Introduction: The main purpose of periacetabular osteotomy is to increase femoral head coverage and decrease joint contact stress in patients with dysplastic hips suffering pain and instability. The joint may become more stable with decreased pressure after proper reconstruction. On the other hand, proximal femoral osteotomy often alters hip muscle line of action, which would affect the overall hip joint contact pressure in addition to changing the area of joint contact. We postulated that properly select the type of osteotomy, the location and amount of correction could significantly affect the surgical outcome. Since the key determining factors in joint osteotomy are biomechanical in nature, analysis using visual, interactive, computational and anatomic simulation model to determine hip joint contact area and pressure distribution in normal population and in patients with dysplastic hips can be a useful preoperative planning tool. The objectives of this study were to establish the normal values of hip anatomic parameters and joint contact pressure distribution, and to apply the analysis techniques on patients underwent hip osteotomy to evaluate the validity of the proposed preoperative planning scheme.

Methods: In normals, the joint area of contact was estimated from the AP radiograph assuming that the femoral head is a perfect sphere. Hip joint resultant forces were calculated based on the estimated muscle directions (Fig. 1) [1]. To calculate joint contact pressure and ligament tension, the discrete element analysis (DEA) or the rigid body spring modeling (RBSM) technique was used [2]. In order to better express the joint force and pressure for comparative analysis, the data were normalized with respect to the BW. We have studied 41 women and 15 men with no history of lower extremity problems and radiographic abnormalities. Twelve anatomic and seven biomechanical parameters were measured and calculated. In 12 patients before and after periacetabular osteotomy for hip dysplasia, their acetabular orientation, simulated joint forces and contact pressure were determined. The median follow-up was 1.9 years (range 1.3-2.2) and the pre- and postoperative x-rays were analyzed. CT information was studied to detect changes in acetabular orientation. The clinical outcome according to the Harris hip score, the patients’ satisfaction (q-score) using a standardized questionnaire, and a visual analog scale were obtained.

Results: The head-trochanter ratio (HT), femoral head radius, pelvic height, the joint contact area, the normalized peak contact pressure, abductor force, and the joint contact force were significantly different between women and men. The normalized joint contact peak pressure was correlated with acetabular coverage and HT. In seven patients operated for hip dysplasia, the contact area increased and the peak pressure decreased postoperatively (Fig. 2). In these cases, the q-score averaged 92.1 ± 9.6, the Harris hip score was 99.4 ± 1.3, and the acetabular index angle (AC-angle) was 6.4 ± 5.8°. In two patients, the simulation analysis indicated that there was no change in loading conditions and the q-score averaged 94.1 ± 8.4, the Harris hip score was 98.5 ± 2.1, and the AC-angle was 8.5 ± 7.8°. In the remaining three patients of the clinical series studied, the computer analysis indicated better loading conditions preoperatively than postoperatively. In these cases, the q-score averaged 67.2 ± 21.8 (p=0.05, compared with the seven improved cases), the Harris hip score was 82.7 ± 26.6 (p=0.11), and the AC-angle was -1 ± 13.7° (p=0.23).

Discussion: Anatomic and biomechanical parameters involving hip joint loading varied between genders. Hence, in assessing reconstructive procedures, different normative database must be used. The computer-aided simulation using the biomechanical model of the hip can be a valuable tool in preoperative planning in hip dysplasia surgery. Periacetabular osteotomy can be effective in changing hip joint coverage but only proximal femoral osteotomy can redirect hip joint resultant force. Therefore, the type of osteotomy and amount of angular corrections to be performed must be studied in each patient based on his/her preoperative condition. This contention was supported by the biomechanical loading results in the patients before and after surgery and their short-term clinical and functional outcome. To conclude, the computer-aided simulation using biomechanical model of the hip can be a valuable tool in preoperative planning before hip reconstructive surgery for dysplasia. Planning information can be used as the scientific basis to justify image-guided surgery using operative navigation system and surgical robots. Finally, such analysis may provide a strong motivation for surgeons to achieve the precision of the correction as a means to improve treatment outcome as strongly suggested by the short-term clinical follow-up results of this study.