Comparison of Mechanical Stress between Two Different Types of Femoral Implants 
Using Finite Element Analysis

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INTRODUCTION

There are various types of femoral stem for total hip arthroplasty (THA), and each implant has its own concept. For example, the Zweymuller type has a characteristic rectangular shape that makes solid fixation in the distal femur possible. On the contrary, the fit and fill type stem produces stable fixation relatively in the proximal femur. Since patterns of mechanical stress are likely to depend on the type of femoral stem, it would be useful to understand how the mechanical stress differs according to the stem type, which might influence the bone mineral density (BMD) change after THA. However, there have been few studies concerning the nature of the mechanical stress around different femoral implants after THA.

The purpose of this study was therefore to compare the difference in mechanical stress conditions between Zweymuller type and fit and fill type implants.

METHODS

A total of 10 cases that underwent THA for osteoarthritis (OA) or osteonecrosis (ON) with SL-plus® (Smith & Nephew Memphis, Tennessee) or Versys® Fiber Metal mid coat (Zimmer, Inc. Warsaw, Indiana) were submitted to this study. SL-plus is a typical Zweymuller type implant, and Versys is a fit and fill type. Table 1 shows the demographic data of each group.

Table 1. Patient characteristics of each group.

<table>
<thead>
<tr>
<th>Implants</th>
<th>SL-plus</th>
<th>Versys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>5 cases (all female)</td>
<td>5 cases (all female)</td>
</tr>
<tr>
<td>Mean age</td>
<td>62.6 (54-72)</td>
<td>64.2 (57-69)</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>OA 5 cases</td>
<td>OA 3 cases, ON 2 cases</td>
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</tbody>
</table>

CT scans were performed before and after THA. A three-dimensional model of each femur was made from the CT data. After adding the information about loading conditions (2400N to the femoral head, and 1200N to the greater trochanter, in a direction 15° and 20° from the femoral axis, respectively), finite element analysis was performed using Mechanical Finder® (Research Center of Computational Mechanics, Inc., Shinagawa Tokyo) (Fig 1). Mechanical stress was evaluated in each region of interest (ROI) based on Gruen’s zones. We also analyzed the difference in stress before and after THA in each case.

RESULTS

The strongest stress was confirmed in Zone 4, whereas Zone 7 was revealed to have the weakest stress for both types. The SL-plus Group exhibited less mechanical stress in Zone 7, and higher stress in Zone 4 than the Versys Group (p < 0.05) (Fig.2).

In Zone 4 on both the lateral and medial sides, stress increased post-operatively (Figs. 3 and 4), whereas no change was recognized in other zones.

DISCUSSION

The difference in mechanical stress in Zones 4 and 7 between the Zweymuller type and fit and fill type was demonstrated, which is believed to be caused by the difference in fixation sites in the femur. The Zweymuller type exhibited less stress in the proximal zone and more stress in the distal zone than the fit and fill type. These results were compatible with the concept of the Zweymuller type stem. Although the number of cases included in the current study is limited, these mechanical stress characteristics might be related to changes in bone mineral density and stress shielding after THA.