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A COMPARATIVE CASE STUDY OF THE PRE AND POST OPERATIVE STRESS DISTRIBUTION IN A DYSPLASTIC HIP JOINT

Freddy L. Bueno-Palomeque (1), Carlos J. Cortés-Rodríguez (1,2), Carlos D. García-Sarmiento (1,3), Mauricio Cuervo-Campos (1)

(1) Biomechanics Research Group
Universidad Nacional de Colombia
Bogotá, Colombia

(2) Department of Mechanical Engineering and Mechatronics
Universidad Nacional de Colombia
Bogotá, Colombia

(3) Department of Surgery
Universidad Nacional de Colombia
Bogotá, Colombia

INTRODUCTION

Hip dysplasia is the main cause of pain on the hip joint in young and adult people and it is the major common cause of osteoarthrosis in adults [1] [2]. A biomechanical analysis of the hip joint represents an important tool in the surgical planning field. Simulations about the behavior of the hip joint in different scenarios give us information that allow us to have a better understanding of the patient reality**,** furthermore simulations help to create a better approach about the surgery process in order to decrease or eliminate the pathology. The aim of this investigation was to obtain and compare the stress distribution on a dysplastic residual hip joint, before and after a surgery, using finite elements analysis.

METHODS

The three dimensional model was developed through computed tomography scan (CT) of the left hip of a 16 years old female patient with residual dysplasia. We took the geometrical data of the proximal femur bone and the acetabular segment of the pelvis. The patient had a Wiberg center-edge angle of 8±1º, an anteversion angle of 52±2º and an angle between the femoral shaft and the femoral neck of 150±3º (coxa valga).

The CT images of the patient were obtained using a Scanner Toshiba/Aquilion 120 Kv and 39.5 mAs, with a number of slices of 71, pixel size of 0.782mm, slice thickness of 3mm and a resolution of 512 x 512.

The three dimensional model of the hip joint was created by a reconstruction software that builds a 3D medical imaging based on a sequence of 2D DICOM data (INVESALIUS v3.0) (Figure 1).

The geometries of the femur and the acetabulum were selected from the 3D model and meshed each one applying tetrahedral elements Tet4. Ranges of segmentation were used to assign three kinds of materials to the femur: cortical bone, trabecular bone and subchondral bone. Afterwards the model was exported to the nonlinear finite element solver for biomechanics FEBIO v1.5 [3]. The pre process of the model was developed using PREVIEW v1.7 [3] and the post process with POSTVIEW v1.4 [3].

Pre-operative **Post-operative**

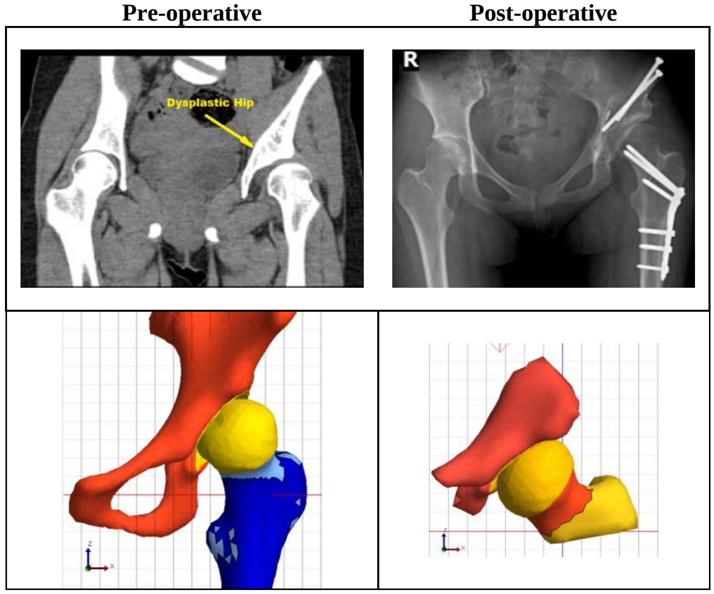

Figure 1: *Pre-operative* – CT image of dysplastic hip and the finite element model. *Post-operative* – Radiography post-operative of the patient and the articular relocated model.

Two volumes with constant thickness (1±0.3mm) were incorporated to the model between the femur and the acetabulum with the mechanic properties of the articular cartilage. Femur was represented as isotropic linear elastic and was segmented based on the densities obtained in the CT images [4]. Cortical, subchondral and trabecular bone were modeled with a Young´s Modulus of 14 GPa, 700 MPa y 1150 MPa respectively, additionally the Poisson´s ratio assigned were 0.29, 0.2 y 0.24 respectively. Articular cartilage was modeled as a homogeneous, isotropic, compressible and Neo Hookean hyper-elastic material with a Young´s Modulus of 13 MPa and a Poisson´s ratio of 0.38. The acetabular region of the pelvis was considered as a rigid body to simplify the model. The Acetabular cartilage has the same morphological characteristics of the acetabulum to enable a smooth contact, and the femoral head and the femoral cartilage have a common surface to obtain an appropriate contact.

