Novel Image-matching Software for Postoperative Evaluation After TKA

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abstract

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Although 2-dimensional assessments using postoperative plain radiographs have been used after total knee arthroplasty (TKA) in previous studies, a strong possibility exists that deviation can occur when assessing 3-dimensional (3-D) objects. The purpose of this study was to test the hypothesis that novel 3-D image-matching software could accurately assess the positioning of implants and could be a useful tool in postoperative evaluation after TKA.

Total knee arthroplasty was performed in 30 consecutive patients. Intraoperatively, the thickness of each bone cut was measured. Postoperatively, the thickness of each part of the bone cut was measured using Athena Knee (SoftCube Co, Ltd, Osaka, Japan) 3-D image-matching software. The results revealed no significant differences in the medial compartment and significant differences of approximately 1 mm in the lateral compartment. The difference was possibly caused by the remaining cartilage in the lateral compartment. Linear regression analysis revealed a statistically excellent correlation between intra- and postoperative values in all parts of the bone cuts. Although the 3-D image-matching software used in this study was originally developed for preoperative planning in TKA, it is considered accurate enough to assess the positioning of implants with respect to the bone after TKA.

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Figure: A 3-dimensional marker was attached on the surface of the patient’s lower leg, and marker silhouettes were used on the images to 3-dimensionally couple the 2 radiographic images.
A uthough the significant benefits of total knee arthroplasty (TKA) for osteoarthritis are well recognized, debate continues about the best surgical treatment. Numerous failure mechanisms in TKA have been previously described. Implant position with respect to the bone and postoperative lower-extremity alignment are commonly considered critical factors affecting the long-term survival of TKA. It is necessary to improve the methods of evaluating implant position with respect to the bone and mechanical axis more concisely.

Although 2-dimensional (2-D) assessments using postoperative plain radiographs have been used in previous studies, deviation can occur when assessing 3-dimensional (3-D) objects. Clinically, surgeons have to create 3-D images from 2-D radiographs. An automated image-matching technique using a computer-aided design program has been introduced that can assess alignment of the entire lower extremity for normal and implanted knees and the positioning of implants with respect to the bone cut. An image-matching software system (Athena Knee; SoftCube Co, Ltd, Osaka, Japan) capable of 3-D assessments of lower-extremity alignment and implant positioning using plain radiographs, computer-aided design, and computed tomography (CT) images has also been developed for preoperative planning and has been widely adopted in Japan. This software is capable of comparing preoperative conditions with postoperative prosthetic positioning by combining preoperative CT images with postoperative radiographs. The authors have also begun to use this software for postoperative evaluation. However, the accuracy of postoperative assessment using this software system has not been clarified.

The purpose of this study was to test the hypothesis that novel 3-D image-matching software could assess the positioning of implants accurately and would be a useful tool for postoperative evaluation after TKA.

**Materials and Methods**

Thirty consecutive patients with osteoarthritis of the knee with varus deformity were investigated for this study. The patients included 28 women and 4 men with a mean age of 71.6±7.8 years at the time of surgery. All TKAs were performed using the measured resection technique with a medial parapatellar approach. A Triathlon Posteriorly Stabilized Total Knee (Stryker, Mahwah, New Jersey) was used in each patient and was placed using computer navigation.

Intraoperatively, the thickness of each bone cut was measured: the medial (MDF) and lateral (LDF) condyles of the distal femur, medial (MPF) and lateral (LPF) condyles of the posterior femur, and medial (MPT) and lateral (LPT) proximal tibias. Attempts were made to remove the remaining cartilage completely using sharp curettes. The thickness of the saw blade, 1.27 mm, was added to each value. Three weeks postoperatively, anteroposterior and lateral radiographs were obtained and evaluations were performed using Athena Knee 3-D image-matching software.

A 3-D marker was attached to the surface of the patient’s lower leg, and the silhouettes of the marker on the images were used to couple the 2 radiographic images 3-dimensionally (Figure 1A). Next, implanted components were matched to the images using a computer-aided design program (Figure 1B). In addition, CT images taken preoperatively were matched to the coupled radiographic images (Figure 1C). In this process, continuous CT data could be divided into femur and tibia. In the matched image, the thickness of each part of the bone cuts was measured as follows: medial (A-MDF) and lateral (A-LDF) condyles of the distal femur, medial (A-MPF) and lateral (A-LPF) condyles of the posterior femur, and medial (A-MPT) and lateral (A-LPT) proximal tibias (Figure 1D). The data were compared with the actual thickness of each bone cut to investigate whether postoperative values correlated with intraoperative values.

Evaluations were performed by 2 authors (K.T., H.S.) blinded to clinical information, and averages were used. For descriptive analysis, the mean and SD were calculated. Paired Student’s t test was used for within-group analyses. Pearson product-moment correlation coefficient and linear regression analysis were used to evaluate the contribution of quantitative parameters. A P value less than .001 was considered significant. All statistical analyses were performed with SPSS version 18.0.0 software (SPSS, Inc, Chicago, Illinois).

