Stress Fracture of the Inferior Pubic Ramus after Periacetabular Osteotomy ~ Biomechanical Study Using a Finite Element Model

INTRODUCTION

Periacetabular osteotomy (PAO) is a useful treatment for patients with dysplastic hips and has been performed for the young patients with or without osteoarthritis of the hips. We have occasionally experienced inferior pubic ramus fractures in patients several months after PAO (Figure 1). Stress fractures of the pubis are known to occur in athletes or patients who have undergone total hip or knee arthroplasty. Although the causes of such fractures are reported to be tensile stress from the adductor muscles or leg length discrepancy, no patients in this series had high activity after PAO or obvious leg length discrepancies. We supposed that the superior pubic ramus and the ischium were shifted from the weight bearing axis after osteotomy, thus causing a load concentration at the inferior ramus.

A computed tomography (CT) based finite element (FE) model was used to ascertain the stress load on the pubis before and after PAO. CT-based FE models are known to be able to make accurate predictions on fracture loads on femur or vertebra. Several recent studies of FE models have verified that the predictive strength of the bones significantly correlated with the actual measured bone strength. We studied the load stress on the pelvis before and after PAO using a CT-based FE model to investigate the cause of inferior pubic fracture.

METHODS

We examined 4 woman patients aged 24, 30, 31, and 50 years old who underwent PAO with a diagnosis of acetabular dysplasia. CT scans were performed at both 2-weeks before and 2-weeks after surgery. The three-dimensional FE models were constructed from CT data using Mechanical Finder software (Research Center of Computational Mechanics Inc., Tokyo, Japan). We set each element based on a previously dependable FE model. The trabecular bone was simulated using 1 mm linear tetrahedral elements, and the outer cortex was modeled using 1 mm triangular plates with a thickness of 0.4 mm (Figure 2). To allow for bone heterogeneity, the mechanical properties of each element were computed from the Hounsfield unit value. Ash density of each voxel was determined from the linear regression equation created by the values of the calibration phantom. Young’s modulus of each triangular plate was set as 10 GPa, Poisson’s ratio of each element was set as 0.4. We applied a vertical force of 1500N (3 times body weight) to the bottom of the femur. The sacroiliac joint and pubic symphysis areas were completely restrained. Each element was assumed to yield when its Drucker-Prager equivalent stress reached the element yield stress. Institutional review board approval and informed consent were obtained from all patients.

RESULTS

The load-stress before PAO was distributed across the superior pubic ramus and into the whole inferior ramus. The load on the superior ramus was higher than that on the inferior ramus. The load-stress after PAO was concentrated on the inferior ramus without the concentration on the superior ramus (Figure 3). The equivalent stress on the inferior pubic ramus after PAO (1.54-fold) was compared with that before (Figure 4).

DISCUSSION

Although stress fractures of the pubis have been reported in active young athletes and patients after total hip or knee arthroplasty, fractures after PAO have not been well documented. Normally, the load on the obturator ring is higher in the superior pubic ramus than the inferior ramus. However, when the superior ramus is osteotomized during PAO, load transmission occurs only through the inferior ramus. Although pubic stress fractures seem not so problematic because they are generally healed conservatively, patients experience long durations of symptoms related to these fractures. Our results showed that if the region of the osteotomy in the superior pubic ramus was widely separated, the load-stress on the inferior pubic ramus was high. Therefore we postulated that the weight bearing for the ipsilateral limb should be restrained until a callus appears at the inferior ramus radiographically.

A limitation here is that a mechanical test for the pelvic bone was not conducted to verify our analyses. However, because we constructed the FE model based on previously dependable models, we believe importance needs to be attached to the increment of the load at inferior pubic ramus.

References