Original article

Cruciate-sacrificing total knee arthroplasty and insert design: A radiologic study of sagittal laxity

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A R T I C L E   I N F O

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A B S T R A C T

Introduction: Ultracongruent inserts avoid some of the drawbacks of central spine postero-stabilized inserts. However, early wear has been reported, and may be due to increased sagittal laxity. The principal objective of the present study was to compare sagittal laxity in rotating platform total knee replacements (TKR) according to insert design: ultracongruent versus central spine. The principal hypothesis was that insert design influences global sagittal laxity.

Material and methods: A retrospective comparative study recruited 3 consecutive series of patients treated for primary osteoarthritis of the knee, with a minimum 1 year’s follow-up. The UC series comprised 35 knees in 34 patients, receiving a Total Knee Triathlon™ (Stryker Orthopaedics, Mahwah, NJ) TKR with ultracongruent insert, at a mean 2.0 years’ follow-up. The UC+ series comprised 36 knees in 34 patients, receiving the Balansys™ (Mathys Ltd, Bettlach, Switzerland) TKR with ultracongruent insert, at a mean 2.5 years’ follow-up; in this model, the anterior edge of the insert is higher than in the UC series (“deep-dish” design). The PS series comprised 43 knees in 40 patients, receiving a Total Knee Triathlon™ (Stryker Orthopaedics, Mahwah, NJ) TKR with central spine posterior stabilization, at a mean 1.5 years’ follow-up. The principal assessment criterion was sagittal laxity at 90° flexion as measured by the Telos Stress Device® (Metax GmbH, Hungen, Germany).

Results: Sagittal laxity did not significantly differ between the UC and UC+ series: mean 8.2 mm (range: 0–19.5 mm) and 8.4 mm (4.5–15.8 mm), respectively. Sagittal laxity in the PS series was significantly less: 1.4 mm (0.2–3.9) (P<0.0001).

Conclusion: Sagittal laxity was greater in ultracongruent than central spine posterior stabilized TKR. This anteroposterior movement may induce polyethylene wear. The ideal degree of sagittal laxity for ultracongruent inserts remains to be determined.

Level of evidence: IV – retrospective study.

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1. Introduction

Ultracongruent (UC) inserts avoid certain drawbacks of central spine posterior stabilized (PS) models: greater loss of femoral substance due to the posterior stabilization cage, wear and insert spine fracture [1], and anterior knee pain [2]. Biomechanically, the greater femorotibial contact area of UC models should reduce long-term polyethylene wear [3], but in fact early wear has been reported in UC total knee replacements (TKR) with conventional polyethylene inserts [4,5]. The hypothesis that paradoxical movement in anterior translation of the tibiofemoral contact area could constitute an aggravating factor was put forward by Marion [5]. Increased sagittal laxity induces abnormal tibiofemoral kinematics [6], impacting functional outcome [7]. Even so, UC TKRs show medium-term results comparable to those of PS designs [8,9]. The principal objective of the present study was to compare sagittal laxity in rotating platform TKRs according to insert design: ultracongruent versus central spine. The principal hypothesis was that insert design influences global sagittal laxity. The secondary objective was to assess postoperative function.

2. Material and methods

The study was approved by the Comité de protection des personnes IRB on July 17, 2013, under the number 2013–45; all participant
patients provided written consent. A retrospective comparative study recruited three consecutive series of patients undergoing TKR for primary osteoarthritis of the knee without severe frontal deformity (varus or valgus < 15°), with a minimum 1 year's follow-up.

2.1. UC series: ultracongruent insert

The first series recruited 48 consecutive knees in 46 patients operated on between February 2007 and January 2009 using the condylar-stabilizing (CS) ultracongruent model of the Total Knee Triathlon™ range (Stryker Orthopaedics, Mahwah, NJ) (Fig. 1a). The femoral component had a single sagittal curve radius between 10° and 110° flexion. Thirteen knees (12 patients) were excluded (Fig. 2). Finally, 35 knees (34 patients) were included in the UC series. Mean follow-up was 2.0 years (range: 1.0–2.6 years).

