KNEE

Total knee replacement in patients with significant femoral bowing in the coronal plane

A COMPARISON OF CONVENTIONAL AND COMPUTER-ASSISTED SURGERY IN AN ASIAN POPULATION

We conducted a retrospective study to investigate the effect of femoral bowing on the placement of components in total knee replacement (TKR), with regard to its effect on re-establishing the correct mechanical axis, as we hypothesised that computer-assisted total knee replacement (CAS-TKR) would produce more accurate alignment than conventional TKR. Between January 2006 and December 2009, 212 patients (306 knees) underwent TKR. The conventional TKR was compared with CAS-TKR for accuracy of placement of the components and post-operative alignment, as determined by five radiological measurements. There were significant differences in the reconstructed mechanical axes between the bowed and the non-bowed group after conventional TKR (176.2° (SD 3.4) vs 179.3° (SD 2.1), p < 0.001).

For patients with significant femoral bowing, the reconstructed mechanical axes were significantly closer to normal in the CAS group than in the conventional group (179.2° (SD 1.9) vs 176.2° (SD 3.4), p < 0.001). Femoral bowing resulted in inaccuracy when a conventional technique was used. CAS-TKR provides an effective method of restoring the mechanical axis in the presence of significant femoral bowing.

The outcome of total knee replacement (TKR) is related to surgical factors, such as accurate restoration of the mechanical axis of the limb, the position of the components and soft-tissue balance; prosthetic factors, including design, size, tribology and geometry, and patient factors, including body weight, activity and medical comorbidities.1,2 Of these, an effective surgical technique that sites the prosthesis accurately along the mechanical axis is crucial in order to prevent accelerated wear and reduce the rate of revision.1,3,8

Several alignment guidance systems based on intra- and extramedullary rods have been developed in order to aid identification of the mechanical axis.5,9-12 However, the post-operative alignment has been reported to be inaccurate in more than 25% of cases when using an intramedullary alignment system.13-15 Deformity of the femur from excessive femoral bowing, distortion of the bony canal, malunited fractures and metabolic bone disease further limit the accuracy of an intramedullary alignment system.16-20

Recently, there has been greater interest in excessive bowing of the femur and its relationship to the performance of the implant. The geometry of the femur in the coronal plane differs between Asian and Western populations.21-23 In Asian populations bowing of the femur is commonly found in patients with osteoarthritis of the knee. Its incidence is said to be in the region of 62%.21,24 This may alter the mechanical axis of the lower extremity and thereby affect the correct positioning of the femoral component.21-23 The effectiveness of computer-assisted TKR surgery (CAS-TKR) for arthritic knees with extra-articular deformities has recently been described.25-29 However, there have been few attempts to clarify the effect of femoral bowing on conventional TKR and the role of CAS-TKR in limbs with significant femoral bowing.25 The purpose of this study was to investigate the effect of femoral bowing on the post-operative mechanical axis and the alignment of the components after conventional TKR, and to compare them with those found after using computer navigation.

Patients and Methods
Between January 2006 and December 2009, 212 non-consecutive patients (306 knees) underwent primary TKR at our hospital. The medical records and radiological data for all
patients were reviewed retrospectively. Clinical data collected included age, gender, diagnosis, model of prosthesis, operative procedure, peri-operative findings, tourniquet time, blood loss and radiological assessment both pre- and post-operatively. Patients who had an extra-articular deformity of the femur or tibia related to trauma or previous surgery, or incomplete medical records and radiographs, were excluded. The study was approved by the Institutional Review Board of the Chang Gung Memorial Hospital.

All patients enrolled in the study were evaluated with long-leg weight-bearing split scanograms and pre- and post-operative anteroposterior (AP) and lateral radiographs of the knees, as described in detail in a previous publication. The radiological measurements included the mechanical axis, the valgus correction angle of the distal femur, the femoral bowing angle and the four modified component alignments, including the femoral valgus angle, tibial valgus angle, femoral flexion angle and tibial flexion angle. The valgus correction angle of the distal femur and the amount of femoral bowing were measured using the method described by Yau et al.24 The valgus correction angle of the distal femur was defined as the angle between the line joining the centre of the femoral head and the intercondylar notch of the distal femur, and the line joining the femoral intercondylar notch and the femoral isthmus. In order to measure bowing, the diaphysis of the femur was divided into four equal parts; a line was then drawn in each quarter to describe the midpoint of the endosteal canal. The degree of bowing was defined as the angulation between the proximal and distal quarters of the femoral diaphysis.24 The definition of significant femoral bowing was set at > 5° of angulation. The patients were divided into three groups: those without femoral bowing who underwent conventional TKR (group 1); those with bowing who underwent conventional TKR (group 2); and those with bowing who underwent CAS-TKR (group 3).

The planned position of the tibial component was at a valgus angle of 90° in the coronal plane and a flexion angle of 87° in the sagittal plane. The planned position for the femoral component was at a flexion angle of 0°. The desired femoral valgus angle was determined according to the valgus correction angle of the distal femur which was measured on a long-leg weight-bearing split scanogram. The goals of implantation were to reconstruct the mechanical axis and to align the components within 3° of their optimal position (femoral valgus, tibial valgus, femoral flexion and tibial flexion).

An anterior longitudinal incision with a medial parapatellar approach were used in all cases. The CAS-TKR was implanted using a CT free navigation system (Brain-LAB Inc., Munich, Germany). The conventional TKRs were implanted using conventional guides, with an intramedullary femoral system and an extramedullary tibial system. Each operation was carried out by a senior surgeon (RWWH, WHH, KTP) with extensive experience in the use of conventional guides and computer-assisted navigation.

Data, including tourniquet time, blood loss, length of hospital stay, complications of the surgical technique and radiological measurements, were collected and analysed by two independent surgeons who were blinded to the technique used. Clinical and radiological data, including the percentage of TKRs within 3° of the mechanical axis and target component alignments, were also compared between the groups.

Statistical analysis. All data were entered onto an Excel spreadsheet (Microsoft Corp., Redmond, Washington), re-checked for missing and potentially illogical data by an independent reviewer (TWH), and subsequently copied into SPSS version 13.0 (SPSS Inc., Chicago, Illinois). Statistical analysis was performed by an independent statistician blinded to surgical outcome. A one-way analysis of variance test and the chi-squared test were used for statistical analysis. The Scheffe post hoc test was performed for comparisons between groups. The level of statistical significance was set at p < 0.05.

Results
A total of 212 patients (306 knees) were enrolled in the study. The 250 knees that underwent conventional TKR were further divided into 128 knees without significant bowing (group 1), and 122 with significant bowing (group 2). The remaining 36 patients (56 knees) underwent CAS-TKR because they had significant bowing. Demographically, there were no statistical differences between the three groups in age at the time of operation, height, weight and body mass index (Table I). The total blood loss, the length of hospital stay and the pre-operative mechanical axis were also similar in the three groups. The mean tourniquet time appeared to be longer in the CAS group: group 1, 69 minutes (SD 19), group 2, 67 minutes (SD 17) and group 3, 87 minutes (SD 19), p < 0.001 (Table II).

The Scheffe post hoc test revealed that there were differences in the valgus correction angle of the distal femur between groups 1 and 2, and between groups 1 and 3 (both p < 0.001), but no differences between groups 2 and 3 (p = 0.274). Similar differences in the angle of femoral bowing were found between the groups, but once again no differences were seen between groups 2 and 3 (p = 0.479) (Table II). There were also differences in the post-operative mechanical axis between the groups. The mean post-operative mechanical axes in groups 1, 2 and 3 were 179.3° (SD 2.1), 176.2° (SD 3.4) and 179.2° (SD 1.9), respectively (p < 0.001). The Scheffe post hoc test revealed that there were differences between groups 1 and 2, and between groups 2 and 3 (p < 0.001 and p < 0.001, respectively). No such difference could be detected between groups 1 and 3 (p = 0.952). Similar results were seen when the percentages of knees within the target zone in the various groups were compared; these were 81%, 52.6% and 88%, respectively (p < 0.001) (Table II).

A radiological analysis of component alignment in the coronal and sagittal planes revealed no difference between
the three groups for tibial valgus angle (90.0° (SD 1.4) vs 90.0° (SD 1.6) vs 89.9° (SD 1.0), p = 0.989) or tibial flexion angle (87.7° (SD 2.0) vs 87.6° (SD 1.9) vs 88.3° (SD 1.8), p = 0.162) (Table III). However, there were differences of mean femoral valgus angle in all groups (96.2° (SD 2.0) vs 96.1° (SD 1.9) vs 98.0° (SD 2.0), p < 0.001) (Table III), and the mean femoral flexion angle also differed significantly between the groups (3.2° (SD 2.3) vs 3.6° (SD 2.3) vs 1.6° (SD 1.5), p < 0.001) (Table III). The Scheffe post hoc test revealed significant differences of mean femoral valgus angle between groups 3 and 1, and groups 3 and 2 (p < 0.001 and p < 0.001, respectively). Statistically significant differences in the mean femoral flexion angle were also seen between groups 3 and 1, and groups 3 and 2 (p < 0.001 and p < 0.001, respectively). No statistically significant differences existed between groups 1 and 2 when the femoral valgus and flexion angles were compared (p = 0.985 and p = 0.351, respectively) (Table III).

Overall, the percentage of TKRs achieving the target component alignment was higher in the CAS-TKR than in the conventional TKRs, for both femoral valgus and flexion angles (p < 0.001 and p < 0.001, respectively); however, there was no statistically significant difference in the planned component alignment of tibial valgus and flexion angles between the two techniques (p = 0.291 and p = 0.174, respectively) (Table III).

One patient (one knee) sustained a peri-prosthetic femoral fracture in a traffic accident 26 months after a conventional TKR. This was treated by open reduction and internal fixation using Less Invasive Surgical Stabilization locking plates (Synthes, West Chester, Pennsylvania), to good effect. No peri- or post-operative fracture related to the placement of pins for the femoral and tibial reference arrays was noted in the 56 CAS-TKRs. No other complications, such as pulmonary embolism, deep-vein thrombosis, post-operative peri-prosthetic fracture or wound infection, were recorded.

### Table I. Patients' demographic data. Values are given as the mean (sd) and statistical significance at p < 0.05

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group 1† (n = 128)</th>
<th>Group 2‡ (n = 122)</th>
<th>Group 3‡ (n = 56)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at time of operation (yrs) (sd)</td>
<td>72.0 (6.9)</td>
<td>71.3 (6.6)</td>
<td>71.5 (6.5)</td>
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<tr>
<td>Height in cm (sd)</td>
<td>152.8 (5.7)</td>
<td>151.7 (6.9)</td>
<td>151.2 (8.3)</td>
<td>0.234</td>
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<tr>
<td>Weight in kg (sd)</td>
<td>64.7 (8.7)</td>
<td>64.4 (10.7)</td>
<td>61.4 (10.2)</td>
<td>0.099</td>
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<tr>
<td>Body mass index in kg/m² (sd)</td>
<td>273 (3.1)</td>
<td>281 (4.2)</td>
<td>268 (3.4)</td>
<td>0.091</td>
</tr>
</tbody>
</table>

### Table II. Peri-operative and radiological data. Values are given as the mean (sd) or n (%) where stated. Statistical significance was set at p < 0.05, and one-way analysis of variance tests were used for comparison unless otherwise stated

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group 1† (n = 128)</th>
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<th>Group 3‡ (n = 56)</th>
<th>p-value</th>
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<tr>
<td>Peri-operative data</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tourniquet time in mins (sd)</td>
<td>69 (19)</td>
<td>67 (17)</td>
<td>87 (19)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Hospital stay in days (sd)</td>
<td>7.1 (1.2)</td>
<td>7.3 (1.0)</td>
<td>6.9 (2.1)</td>
<td>0.259</td>
</tr>
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</table>

### Table III. Peri-operative and radiological data. Values are given as the mean (sd) or n (%) where stated. Statistical significance was set at p < 0.05, and one-way analysis of variance tests were used for comparison unless otherwise stated

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group 1† (n = 128)</th>
<th>Group 2‡ (n = 122)</th>
<th>Group 3‡ (n = 56)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus correction angle of the distal femur (°) (sd)</td>
<td>6.4 (1.3)</td>
<td>11.8 (1.7)</td>
<td>12.1 (1.9)</td>
<td>&lt; 0.0011</td>
</tr>
<tr>
<td>Femoral coronal bowing angle (°) (sd)</td>
<td>2.1 (1.4)</td>
<td>11.9 (2.6)</td>
<td>12.1 (3.0)</td>
<td>&lt; 0.0011</td>
</tr>
<tr>
<td>Pre-operative mechanical axis (°) (sd)</td>
<td>163.3 (3.1)</td>
<td>163.8 (6.5)</td>
<td>162.5 (4.5)</td>
<td>0.252</td>
</tr>
<tr>
<td>Post-operative mechanical axis (°) (sd)</td>
<td>179.3 (2.1)</td>
<td>176.2 (3.4)</td>
<td>179.2 (1.9)</td>
<td>&lt; 0.0014</td>
</tr>
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</table>

### Table IV. Mechanical axis within 3° (%)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group 1† (n = 128)</th>
<th>Group 2‡ (n = 122)</th>
<th>Group 3‡ (n = 56)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical axis within 3° (%)</td>
<td>103 (81)</td>
<td>63 (52.6)</td>
<td>49 (88)</td>
<td>&lt; 0.0014</td>
</tr>
</tbody>
</table>

* group 1†, patients without femoral bowing who underwent conventional total knee replacement
† group 2‡, patients with femoral bowing who underwent conventional total knee replacement
‡ group 3‡, patients with femoral bowing who underwent computer-assisted surgery-total knee replacement
§ Student’s t-test
¶ chi-squared test
Discussion
The key finding of this study is that the presence of femoral bowing resulted in malalignment following conventional TKR but this malalignment occurred less following CAS-TKR. Our results are comparable to those of Mullaji and Shetty, who retrospectively reviewed 34 knees with an extra-articular deformity (including 14 with femoral bowing) and found the results to be better using CAS-TKR. Our series is larger and we included patients with normal and bowed femora treated by conventional TKR as well as those treated by CAS-TKR. By comparing groups 1 and 2 we have shown an increased number of outliers in those patients with femoral bowing who underwent conventional TKR, whereas a better post-operative mechanical axis was achieved using CAS-TKR. There was, however, no significant difference in post-operative mechanical axis between patients with a bowed femur who underwent CAS-TKR and those without bowing of the femur who had a conventional TKR.

The valgus correction angle of the distal femur determined the choice of the femoral cutting block to make the femoral bone cut perpendicular to the mechanical axis of the femur. Most surgeons use intramedullary femoral jigs to obtain a 5° to 7° valgus angle of the distal femoral cut. However, femoral bowing changes the angular relationship between the anatomical axis and the mechanical axis of the femur. Therefore, the reliability of using a 5° to 7° valgus distal femoral cut is questionable. In this study, an increased valgus correction angle of the distal femur was seen. The mean was

Table III. Comparison of post-operative component alignment and percentage within 3° of optional position

<table>
<thead>
<tr>
<th>Post-operative component alignment (SD)*</th>
<th>Number of post-operative component alignments within 3° deviation (%)</th>
<th>p-value†</th>
<th>p-value‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n = 128)</td>
<td>Group 2 (n = 122)</td>
<td>Group 3 (n = 56)</td>
<td>p-value†</td>
</tr>
<tr>
<td>Femoral valgus angle (°)</td>
<td>96.2 (2.0)</td>
<td>96.1 (1.9)</td>
<td>98.0 (2.0)</td>
</tr>
<tr>
<td>Femoral flexion angle (°)</td>
<td>3.2 (2.3)</td>
<td>3.6 (2.3)</td>
<td>1.6 (1.5)</td>
</tr>
<tr>
<td>Tibial valgus angle (°)</td>
<td>90.0 (1.4)</td>
<td>90.0 (1.6)</td>
<td>89.9 (1.0)</td>
</tr>
<tr>
<td>Tibial flexion angle (°)</td>
<td>87.7 (2.0)</td>
<td>87.6 (1.9)</td>
<td>88.3 (1.8)</td>
</tr>
</tbody>
</table>

* group 1, patients without femoral bowing who underwent conventional total knee replacement (TKR); group 2, patients with femoral bowing who underwent conventional TKR; group 3, patients with femoral bowing who underwent computer-assisted surgery TKR
† one-way analysis of variance tests
‡ chi-squared tests
11.8° (9.6° to 18.6°) in group 2 and 12.1° (7.9° to 18.6°) in group 3 (Table I). Femoral components implanted using a 5° to 7° valgus cut during a conventional TKR resulted in unacceptable alignment of the mechanical axis of the limb (Table II) (Fig. 1).

A statistically significant difference in component alignment was only seen following the femoral cuts (femoral valgus and flexion angles) after CAS-TKR when compared with conventional TKR. The overall percentage of TKRs that achieved the target component alignment in femoral valgus and flexion angles were also higher with CAS-TKR. A comparison of alignment showed that computer navigation was better than conventional instrumentation for restoring femoral component alignment in patients with femoral bowing (Table III) (Fig. 2).

Although the prevalence of femoral bowing is high in the Asian population, especially in those with osteoarthritis, this characteristic is still underestimated in clinical practice. This is because femoral bowing is neither clinically apparent nor evident on radiographs of the knee21 (Fig. 1a). Although the need for a long-leg weight-bearing split scanogram prior to TKR is still debated,5,21,23,24,32,33 we recommend that it be undertaken in Asian patients. It can provide important information about malalignment in the coronal plane and about other extraarticular deformities of the femur that require correction to establish a neutral post-operative mechanical axis (Fig. 1b).

Several limitations in this study must be acknowledged. First, this was a radiological study in which we were unable to assess any correlation between alignment and functional outcome. There have been several recent articles2,29,34-37 with short-term follow-up concerning computer navigation-assisted versus conventional knee replacement. Long-term results for both techniques are needed to determine whether CAS-TKR results in improved long-term outcome. Secondly, our study was limited by its retrospective design. However, all the patients underwent TKR following the same protocol in a single centre with a registry system, which might reduce the selection bias.

In conclusion, femoral bowing produced inaccuracies in placement of the components during conventional TKR using an intramedullary femoral guide and an extramedullary tibial guide. This was not the case with CAS-TKR, which allowed accurate placement of the components and restoration of the normal mechanical axis. In cases without femoral bowing, conventional TKR can achieve alignment as accurate as CAS-TKR.

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References