The Femoral base was constrained in two sections. On the outside of the diaphysis (distal femur), movement was constrained in all degrees of freedom; inside the diaphysis there was a constraint only in the vertical direction.

On this model two patient positions were simulated: standing upright on two legs and single leg standing. In bipedal position the half of the weight body (WB) was applied on the acetabulum in a vertical direction. To simulate one leg standing we calculated the resultant force produced on the hip joint from the equilibrium equations for that it is necessary to add some geometrical data from images CT [5] [6]. Established the equilibrium equations, it is possible to solve the momentum and force equations on a center point located on the femoral head. We considered six muscles actuating in the equilibrium of the joint: gluteus medius, gluteus minimus, tensor fascia lata, rectus femoris, sartorius and piriformis.

Tied contact was defined between the femoral cartilage and the femoral head; and a slide contact between the acetabular and femoral cartilage.

The post-operative finite element model was developed based on the surgery process proposed by the orthopedic surgeon and a relocation of the femur and acetabulum was accomplished. A surgical cut to correct the femoral anteversion was developed, it was proposed at lesser trochanter level and a rotation of 20±2º was done on the transverse plane. Another surgical cut was developed on the pelvis to improve the covering of the femoral head. The relocation of the acetabulum consisted of a rotation of 15±2º in the coronal plane and a rotation of 2±0.3º in the transverse plane. On the 3D model the anteversion angle was reduced to 32±2º and the Wiberg center-edge angle increase to 27±2º [7]. The resultant force applied on the hip joint acted on the acetabulum in vertical direction. Stress produced on the femoral head was determined simulating the two patient positions in the pre-operative model as in the model of the hip joint relocated.

RESULTS

Due to dysplasia, the irregular coverage of the femur produced a high and concentrated stress distribution on a small posterior segment of the femoral head. The results indicate that the pathological femoral head supports a considerably higher load than the post-operative model. On a bipedal position the stress generated on the femoral head is 43% lower on the post-operative model. Similarly, on the simulation of the single leg stance, the stress generated on the femoral head is reduced in 25% after the surgery process (Figure 2).

The location of the bearing weight area was displaced in direction posterior-anterior in the simulation of the model post-operative, in contrast with the pre-surgical area which was lateralized and concentrated, and a considerably increase of this area was obtained.

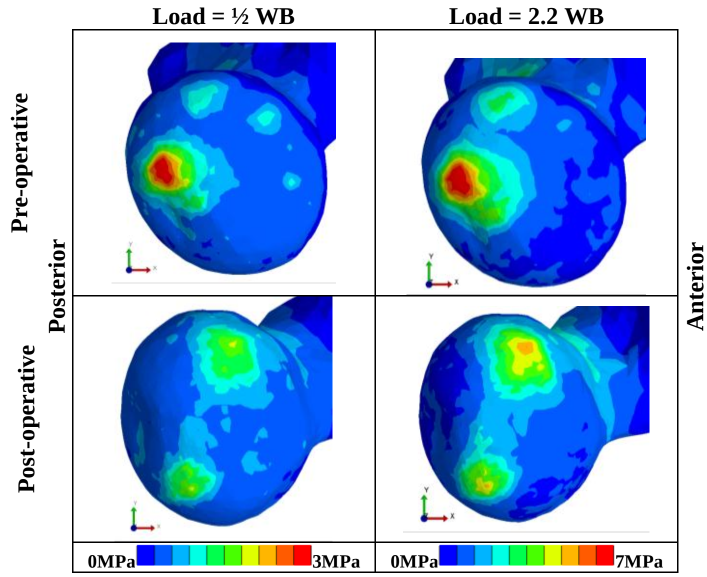

Figure 2: Effective stress produced on the femoral head. There is a higher stress and a reduced bearing weight area on the dysplastic model and there is a better load distribution on the post-operative model.

DISCUSSION

This study showed what the stress distribution on a residual dysplastic hip joint is and what would it be the stress distribution after performing a specific surgery process. Estimating the biomechanical behavior of the hip joint, starting from CT images, will provide a specific knowledge about the articular behavior of the patient. This knowledge can be useful to the surgeon at the moment of planning and evaluating different surgeries. This will contribute to the surgeon decision about what surgery process will be more appropriate to develop for a particular problem in order to obtain better results.

The stress values obtained in this study are in the ranges presented on the literature. The force applied on the vertical direction of the hip joint was calculated taking into account only six muscles and their coordinates of application according to the literature [6]. The finite elements analysis on the patient geometry allows us to obtain results nearer to the patient reality. Although there are some irregularities between the cartilages contact, it does not represent a significant factor in the results. The position of the hip joint was maintained according to the CT images and its morphology has not been largely modified in order to lose less important details.

In conclusion, this study presents a comparison about the stress distribution on a hip joint with residual dysplasia and a model in which the articular components were relocated simulating a surgery process.

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