INTRODUCTION

In total knee arthroplasty, the most severe complication is polyethylene wear. Most previous studies including \textit{in vitro} biomechanical testing and finite element analysis to predict the stresses on the polyethylene components of total knee prostheses were assumed that the knee components were at the neutral position or ideal contact alignment. It is very difficult to maintain an ideal alignment of the knee prosthesis in \textit{in vivo} circumstance. Additionally, many retrieval analyses of polyethylene wear had proved the malalignment would accelerate the wear rate. However, the effect of malalignment on polyethylene wears of different designs of knee prostheses has not been investigated extensively. The objective of this study was using three-dimensional finite element analysis to investigate the effect of malalignment on stress in tibial polyethylene component of total knee prostheses.

METHODS

Three-dimensional finite element models of the tibiofemoral joint of knee prostheses for three different designs were constructed. The conventional parameters used in knee design of those three knee prostheses were summarized in Table 1. Three malalignment conditions including the medial translation (0.25, 0.5 and 1.0 mm), internal rotation (1, 3 and 5 degrees), and varus tilt (1, 3 and 5 degrees) of the femoral component relative to the tibial component were simulated (Figure 1). A compression load of 3000 N was applied to the tibiofemoral joint at 0° of flexion. The maximum contact stress and von Mises stress in the tibial component were compared to investigate the effects of malalignment.

Table 1: Three different designs of knee prostheses which were defined by varying the frontal parameters of femoral and tibial components.

<table>
<thead>
<tr>
<th>Model</th>
<th>Femoral frontal radius (mm)</th>
<th>Tibial frontal radius (mm)</th>
<th>Femoral sagittal radius (mm)</th>
<th>Tibial sagittal radius (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFF</td>
<td>120</td>
<td>120</td>
<td>34.5</td>
<td>90</td>
</tr>
<tr>
<td>HCC</td>
<td>70</td>
<td>72</td>
<td>34.5</td>
<td>90</td>
</tr>
<tr>
<td>MCC</td>
<td>70</td>
<td>80</td>
<td>34.5</td>
<td>90</td>
</tr>
</tbody>
</table>

Note: HFF: high conformity flat-on-flat design. HCC: high conformity curve-on-curve design. MCC: medium conformity curve-on-curve design.

Fig. 1: The femoral component of finite element model was at (A) neutral position, (B) maltranslation condition, (C) malrotation condition, and (D) varus tilt condition.

DISCUSSION

Matsuda et al.\textsuperscript{1} used an experimental setup to investigate the effect of varus tilt on contact stresses in five total knee prostheses. They divided those knee prostheses into two groups - the curve-on-curve and flat-on-flat groups. Their results showed that the maximum contact stress increased greater for flat-on-flat design than curve-on-curve one when the tibial component was 5° of varus tilt at 15° of flexion. In our study, the increase of maximum contact pressure was greater in flat-on-flat design than curve-on-curve design of knee prostheses when the femoral component was 5° of varus tilt at 0° of flexion. Our results showed the same tendency with Matsuda’s study. The limitations of finite element analysis were that the maximum medial mal-translation distance was one millimeter, and the maximum rotation and varus tilt’s angle was five degrees. To approach the actual condition in vivo, the larger translation distance, and larger rotation angle need to be further investigated in the future study.

This study revealed that the malalignment in medial translation and varus tilt, especially in varus tilt of the femoral component would significantly increase the stresses in the tibial component for those three designs of knee prostheses. The high conformity curve-on-curve design of knee prosthesis showed a smaller increase in the stresses than the high conformity flat-on-flat and medium conformity curve-on-curve designs under malalignment conditions. Therefore, the high conformity curve-on-curve design of knee prosthesis has the minimal risk of polyethylene wear under malalignment conditions.

REFERENCE


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