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Original article

Primary cup stability in THA with augmentation of acetabular defect. A comparison of healthy and osteoporotic bone☆

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ABSTRACT

Background context: Reconstruction of acetabular defect has been advocated as standard procedure in total hip arthroplasty. The presence of bony defects at the acetabulum is viewed as a cause of instability and acetabular wall augmentation is often used without proper consideration of surrounding bone density. The initial cup-bone stability is, however, a challenge and a number of studies supported by clinical follow-ups of patients suggested that if the structural graft needs supporting more than 50% of the acetabular component, a reconstruction cage device spanning ilium to ischium should be preferred to protect the graft and provide structural stability. This study aims to (1) investigate the relationship between cup motion and bone density and (2) quantify the re-distribution of stress at the defect site after augmentation.
Hyphotesis: Paprosky type I or II, acetabular defects, when reconstructed with bone screws supported by bioabsorbable calcified triglyceride bone cement are significantly less effective for osteoporotic bone than healthy bone.
Materials and methods: Acetabular wall defects were reconstructed on six cadaveric subjects with bioabsorbable calcified triglyceride bone cement using a re-bar technique. Data of the specimen with higher bone density was used to validate a Finite Element Model. Values of bone apparent density ranging from healthy to osteoporotic were simulated to evaluate (1) the cup motion, through both displacement and rotation, (2) and the von Mises stress distribution.
Results: Defect reconstruction with bone screws and bioabsorbable calcified triglyceride bone cement results in a re-distribution of stress at the defect site. For a reduction of 65% in bone density, the cup displacement was similar to a healthy bone for loads not exceeding 300 N, as load progressed up to 1500 N, the reconstructed defect showed increase of 99 μm (128%) in displacement and of 0.08° in rotation angle.
Conclusions: Based on the results, we suggest that an alternative solution to wall defect augmentation with bone screws supported by bioabsorbable calcified triglyceride bone cement, be used for osteoporotic bone.
Level of evidence: Level IV, experimental and cadaveric study.

1. Introduction

The number of primary hip replacements has increased substantially in the United States between 1990 and 2002 [1]. Understanding initial cup stability is especially important in a total hip replacement (THR) done in the presence of defects on the acetabular wall. The stability and fixation can be compromised due to deficiencies on the posterior or anterior acetabular walls [2]. A number of corrective methods for stabilizing the wall prior to cup implantation are currently in use, such as bone grafting [3,4] or screw fixation [5]. A number of studies supported by clinical follow-ups of patients suggested that if the structural graft supports more than 50% of the acetabular component, a reconstruction cage device spanning ilium to ischium should be used to protect the graft and provide structural stability [6]. Noted is a complication rate of 21.2% in the mid to long-term of these procedures. It has also been suggested that cementless components be used to treat major acetabular bone loss [7–9]. Winkler et al. [10] investigated defects augmentation with an antibiotic compound for 37

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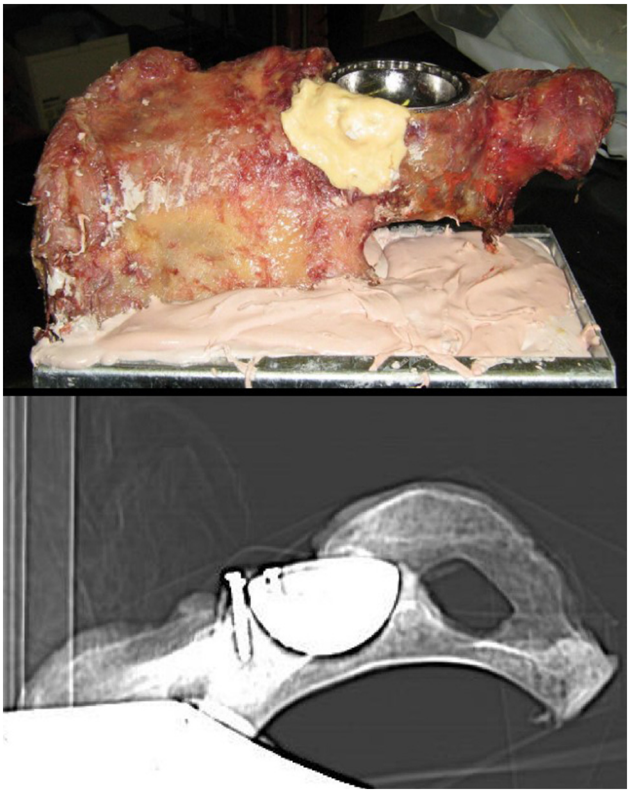

Fig. 1. CT Scout image and actual picture of the implanted pelvis after acetabular augmentation.

patients with success rate of 92 % after 4.4 years. There are several ways to measure and evaluate the defect and hence their classification and method of repair might not be unique [11,12]. Because defects may also occur in conjunction with various levels of osteoporosis characterized by reduced bone density, we hypothesized that Paprosky type I or II, acetabular defects, when reconstructed with bone screws supported by bioabsorbable calcified triglyceride bone cement are significantly less effective for osteoporotic than for healthy bone. This hypothesis was tested using a validated Finite Element Model simulated with different bone apparent densities and both cup displacement and rotation were evaluated as measure of cup motion. Furthermore, the von Mises stresses for all three cases were analyzed to identify threshold limits of stress distribution. This study aims to:

- investigate the relationship between cup motion and bone density;
- quantify the re-distribution of stress at the defect site after augmentation.

