Evaluation of the alignment discrepancies during total knee arthroplasty using an image-free computer-assisted guidance system

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Introduction: Clinical outcomes of total knee arthroplasty (TKA) are especially sensitive to lower extremity alignment and implant positioning, with research associating tibial bone cuts in more than 3° of residual varus with higher risk of implant failure. From pre-operative planning to final implant cementation, TKA preparation is defined by a succession of many individual steps, each presenting potential sources of error that can result in devices being implanted out of the desired range of alignment.

Figure 1: Alignment acquisition sequence starting from target planning (A), cutting block adjustment (B), attachment of the cutting block to the bone (C), making bone cut and final checks (D)
The objective of our study was to evaluate alignment discrepancy occurring during different steps associated with TKA using a novel image-free CAOS guidance system (Exactech GPS, Blue-Ortho, Grenoble, FR).

**Materials and Methods:** We assembled seven synthetic neutral knee inserts (MITA knee insert M-00598, Medical Models, Bristol, UK) with a commercially available artificial leg (MITA trainer leg M-00058, Medical Models, Bristol, UK).

A pre-surgical profile was established to define resection parameters for the proximal tibial and distal femoral cuts (Figure 1A). The proximal tibial cut was defined by the resection level off a medial plateau reference point, the varus/valgus alignment and the slope angle. The lateral resection was therefore an output and not reported. A similar rationale applies to the medial resection of the distal femoral cut.

First, the Exactech GPS was used to acquire the pre-identified landmarks. Next, the cutting block was adjusted to match the resection targets and fixed to the bone using locking pins. Bone cuts were performed, and finally, the actual cuts were checked. Data from the guidance system were collected at three separate steps: (1) cutting block adjusted but not pinned to the bone (Figure 1B), (2) cutting block adjusted and pinned to the bone (Figure 1C) and (3) after the cuts were checked (Figure 1D). These data were then compared to the resection target parameters to track potential dispersions occurring during the process.

<table>
<thead>
<tr>
<th>Bone</th>
<th>Parameter</th>
<th>Adjusted vs. targeted</th>
<th>Attached vs. targeted</th>
<th>Checked vs. targeted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>[Min, Max]</td>
<td>Mean</td>
</tr>
<tr>
<td>Tibia</td>
<td>Medial resection thickness (mm)</td>
<td>-0.03</td>
<td>0.10</td>
<td>[-0.20, 0.10]</td>
</tr>
<tr>
<td></td>
<td>Varus/Valgus (°)*</td>
<td>-0.09</td>
<td>0.07</td>
<td>[-0.20, 0.00]</td>
</tr>
<tr>
<td></td>
<td>Slope (°)*</td>
<td>0.04</td>
<td>0.08</td>
<td>[0.00, 0.20]</td>
</tr>
<tr>
<td>Femur**</td>
<td>Lateral resection thickness (mm)</td>
<td>0.08</td>
<td>0.18</td>
<td>[-0.10, 0.40]</td>
</tr>
<tr>
<td></td>
<td>Varus/Valgus (°)*</td>
<td>0.05</td>
<td>0.10</td>
<td>[-0.10, 0.20]</td>
</tr>
<tr>
<td></td>
<td>Flexion/Extension (°)*</td>
<td>-0.03</td>
<td>0.10</td>
<td>[-0.20, 0.10]</td>
</tr>
</tbody>
</table>

*Varus/Valgus: varus is signed negative, valgus is signed positive; Slope: decreased slope is signed negative, increased slope is signed positive; Flexion/Extension: Flexion is signed negative, extension is signed positive

**Based on six bones only, as the locking pins dissociated from the synthetic bone during the preparation of femur #2

Table I: Differences in data between the sequences
**Results:** Resection and rotational measurement data for both the tibia and femur along the study are given in Table I.

For all measurement data, the dispersions were limited as the difference in bone resection thickness and angular measurement along the process were less than 1 mm and 1°, respectively.

For each studied parameter, the mean value was nominal, demonstrating that the distribution was well centered. This being said, there was a consistent derive of the distal femoral in extension (up to 0.9°) along the preparation, resulting in lower than expected resection of the distal femur (up to 0.9 mm).

**Discussion:** Few studies present possible causes for errors when using CAOS for TKA. Notably, Bathis et al. evaluated cutting errors as the difference between the primary cutting block position and the resulting resection plane. As a result, errors due to a malpositioning of the guide jig itself were not described. In other words, they weren’t able to directly differentiate the degree to which the deviation of the resection plane is the effect of inadequate fixation of the cutting block itself or the result of the sawing procedure. Based on 50 patients, they reported mean errors of 1.4°±1.3° and 1.0°±1.0° for the femoral and tibial flexion/extension, respectively.

Based on our study, we found that, in general, the dispersions at each step seem random and there was no apparent accumulating trend from step 1B to 1D. The only parameter associated with a trend was the flexion/extension of the distal femoral cut. First, there was a slight dispersion in extension from step 1B to 1C; which can be due to the offset weight of the tracker acting on the adjustable instrumentation during the pinning step. Secondly, there was, also, a consistent dispersion in extension from step 1C to step 1D; which is perceived as resulting from the skiving of the saw during the cut process.

One limitation of our study is that we didn’t evaluate the steps after the preparation of the bone cuts. Catani et al. stated that alignment deviations are also caused by the cementation and impaction of the implants.

The evaluated image-free computer-assisted guidance system did not exhibit substantial alignment dispersions during each step of the procedure, which reflected the robustness of the system and the surgical technique.

**References**