Investigating Stress Changes in Fragility Fractures of the Pelvis due to Altered Falling Postures using Finite Element Analysis

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INTRODUCTION

As the global population continues to grow, the increase in the elderly population has led to a rise in the incidence of fragility fractures. Among these fractures, fragility fractures of the pelvis (FFP) have been on the rise, becoming more frequently encountered in routine clinical practice, similar to proximal femoral fractures. However, the mechanisms underlying FFP occurrence and fracture progression remain elusive. In this study, we employed finite element analysis to investigate the mechanisms of fracture occurrence by varying falling positions.

MATERIAL AND METHODS

CT data from actual case with FFP in woman in their 60s who underwent treatment was utilized. Informed consent was obtained from the patient for the use of her data. Initially, a three-dimensional pelvic model was constructed using finite element analysis software (mechanical finder ver. 12). A cylindrical model with dimensions 6 cm in diameter and 4 cm in height, superimposed by 2 mm at the sacral upper edge, was created. Additionally, a rectangular prism model measuring 5 cm × 5 cm × 3 cm was created, with the pubic symphysis and bilateral proximal pubic regions superimposed by approximately 2 mm. Mesh generation for these 3D models was performed using a 4 mm tetrahedron, with attached shells. Material properties were defined as follows; bone material was corrected using Keyak's conversion formula for CT values, and the cylindrical and rectangular prism models were assigned resin properties (Young's modulus 372, Poisson's ratio 0.4). Constraints were applied by fully constraining the cylindrical and rectangular prism materials. A load of approximately 4000 N, corresponding to approximately eight times the body weight, was applied to both the left and right ischial bones. To evaluate whether the fracture pattern changes with the falling position, the load axis was altered. The axis passing through the center of the left and right ischial tuberosities and the center of the superior plane of the L1 sacrum was set as 0°, and finite element analysis was conducted with axes tilted at 20°, 40°, and 60° to simulate a posteriorly tilted pelvic position during a fall (figure 1). The von Mises stresses were evaluated for six surface points of the left and right superior pubic rami, sciatic buttress, and S1 alar for these four axes. Furthermore, to examine whether changes in posture led to alterations in fracture patterns, a load of up to 10,000 N, applied in 200N increments to the left and right ischial bones, was used to determine the stress at which fracture occurred in the pubic rami and sacrum.

RESULTS

Von Mises stress values of the surface in the left and right superior pubic rami, iliac bones, and sacrum were as follows: at 0° tilt, 34.1/31.7/131.5/85.6/86.6/73.0 MPa; at 20° tilt, 37.8/42.5/101.4/71.2/70.9/59.8MPa; at 40° tilt, 41.9/49.3/71.3/82.1/59.8/50.6MPa; and at 60° tilt, 53.6/65.3/69.8/44.4/18.7/18.2MPa, respectively (Figure 2). Additionally, when the right and left superior pubic rami elements began to destruction, the stresses were 4600/4600N at 0° tilt, 5400/5400N at 20° tilt, 4800/4600 N at 40° tilt, 4200/4200N at 60° tilt, respectively (figure 3). Furthermore, when the right and left sacral surface elements began to destruction, the stresses were 4800/4600 N at 0° tilt, 5600/5600 N at 20° tilt, 5000/4800 N at 40° tilt, 4200/4200N at 60° tilt, respectively.

DISCUSSION

The classification and treatment of FFP often rely on the Rommens classification. In this study, it was observed that as the tilt of the pelvic position increased, stress on the sacrum decreased, while stress on the pubic rami increased. This suggests that the stress distribution on the pelvis changes with the posture during a fall and may be related to the type of fracture. Furthermore, it was evident from nonlinear analysis results that fractures in the pubic symphysis initiated once stresses exceeded 4000 N, indicating that Rommens type Ia fractures represent initial fractures (figure 3).

SIGNIFICANCE/CLINICAL RELEVANCE

The results of this study showed that postural falls altered the anterior and posterior pelvic stresses, but pubic fractures are more likely to occur early in the fall. Thus, the presence of groin pain despite a posterior fall may indicate FFP.

IMAGE

Figure1

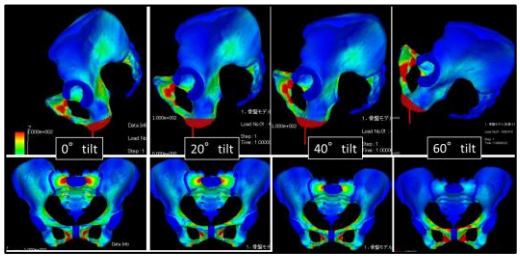

Figure 2

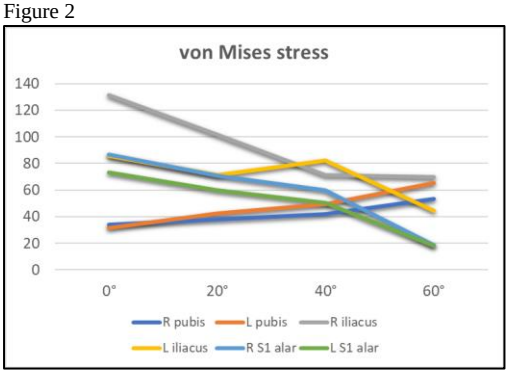

Figure 3