2. Material and methods

2.1. Material

The present study is based on six cadaveric subjects with age of 79.4 ± 7.8. We harvested one pelvis side from each subject and measured for all, the distance from the Posterior (PSIS) to the Anterior (ASIS) iliac spines of 162.9 ± 7.66 mm. To develop the 3D FEM, a specimen characterized by a rim circumference of 135 mm, a femoral head diameter of 38.6 mm and a distance ASIS-PSIS of 160.3 mm was selected. The latter is characterized by the highest Hounsfield unit values measured in area 2 (posteroinferior acetabular quadrant) as described by Dalstra et al. [13] and located on the opposite side of the defect.

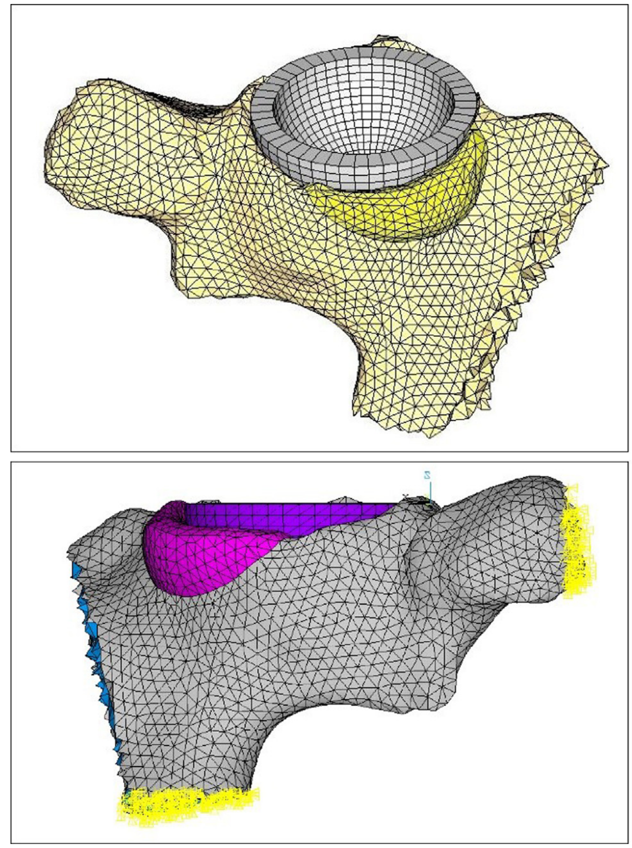

Fig. 2. 3D reconstruction of the hemi-pelvis following defect creation and cup placement and Boundary condition adopted.

2.2. Defect reconstruction

For an intact pelvis, an artificial defect with length of 41.5 mm and depth of 12.5 mm was created on the posterior acetabular wall using a bone rongeur. The resulted acetabular wall defect was less than 50% and was reconstructed with bone screws supported by bioabsorbable calcified triglyceride bone cement (Kryptonite^{TM} Bone Cement, Doctors Research Group, Oxford, CT) [14]. The reconstruction was reinforced by three Zimmer 2.7-mm Cortical Screws (Zimmer, Inc. Warsaw, IN) with length of 22 mm and hex size of 2.5 mm located equidistant from one another within the defect. After the defect reconstruction, a 54-mm DePuy Pinnacle acetabular cup (DePuy, Warsaw, IN) was press-fit with 1 mm of under-reaming. Considering that the cup inclination doesn't influence the migration [15], the cup was oriented with an anteversion of 12° to help with sensors placements (Fig. 1).

2.3. Finite element model

Diagnostic images obtained through a CT scan using a Bright-Speed (GE Medical Systems, Little Chalfont, UK) scanner (slice thickness of 0.625 mm, pixel size of 0.422 mm, field view of 216 mm) were taken of the complete hemi-pelvis from the selected cadaveric female subject prior to cup implantation in order to develop a 3D reconstruction of the hemi-pelvis. The 3D reconstruction of the hemi-pelvis was constructed and thresholding done on the Hounsfield scale to allow for material property segmentation [16,17]. A Boolean subtraction was used to simulate reaming of the acetabulum with a diameter of 53 mm (Fig. 2).