Analysis of the stability of percutaneous fixation of acetabular fractures with mechanical experiment and FE simulation

+1Shim, V B; 2Bohme, J; 3Vaitl, P; 4Josten, C; 1Anderson, I. A
+1Auckland Bioengineering Institute, University of Auckland, New Zealand, 2University of Leipzig, Germany, v.shim@auckland.ac.nz

Introduction
Acetabular fractures are one of the most complicated and challenging injuries for trauma surgeons. Despite the advancement made during the last few decades, it is still very difficult to clearly diagnose and classify fracture types according to a clinical standards, which will guide the type of osteosynthesis to use for fracture fixation. The standard way of stabilizing a posterior wall/column fractures is by open reduction and internal fixation[1]. However a new percutaneous fixation was developed in the last decade for simple acetabular fractures with an aid of navigation devices[2]. This new technique was successfully done in a number of patients but the stability of percutaneous osteosynthesis has not been sufficiently investigated. The aim of this study is to investigate the stability of percutaneous osteosynthesis by means of mechanical experiment with synthetic bones as well as finite element models.

Methods
1. Mechanical experiment
7 synthetic pelvis (Full Male Pelvis 1301-1, Sawbones, Pacific Research Laboratories, INC, Washington, WA, USA) were used to generate acetabular fractures according to the method previously developed.[3]. All the resulting fractures resembled either posterior column or wall fractures according to Letournel’s classification. The fractures were then reduced and fixed with two screws (Titan Screws, Synthesis) by an experienced surgeon. Initial reduction of the fractures were very good with a maximum remaining crack or step of 0.7 mm. Pelvis were then placed upside down in a mounting pane and potted with acrylic cement. The pelvis were loaded in the Instron Machine (Instron 5800 series, Norwood, MA, USA) with a cyclic load that oscillated between 0N to 900N at 40N/s. At the multiple of 300N the loading was paused for 3 seconds to measure the displacement between the fragment and the bone by taking photographs of the crack. A digital SLR camera (Nikon D70) with a 50mm macro lens was used to accurately measure the small crack openings(Figure 1). As a result, the final resolution of the photographs was 10 μm. The displacement was measured in two different angles to obtain both lateral and anterior/posterior movements of the fragments (Figure 2).

2. Finite element simulation
One of the fractured pelvis and its fragment along with the two screws placed on the fragment were scanned with a Faro Arm (Siler Series Faro Arm) and a laser scanner (Model Maker H40 Laser Scanner). Clouds of data points were obtained from the laser scanner, which accurately described the shape of the fragment and location of the two screws (Figures 4 & 5). A previously developed and validated FE model of the pelvis [3][4] was then fitted to the pelvis data points to generate a fractured pelvis model (Figure 6). Likewise a FE model of the fragment was generated from the fragment data set. The same loading and boundary conditions as the experiment were used in the simulation. The force was applied from the femoral head to the fracture acetabular and the displacement between the fragment and bone was measured and compared with the experimental value. The contact between the bone and fragment was modeled with frictional contact with a friction coefficient of 0.3 while the faces where the screws were placed were modeled as a tied contact to simulate the connection between the fragment and bone.

Results
The overall amount of displacement was relatively small with the main direction of the fragment movement was in the proximal lateral posterior direction. The average displacement was around 0.4 – 0.7 mm. Considering the fact that the maximum load of our experiment was higher than normally allowed weight bearing (around 20kg after the surgery for 6 months), the stability of screw fixation was sufficient for the cyclic loading condition used.

The FE model predicted movement of the fragment with a good accuracy. The values predicted by the FE simulation were within one standard deviation except for the vertical case, where the error was the largest. This may be due to the contact conditions in the vertical direction was too strict hence did not allow the fragment to move this direction (Figure 7).

Discussions
This study examined the stability of percutaneous fixation of acetabular fractures. The mechanical experiment with synthetic pelvis showed that the displacement between fragment and bone was relatively small, indicating that percutaneous fixation may be a good alternative current gold standard of open reduction and internal fixation. The FE model showed great potential for use in analyzing fracture fixation techniques. Our model was able to predict the movement of the fragment with a reasonable accuracy. The future study will be to apply various physiological loading conditions to identify activities that adversely affect fracture fixation. Moreover various soft tissues will be added to examine the role they play in stabilizing fractures.

Reference