BIOMECHANICAL EFFECTS OF CEMENT AUGMENTATION IN THE TREATMENT OF INTERTROCHANTERIC FRACTURES WITH COMPRESSION HIP SCREW SYSTEMS IN RELATION TO OSTEOPOROSIS OF VARYING DEGREES

Introduction: Screw cut-out and non-union have been cited as major complications with hip screw systems for the treatment of intertrochanteric femoral fractures. Recently, cement augmentation of hip screw systems has been introduced to provide better purchase of the screw. However, its effectiveness is not entirely clear when the various degrees of osteoporosis has progressed within the femoral head region. This study investigates the biomechanical efficacy of cement augmentation technique for varying degrees of osteoporotic femur. For this purpose, the stress distributions within the femur and the surgical construct was assessed. The relative movement at the interfacial junctions were predicted to assess its fixation strength that is critical for post-op bony healing.

Methods: A three-dimensional finite element model of the femur was constructed using geometric data of a patient acquired from computed tomography(CT) scans. Intertrochanteric fracture was simulated by assigning a fracture plane from the greater trochanter to the lesser trochanter at 30 degrees with respect to the long axis of the femur. Based on this hip fracture model, two types of surgical model were generated. One is the non-cemented model (NC) in which only the hip screw assembly was added to the femur and the other is the cement-augmented model (CA) where the cement mantle was added to surround the hip screw (Fig. 1). The distance from the apex of the femoral head to the tip of the screw known as Tip-Apex Distance(TAD) was set at 20-24mm near the center of the femoral head according to suggestion by Baumgaertner et al. The average thickness of the cement mantle was determined as 12.5mm distributed uniformly over the hip screw based on the clinical experience of one of the authors (STK). To accommodate the trabecular structures such as primary compression trabeculae, anisotropic material properties were assigned for the cancellous portions of the femur (Ex = Ey, Ez) [2]. The degree of osteoporosis was varied by assigning appropriate modulus of elasticity according to the classification by Singh Index [3]. To simulate the interfacial conditions, appropriate friction coefficients (μ) were assigned at the fracture plane (μ=0.3), the interface between screw and surrounding cancellous bone (μ=0.5), and between the screw and the cement (μ=0.2)[4,5]. 2014N of compressive loading in a cubic cosine distribution was simulated on the top of the femoral head at angles of 12 and 26 degrees in sagittal and transverse planes, respectively. This loading condition is designed to simulate the after heel strike phase in a gait cycle in which the highest compressive load is applied to the femur. It was assumed that the distal part of the model was fixed in all directions. Eight-noded 3-D brick elements were used for the entire model except for the interfacial regions where the 3-D contact elements were used. Total numbers of element and node were 9603 and 11094, respectively. Static and nonlinearity conditions were assumed and ANSYS (Swanson Analysis Corp., USA) was used.

Results: Compressive stress and interfacial movement results are shown for the cement-augmented (CA) and non-cemented (NC) with respect to various Singh Index (Table. 1). Also listed are the corresponding compressive strength values for the cancellous bone as affected by osteoporosis. Results showed that cement augmentation had resulted in decrease in stresses in the cancellous bone, an indication of favorable stress transfer due to the addition of bone cement. It was also observed that cement augmentation was far more effective in reducing the stress in more severe osteoporosis as shown with maximum 27.9 % reduction in Singh Index of 1. However, for Singh Index of 3 or less, even the cement augmentation was not able to reduce the peak stress level lower than the deteriorated cancellous bone strength due to osteoporosis. Relative micromotion results at the screw interface indicated that cement augmentation had reduced the micromotion considerably (from 0.772mm to 0.012mm, a reduction of 98%). From there on the relative percent changes remain quite constant at about 87%.

Discussion: This study investigated the biomechanical advantages of bone cement augmentation in hip screw fixation in terms of varying degrees of simulated osteoporosis.

Relative micromotion results at the screw interface indicated that cement augmentation had reduced the micromotion considerably (from 0.772mm to 0.012mm, a reduction of 98%). From there on the relative percent changes remain quite constant at about 87%.

Fig. 1. FE models, (A) non-cemented(NC) (B) cement-augmented(CA)

Table 1. Comparison of peak compressive stress (PCS) and relative micromotion for the non-cemented (NC) and the cement-augmented (CA) cases

<table>
<thead>
<tr>
<th>Singh Index (g/cm²)</th>
<th>1</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancellous region</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC (MPa)</td>
<td>6.8</td>
<td>5.3</td>
<td>5.0</td>
<td>4.9</td>
</tr>
<tr>
<td>CA (MPa)</td>
<td>4.9</td>
<td>4.3</td>
<td>4.2</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Relative %change in PCS

| Compressive strength (MPa) | -27.9 | -18.9 | -16.0 | -18.4 |
| Micromotion at the screw junction (mm) | 0.772 | 0.085 | 0.090 | 0.083 |
| CA (mm) | 0.010 | 0.011 | 0.011 | 0.010 |

Relative %change in Micromotion

-98.4 -87.0 -87.7 -87.9

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