A multicenter evaluation of acetabular cup positioning in robotic-assisted total hip arthroplasty

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Introduction: In total hip arthroplasty, the positioning of the acetabular cup, in particular, has been shown to play an important role in the survivorship of the prosthetic joint. The commonly accepted “safe zone” extends from 5-30° of anteversion to 30-50° of inclination. However, several studies have utilized a more restrictive safe zone of 5-25° of anteversion and 30-45° of inclination, a modification of the Lewinnek zone. By implanting the components within one of these two windows, or ‘safe zones’, there is a decreased risk of complications, including dislocation. However, several studies have documented that, in practice, more than 50% of these components are not positioned in either established safe zone. It has been shown that surgeons who perform a high volume of cases per year are more likely to implant the components within the acceptable ranges. However, in practice, low-volume, general orthopaedic surgeons perform the majority of total hip arthroplasty procedures. Many attempts have been made to develop a more reliable method of positioning the acetabular component. Robotic-assisted surgery is one such method that has been introduced in order to improve the precision of component placement. The purpose of this study was to compare the resulting position of the acetabular component after robotic-assisted surgery with the intraoperative robotic data to determine if improved accuracy can be achieved with the robotic-assisted method.

Methods: One hundred and nineteen patients received THA, at four different medical centers in the United States, using a haptic robotic arm. Pre-operative CT scans were obtained for all patients and used during the planning of the procedure, at which point the proposed component size and positioning was determined. At the time of surgery, markers were placed in the pelvis using bone pins in order to register the three-dimensional position of the pelvis. Preparation of the acetabular bone bed, as well as impaction of the acetabular component itself, was performed using the robotic device. The raw data file collected from the robot was run through a script to parse out all relevant demographic and intraoperative information, including: gender, operating side, implant type, cup size, number of reamers used/final reamer size, impaction depth, cup inclination and cup version as executed. Using an AP Pelvis and Cross-Table Lateral radiograph, each patient’s resulting acetabular inclination and version was measured using the Hip Analysis Suite software. The component position retrieved from the robot was compared to the measured values from the radiographs. The positioning data was compared to two safe zones: the commonly accepted Lewinnek zone of 5-30° of anteversion and 30-50° of inclination, and the more restricted zone of 5-25° of anteversion and 30-45° of inclination.

Results: Of the 119 surgeries performed, 110 could be read with the hip analysis suite software. Table 1 shows the average values of the cup position of the pre-op plan, the inter-op measurement, and the post-op radiographic determination. Radiographically, the average inclination was 40.4° ± 4.1° with a range of 27.4°-53.7° and the average anteversion was 21.5° ± 6.1° with a range of 5.2°-42.6°. Figure 1 displays the inter-operative position data in relation to the two safe zones. As measured inter-operatively, 100% of the components fell within the Lewinnek safe zone and 96% fell within the more restrictive safe zone. Radiographically, 88% of the cases fell within the Lewinnek safe zone and 73% fell within the restrictive...
safe zone. The mean difference between the inclination and version of the component determined by the robot and by radiographic analysis was 0.31° and 2.1° respectively.

**Conclusions:** The inclination and version of the acetabular components implanted with robotic assistance as determined inter-operatively were within the commonly accepted limits in all cases. Variations between the cup positions determined inter-operatively and from the post-operative radiographs are related to differences in the radiographic project of the hip and the robotic registration of the pelvis from CT images. In no procedure was the radiographic inclination greater than 54° or version less than 5°. In this study, the use of robotic-assisted positioning of the acetabular component has significantly reduced the variability of component orientation. This improved reliability of positioning should result in an increase of favorable functioning, and a decrease in early complications such as dislocation, impingement, and component wear.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Op Plan</th>
<th>Intra-Op Robotic Measurements</th>
<th>Martell</th>
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<tbody>
<tr>
<td>Inclination</td>
<td>40.0° ± 1.2°</td>
<td>39.9° ± 2.0°</td>
<td>40.4° ± 4.1°</td>
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<tr>
<td>Version</td>
<td>18.7° ± 3.1°</td>
<td>18.6° ± 3.9°</td>
<td>21.5° ± 6.1°</td>
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<tr>
<td>Count (n)</td>
<td>119</td>
<td>119</td>
<td>110</td>
</tr>
</tbody>
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*Table 1. The average and standard deviation of acetabular cup measurements.*

**References**
1. Lewinnek et al
2. Malchau et al