**Results**

Intra- and postoperative bone cut thickness values are shown in the Table. No significant differences were found between actual and measured average MDF (8.77±1.63 mm) and average MDF (8.56±1.58 mm) (P=.06); average MPF (12.62±2.56 mm) and average MPF (12.47±2.65 mm) (P=.36); and average MPT (3.10±1.82 mm) and average A-MPT (3.01±1.81 mm) (P=.23). Significant differences were found between actual and measured average LDF (9.44±1.92 mm) and average A-LDF (8.87±1.91 mm) (P<.01); average LPF (10.20±2.55 mm) and average A-LPF (9.38±2.32 mm) (P<.01); and average LPT (11.34±2.08 mm) and average A-LPT (10.40±2.02 mm) (P<.01). Linear regression analysis revealed a statistically excellent correlation between intra- and postoperative values of all parts of the bone cuts (P<.001) (Figure 2).

**Discussion**

Acquiring good alignment of the entire lower extremity and soft tissue balance are important for achieving success in TKA. Malalignment may negatively affect implant function and lead to decreased long-term survival rate in TKA. Decreased survival due to malalignment is likely due to off-axis loading, polyethylene wear, and subsequent implant loosening. Therefore, components must
be placed as precisely as possible, and ligaments must be carefully balanced. However, the main problem of postoperative evaluations is that the implant positioning itself is inaccurate.

Two-dimensional anteroposterior and lateral radiographs are usually used to assess postoperative alignment of the lower limb. However, they may be influenced by the position of the radiation source and the orientation of the pelvis and lower extremity. Few studies have described the 3-D characteristics of lower-extremity alignment. These devices are rare and expensive, so it is difficult to use them in clinical practice.

The current authors propose a novel postoperative evaluation method using Athena Knee preoperative templating software. The results revealed statistically excellent correlations between actual values and measured values of every part of the bone cut. The software may be a useful tool for postoperative evaluation of alignment in TKA.

This study had some limitations. Evaluation using this software requires a concise measured resection, not the gap technique. Therefore, the lack of a soft tissue balance evaluation is a limitation of this software. However, it is proposed that a combination of this software and the gap measurement tool would reveal more detailed conditions after TKA.

Regarding the bone cuts on the lateral side, significant differences of approximately 1 mm existed between the actual measurement and the Athena Knee measurement. The difference was possibly caused by the remaining cartilage because the values of the medial side showed no statistically significant differences when the cartilage was almost gone in patients who had relatively severe varus deformity. However, it may be impossible to completely remove cartilage from the subchondral bone; thus, the authors consider the results measured by the software accurate in clinical conditions. Therefore, the differences may not affect assessments of lower-extremity alignment.

Although the 3-D image-matching software used in this study was originally developed for preoperative planning in TKA, it is considered to be accurate enough to assess the positioning of implants with respect to the bone after TKA.

Table

<table>
<thead>
<tr>
<th>Bone Cut</th>
<th>Side</th>
<th>Actual Value</th>
<th>Measured Value</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal femur</td>
<td>Medial</td>
<td>8.77±1.63</td>
<td>8.56±1.58</td>
<td>.06</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>9.44±1.92</td>
<td>8.87±1.91</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Posterior</td>
<td>Medial</td>
<td>12.62±2.56</td>
<td>12.47±2.65</td>
<td>.36</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>10.20±2.55</td>
<td>9.38±2.32</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Proximal tibia</td>
<td>Medial</td>
<td>3.10±1.82</td>
<td>3.01±1.81</td>
<td>.23</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>11.34±2.08</td>
<td>10.40±2.02</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
This software has the advantage of easy and accurate assessment of alignment by matching implants on preoperative CT. One of the most important issues that requires imaging measurement tools is rotational alignment of the component. Much research has focused on the optimal rotational alignment of the femoral component, and tibiofemoral complications, such as flexion instability, component liftoff, increased polyethylene wear, early component loosening, and ongoing knee pain, have been attributed to it.\textsuperscript{20,23} Even the most reliable technique used to measure rotational alignment using postoperative CT has limitations because the haloation of the implant makes the bony landmark unclear for measurement of rotational alignment. The software in this study can easily and concisely measure the rotational alignment by measuring the angle between the preoperative surgical epicondylar axis and the posterior condylar axis with CT-matched computer-aided design data (Figure 1D). Moreover, an unnecessary postoperative CT can increase excessive radiation exposure for patients.

In addition, when adjusting the divided CT data into 2-D radiographs with a marker, the accuracy of the rotational profile on the femur and tibia would be more enhanced than by just matching the radiograph and computer-aided design data (Figure 1D). Matching postoperative radiographs, computer-aided design data, and preoperative CTs enable visualization of 3-D postoperative conditions and measurement of the differences between pre- and postoperative conditions.

**CONCLUSION**

This study found that assessment using Athena Knee 3-dimensional image-matching software, originally developed for preoperative planning, was well correlated with intraoperative conditions. The software is convenient and useful for clinically evaluating component positioning with respect to the bone in TKA.

**REFERENCES**


