3, 4]. Attention has focused on the unique degeneration process associated with "cam" impingement (aspherical femoral head) and "pincer" impingement (excessive acetabular coverage). Protrusio acetabuli is the most extreme representation of a pincer-type deformity. Radiographic observations showed that joint degeneration in such a severe pincer impingement occurs in the superomedial aspect of the hip sourcil, which is not explained by the FAI concept. To better understand this unique degenerative process, 3D finite element simulations of a dysplastic, normal and severe pincer joints were compared for physiological loading cases. Furthermore, the effect of corrective acetabular rim trimming was evaluated.

METHODS:
Morphological data was collected from digital radiographs of 72 hips (21 normal, 26 dysplasia, 25 protrusio). Two parameters were extracted, the lateral-center-edge (LCE) angle and the medial-center-edge (MCE) angle. The angle of the acetabular arc is the sum of LCE+MCE. Kühnlein et al. [5] described the three-dimensional geometry of the acetabulum, based on measurements of 66 patients. The radiographic data, the acetabular model of Kühnlein et al. and the femoral model from [4] were combined into a parametric solid model. Four joint morphologies were created (Figure 1), which were then imported into ABAQUS 6.9 for meshing and solution. Solutions with element lengths of 1.8 and 0.9 mm were compared to ensure convergence.

RESULTS:
The calculated contact pressures and stresses of the severe pincer FAI were concentrated along the medial acetabular cartilage margin, whereby the peak pressure during walking was about 1.6 times that of a normal joint. For the walking case, the dysplastic configuration, compared to the severe pincer FAI, showed an opposite stress and pressure pattern having its peak values located at the anterolateral acetabular rim. Representative contact pressure data for the mid-stance phase of the walking cycle are shown in Figure 2. During all simulations no impingement (contact) occurred, hence the increased pressures and stresses were due to axial overloading.

During walking, comparison of the peak von Mises stresses at the acetabular rim yielded the following results: normal (100%), dysplasia (135%), protrusio (154%), protrusio + rim trimming (167%). Variations in contact pressure were of a similar magnitude.

DISCUSSION:
Calculated pressure and stress values were consistent with previous experimental and computational studies for the normal and dysplastic hip models. Data for the protrusio hip are not available. The predicted stresses and pressures within the acetabular cartilage during the daily activities are highly dependent on the topography of the articular lunate surface and the type of activity. Peak pressures and stresses during standing-to-sitting are of a similar magnitude to those calculated during walking, despite a lower total joint contact force, highlighting the importance also of cartilage contact area.

Significance: These findings substantiate the hypothesis that the acetabulum with severe pincer FAI (protrusio) represents a unique pathology which involves a dynamic impingement problem at the lateral edge of the acetabulum and - similar to a 'medial dysplasia' – a static overload at the medial edge of the acetabular sourcil. Based on these findings, the curative treatment of this pathomorphology would consist of a reorientation of the acetabulum rather than isolated rim trimming alone.

References: