DURABILITY OF ROTATING-PLATFORM TKA

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Mobility of the rotating platform in low contact stress knee arthroplasty is durable.
ABSTRACT

Purpose: The mobile bearing or rotating platform (RP) in total knee arthroplasty (TKA) is originally part of a low contact stress (LCS) concept, with bearing undersurface mobility compensating higher bearing upper-surface congruency. The in vivo range of axial femorotibial rotation in RP knees has been the subject of many studies, but always involving the performance of relatively low demanding task conditions. Hardly any study has addressed the maintenance of this rotation over time.

Methods: two consecutive series of patients with LCS RP knees were studied in a cross-sectional study of one and five years follow-up. They were assessed using optoelectronic motion analysis during gait and the performance of a sit-to-walk (STW) task with and without turning steps.

Results: A mean range of rotation (SD) was found in the one-year group of 13.4 degrees (3.7) during gait, 17.8 degrees (6.8) during STW straight, and 17.9 degrees (6.9) during STW with turning. The range in the five-year group was 11.2 degrees (6.0) during gait, 18.5 degrees (8.7) during STW straight, and 18.3 degrees (8.3) during STW with turning. A so-called paradoxical axial rotation pattern during gait and STW straight occurred in both groups in a normal prevalence.

Conclusions: The amount and pattern of rotation in a LCS RP knee does not become impaired between one and five years postoperatively. The theoretical benefit of RP TKA has not
been proven in any clinical study so far and studies with suitable long-term follow-up need to prove whether this mobility also leads to improved prosthesis survival. However, our findings support the functioning of the rotating platform at a basal science level and illustrate the need for the use of more complex tasks in kinematic studies.

INTRODUCTION

The rotating platform (RP) in total knee arthroplasty (TKA) is originally part of a low contact stress (LCS) concept, in which a bearing with higher upper-surface congruency is compensated by undersurface mobility. This is assumed to reduce articular contact stress without increasing bone-implant interface stress, which in turn would theoretically increase prosthesis survival thanks to reduced polyethylene wear and aseptic loosening. Wear is less of a problem with the ongoing improvement of polyethylene quality, but loosening is still a point of concern in current TKA. Some surgeons also hope to benefit from a natural accommodation of patellofemoral alignment, while others might have to overstep a fear of possible dislocation of a mobile bearing. Although the original LCS RP knee or its derivatives are recognized as a successful prosthesis, the clinical results appear not to be better than those for conventional fixed bearing knees. There is even one study, using national joint replacement registries, which concluded that mobile bearing non-posterior-stabilized variants presented a greater risk of failure than fixed bearing (FB) non-posterior-stabilized variants. These findings raise questions regarding the actu-
al functioning of the concept: does the RP provide sufficient mobility, and if so, is this mobility maintained over time?

Some in vivo kinematic studies found significant differences in axial femorotibial rotation between RP and FB TKA variants,\(^6,26-27\) while others did not.\(^8,18,38\) Apart from magnitudes of rotation, there is also the concern about a so-called reverse or paradoxical axial rotation pattern in both RP and FB TKA variants.\(^2,8\) All these studies had a certain limitation in that they used relatively low demanding task conditions (mostly knee bends during stance). In an earlier study was found that the range of axial knee rotation after RP knee replacement was as large as in healthy knees when moving from sit to walk, with or without turning steps.\(^39\) We figured that such a more demanding task could be helpful in exploring the geometric constraints of TKA variants.

At the time we conducted the current study, only one study had addressed to the maintenance of mobility over the years: a decrease in axial femorotibial rotation was found in RP NexGen knees by Wolterbeek et al.\(^37\) Since the design principles in RP designs vary in femoral congruency and position of the rotational axis, we hypothesized that in case of the originally designed LCS RP knee there would be no decrease in rotation over time. Furthermore, we expected that the proportion of reverse rotation would remain the same. In order to test these hypotheses we used more demanding task conditions than commonly used in in vivo kinematic studies, to actually provoke turning and the explore ranges of axial knee rotation.
MATERIAL AND METHODS

Two consecutive series of TKA patients, including 12 one-year (1y) postoperative patients (15 knees) and 14 five-year (5y) postoperative patients (17 knees), underwent noninvasive movement analysis. All patients had been operated on in the Slotervaart Hospital or VU University Medical Center (Amsterdam, The Netherlands) in the periods of November 2004 to May 2007 or February 2002 and December 2003. Some of the patients in the 5y group also participated in a prior study. All patients were given a non-cemented LCS® Rotating Platform knee (DePuy Inc, Warsaw, IN) by the same surgeon (RGP), except for one patient in each group. The posterior cruciate ligament was sacrificed and a standard balanced gap surgical technique was used for bone cuts and ligament balancing.

Included were patients successfully operated for osteoarthritis or rheumatoid arthritis, with a postoperative Knee Society Knee Score of 80 points or more. Range of motion was comparable for both groups, with a mean flexion of 115 degrees (median 110) in the 5y group and 120 degrees (median 120) in the 1y group. Exclusion criteria were revision surgery, neurological disorders that interfered with walking, and a body mass index (BMI) of 35 or more. The patient characteristics are shown in Table 5.1. There were no statistically significant differences between both groups regarding gender, age at surgery or BMI. The 5y group consisted of both osteoarthritis and rheumatoid arthritis patients, whereas all patients in the 1y group had rheumatoid arthritis.
Movement analysis took place in a laboratory for human movement analysis (Department of Rehabilitation Medicine, VU University Medical Center, Amsterdam, the Netherlands). An OptoTrak motion analysis system (model 3020, Northern Digital Inc, Waterloo, Ontario, Canada) was used to record the three-dimensional position of active surface markers at a sampling rate of 50Hz. For the tibia a cluster of three markers was strapped over the middle lateral shank. For the femur, a cluster of three markers was rigidly attached to an epicondylar frame (Fig. 2.1). The Femoral Epicondylar Frame is a validated tool for noninvasive tracking of femoral axial rotation, with an error of 3.3 degrees up to 40 degrees of knee flexion. For higher flexion the error increases, but the majority of peak rotation took place within this range. The error for tibial rotation

### TABLE 5.1. Patient characteristics.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>1y group (15 knees)</th>
<th>5y group (17 knees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnose (OA/RA)</td>
<td>0/15</td>
<td>11/6</td>
</tr>
<tr>
<td>Gender (female/male)</td>
<td>14/1</td>
<td>13/4</td>
</tr>
<tr>
<td>Side (right/left)</td>
<td>8/7</td>
<td>8/9</td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>29.8 (2.5)</td>
<td>28.3 (3.5)</td>
</tr>
<tr>
<td>Mean age at surgery (years, SD)</td>
<td>66.4 (7.4)</td>
<td>57.4 (4.2)</td>
</tr>
<tr>
<td>Mean interval from surgery to analysis (months, SD)</td>
<td>16.3 (4.3)</td>
<td>64.2 (3.6)</td>
</tr>
</tbody>
</table>

OA: Osteoarthritis; RA: Rheumatoid arthritis; BMI: Body mass index; SD: Standard deviation.
using surface markers is 2 degrees.\textsuperscript{19} For the calculation of three dimensional knee kinematics and the definition of anatomical points and coordinates, we refer to prior publications.\textsuperscript{39-40}

The subjects performed four tasks: gait, move from sit-to-walk (STW) straight ahead, STW crossover step turning and STW sidestep turning. Chair height was adjusted to 90 percent of the lower leg length. Only the prosthetic knee in the weight-bearing leg was measured, the contralateral side acting as the swing leg. The subjects practiced each task until they could perform it smoothly at a natural pace. Three measurements per task were recorded and used for analysis. Videos are available from the original online publication of this article. The tasks were highly standardized and have been described previously in a study with healthy subjects.\textsuperscript{40} Also, in that particular study, good results of within-test reliability for the range of axial knee rotation by means of intraclass correlation coefficients (95 percent confidence interval) were found: 0.76 (0.42–0.92) for STW straight, 0.89 (0.73–0.96) for STW crossover stepping, and 0.96 (0.90–0.98) for STW sidestepping.

Ranges of rotation during the various tasks were compared between the 1y and 5y groups. The difference between peak internal and peak external femorotibial rotation was used to define range of rotation. The difference between internal rotation during crossover stepping and external rotation during sidestepping was used to define overall range of rotation for STW turning. Reverse rotation was defined in terms of timing of peak rotation as a percentage of stance phase and/or the proportion of knees showing a higher peak external than peak internal rotation.

Informed consent was obtained from all subjects and
permission for the study was given by the local medical ethics committee (Medische Ethische Toetsingscommissie voor het Slotervaartziekenhuis, Jan van Breemeninstituut en BovenIJ Ziekenhuis, reference number 0303).

**Statistical analysis**
The original sample size calculation with power set at 0.80 had revealed that 16 patients per group were needed to find a difference of 5 degrees between groups with 5 degrees of variance. An independent Samples Test was used to compare variables (ranges of rotation during gait, STW straight and STW turning) as well as patient characteristics between the groups (1y and 5y). Level of significance was set at $p=0.05$.

**RESULTS**

Results for the individual magnitudes of rotation and mean range of rotation for gait, STW straight ahead and STW with
turning are shown in Table 5.2. The normal values were retrieved from a prior study.\textsuperscript{40} The table shows that there was no significant difference between the values 1y and 5y postoperatively in any of the movements. It also shows that STW implies a higher range of rotation than gait. During normal gait, the 1y group had an average range of rotation of 13.4 degrees (SD 3.7), versus 11.2 degrees (SD 6.0) in the 5y group.

During STW straight, the average peak internal tibial rotation in the 1y group was 16.7 degrees (SD 9.4) and peak external tibial rotation 1.1 degrees (SD 3.9), accounting for a range of rotation of 17.8 degrees (SD 6.8). This did not differ significantly from the range of rotation in the 5y group, which was 18.5 degrees (8.6), with an average peak internal tibial rotation of 16.1 (SD 9.4) and external rotation of 2.5 degrees (SD 2.8). STW turning resulted in an average peak internal tibial rotation for the 1y group of 15.9 degrees (SD 9.7) during crossover stepping and 2.0 degrees (SD 3.7) during sidestepping. This accounted for an overall range of rotation during turning of 17.9 degrees (SD 6.9). In the 5y group crossover stepping resulted in an average peak internal tibial rotation of 16.3 degrees (SD 8.9) and an external rotation of 2.1 degrees (SD 2.3), accounting for a range of rotation of 18.3 degrees (SD 8.3).

The results concerning timing and pattern of rotation are depicted in Table 5.3. During gait and STW straight peaks of rotation one and five years postoperatively occurred in the same half of stance phase. The normal values were retrieved from the same prior study.\textsuperscript{40} Overall, the proportion of patients with a reverse pattern did not alter significantly between both postoperative groups.
TABLE 5.3. Mean timing of peak rotation as percentage of stance phase (± SD). Reverse pattern represents the proportion of subjects with a higher peak external knee rotation than internal rotation magnitude.

<table>
<thead>
<tr>
<th>Task</th>
<th>Normal</th>
<th>1y</th>
<th>5y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait</td>
<td>Peak int</td>
<td>96 ± 5</td>
<td>93 ± 8</td>
</tr>
<tr>
<td></td>
<td>Peak ext</td>
<td>12 ± 8</td>
<td>15 ± 8</td>
</tr>
<tr>
<td></td>
<td>Reverse pattern</td>
<td>33%</td>
<td>13%</td>
</tr>
<tr>
<td>Sit-to-walk, straight</td>
<td>Peak int</td>
<td>96 ± 15</td>
<td>88 ± 25</td>
</tr>
<tr>
<td></td>
<td>Peak ext</td>
<td>28 ± 23</td>
<td>13 ± 18</td>
</tr>
<tr>
<td></td>
<td>Reverse pattern</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Sit-to-walk, crossoverstepping</td>
<td>Peak int</td>
<td>98 ± 4</td>
<td>87 ± 25</td>
</tr>
<tr>
<td></td>
<td>Reverse pattern</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Sit-to-walk, sidestepping</td>
<td>Peak ext</td>
<td>75 ± 32</td>
<td>23 ± 31</td>
</tr>
<tr>
<td></td>
<td>Reverse pattern</td>
<td>67%</td>
<td>27%</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The most important finding of this present is that axial knee rotation in a RP knee did not decrease from one to five years postoperatively. Although the focus of the study was range of rotation, both magnitude and pattern of rotation were comparable to normal values from a prior study on healthy subjects.

The LCS RP knee arthroplasty concept allows for free bearing rotation on a central axis, while muscle activity, capsule and ligaments restrict rotation to ensure knee stability. The results of our study suggest that these soft tissue restrictions do not change in the years following TKA. This finding is in
disagreement with the study by Wolterbeek et al.\textsuperscript{37} They studied a group of seven patients with NexGen RP knees during the performance of a step-up using fluoroscopy, finding a decrease from eleven to six degrees in femorotibial rotation from eight months to three years postoperatively. The authors suggested that the formation of fibrous tissue was possibly restricting of bearing mobility, although this explanation was not based on their own findings at retrieval or revision surgery.\textsuperscript{10} They also proposed that there might be a lack of bearing upper-surface congruency and a non-centrally placed axis of bearing rotation, which might be suboptimal in terms of facilitating bearing undersurface mobility. High articular congruency and a central axis of rotation in the LCS knee could explain the different outcome in our study with respect to maintenance of rotation. LaCour et al. also fluoroscopically analyzed RP knees during the performance of a deep knee bend.\textsuperscript{17} From three months to 10 years postoperatively, the bearing in eight patients with a P.F.C. Sigma posterior-stabilized knee continued to rotate with respect to the tibial component and no decrease in overall femorotibial rotation was found. The Sigma and LCS knee derive from the same company and share the same tibial component, however, they are not comparable at the femoral side of the articulation: the LCS has more bearing upper-surface congruency, while the cam-post mechanism adds congruency to the PFC bearing.

A possible limitation in the former studies is that the fluoroscopic set-up could prohibit freedom of movement. As a result the task loads are relatively simple (mainly knee bends), which may explain the limited ranges of rotation in these studies. Also, bearing mobility during deep flexion becomes irrelevant
because of loss of weight-bearing and articular congruency. In the present study a movement analysis system was chosen, using optical cameras, which provided space for our subjects to perform a transitional task (sit-to-walk) to provoke rotation and imitate daily life activity. The relevance of adding turns lies in the fact that turning steps make up a considerable portion of steps taken during daily life walking and many patients after TKA have difficulty in performing them.

Our findings on reverse rotation patterns are somewhat different from the literature, but this may partly be attributed to defining reverse or paradoxical rotation. The timing of peaks of rotation in the current study were not very different from normal, except for a shift in peak external rotation to the first half of stance during the sidestepping task. Dennis et al. found a proportion of 33 percent reverse rotation in a group of 76 posterior-cruciate-sacrificing mobile bearing knees during a deep knee bend and 49 percent during gait; we found 12 percent during STW straight and 35 percent during, gait five years postoperatively. Other studies also report that the actual mobility of the RP was reversed as opposed to normal knee rotation. In our opinion, however, the importance of reverse rotation should not be overestimated. Rotating platforms were originally designed as part of a concept to achieve less wear and loosening stresses, rather than as the solution to the so-called ‘kinematic conflict’. This means that the attempt to create of a clinically successful TKA design is not necessarily the same as the restoration of natural knee kinematics.

Although the original LCS concept has a good track record of more than 30 years, it still remains a debate whether RP variants of TKA have a potential to be superior to FB variants. In a
recent meta-analysis by Moskal et al.\textsuperscript{22} and a Cochrane review by Hofstede et al.\textsuperscript{12} no difference regarding clinical performance and prosthesis survival were found between RP and FB knees. Mean follow-up in systematic reviews is usually short, but also an original study with 17 years follow-up showed no differences between the LCS and a FB knee within the same patient.\textsuperscript{14} National joint registries make analysis on a larger scale possible: Namba et al.\textsuperscript{23} compared mobile and fixed bearing variants of non-posterior-stabilized knees in 319,616 patients. Their results in terms of risk of failure were in favour of FB, although the interpretation could be troubled by the heterogeneity in de mobile bearing group. Hopley et al.\textsuperscript{13} combined data from a systematic literature search with national joint registry data of LCS RP and non-LCS knees. Their results on survivorship were in favour of the LCS RP knee. Future studies may need to differentiate highly congruent designed RP knees, with a central axis of rotation, from non-LCS related designs. As long as there is no prove of any clinical benefit, it is worthwhile to study whether a RP is functioning according to its original concept at all. The current study focused on the maintenance of rotation over time with a focus on advanced task complexity.

The present study had some limitations. One drawback is that an optical motion analysis system cannot differentiate between bearing rotation and overall femorotibial rotation. It is not possible to visualize bearing motion using external markers. However, previous data from studies using fluoroscopic analysis and tantalum-beats-inserted bearings have showed that most of the rotation of a RP was due to bearing undersurface mobility.\textsuperscript{6-7} Another shortcoming was that not the same series of patients were measured one and five year postoperatively, which means
that the patient groups differed in terms of relevant known and unknown variables. In the five-year postoperative group six out of 17 patients had rheumatoid arthritis, while in the one-year postoperative group none of the 15 patients had rheumatoid arthritis. This may have influenced the results.

Our findings may support the functioning of the rotating platform at a basal science level. Future studies with suitable long-term follow-up need to prove whether this sustained mobility leads to improved prosthesis survival. The present study also illustrates the use of complex tasks in evaluating replaced knee performance. Simple tasks like normal walking or knee bending may not be sensitive enough to differentiate potential kinematic differences.

CONCLUSIONS

The original concept of the mobile bearing TKA depends on free rotation of a highly congruent polyethylene bearing around a central axis. This study showed that under demanding task conditions the amount and pattern of axial rotation in the LCS RP knee does not become impaired from one and five year postoperatively. Although this concept has a theoretical advantage, rotating platforms have not provided better clinical outcomes than fixed bearings nor do they have restored natural knee kinematics.
CONFLICT OF INTEREST

This study was financially supported by an unrestricted grant from DePuy (Johnson & Johnson Medical) and Biomet. All the authors declare that they have no other conflict of interest.
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