2.2. UC+ series: more deeply concave ultracongruent insert

The second series comprised 52 consecutive knees in 49 patients operated on between April 2010 and September 2012 using an ultracongruent implant of the BalanSys™ range (Mathys Ltd, Bettlach, Switzerland) (Fig. 1b). The anterior lip of the ultracongruent rotating insert in this “deep-dish” model was higher than that used in the UC series. The femoral component condyles had multiple sagittal curve radii beyond 90° flexion. Sixteen knees (15 patients) were excluded. Finally, 36 knees (34 patients) were included in the UC+ series (Fig. 2). Mean follow-up was 2.5 years (range: 1.4–3.9 years).

2.3. PS series: insert with central spine posterior stabilization

The third series comprised 51 consecutive knees in 48 patients operated on between February 2009 and September 2009 using a rotating platform implant with central spine posterior stabilization of the Total Knee Triathlon™ range (Stryker Orthopaedics, Mahwah, NJ) (Fig. 1c). The condylar design was identical to that of the UC series. Eight knees (8 patients) were excluded. Finally, 43 knees (40 patients) were included in the PS series (Fig. 2). Mean follow-up was 1.5 years (range: 1.0–3.2 years).

Patients in the 3 series were operated on by 4 experienced surgeons of the Amiens University Hospital orthopedic surgery department. All three series of TKR were rotating platform posterior stabilization designs. All 3 models were in chromium-cobalt alloy; all were cemented, except for the femoral component in the UC+ series. The surgical technique was identical in all cases, using medial parapatellar arthrotomy and a pneumatic tourniquet. Flexion and extension spaces were managed using a dependent bone-cut technique with a primary tibial cut. A ligament tensor was used in all cases, and the spaces were adjusted according to the degree of external rotation of the femoral component. The external rotation of the tibial insert was centered on the anterior tibial

<table>
<thead>
<tr>
<th>SERIES</th>
<th>INITIAL POPULATION (knees)</th>
<th>EXCLUDED</th>
<th>FINAL POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC</td>
<td>48</td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td>UC+</td>
<td>52</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>CS</td>
<td>51</td>
<td>8</td>
<td>43</td>
</tr>
</tbody>
</table>

Fig. 1. Insert diagrams in transverse cross-section perpendicular to the posterior edge at the deepest point of femorotibial contact; a: UC series; b: UC+ series; c: PS series.

Fig. 2. Series recruitment flowchart.
Table 1
Preoperative comparability between series.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>UC 35 cases</th>
<th>UC+ 36 cases</th>
<th>PS 43 cases</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>69.8 (51.0–84.7)</td>
<td>66.8 (41.8–87.7)</td>
<td>64.9 (39.0–83.0)</td>
<td>0.122</td>
</tr>
<tr>
<td>F/M sex ratio</td>
<td>27/8</td>
<td>22/14</td>
<td>26/17</td>
<td>0.235</td>
</tr>
<tr>
<td>Side (L/R)</td>
<td>17/19</td>
<td>18/19</td>
<td>20/23</td>
<td>0.992</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>30.3 (21.5–43.3)</td>
<td>29.9 (20.8–43.4)</td>
<td>32.5 (24.5–48.1)</td>
<td>0.088</td>
</tr>
<tr>
<td>Charnley-Devane score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>8 (22.9%)</td>
<td>4 (11.1%)</td>
<td>8 (18.6%)</td>
<td>0.629</td>
</tr>
<tr>
<td>B</td>
<td>13 (37.1%)</td>
<td>18 (50.0%)</td>
<td>21 (48.8%)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>14 (40.0%)</td>
<td>14 (38.9%)</td>
<td>14 (32.6%)</td>
<td></td>
</tr>
<tr>
<td>History of tibial osteotomy</td>
<td>4 (11.4%)</td>
<td>2 (5.6%)</td>
<td>5 (11.6%)</td>
<td>0.673</td>
</tr>
<tr>
<td>Preoperative mechanical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>femorotibial angle (°)</td>
<td>–3.8 (--14 to 12)</td>
<td>–4.3 (--13 to 14)</td>
<td>–2.1 (--14 to 13)</td>
<td>0.286</td>
</tr>
</tbody>
</table>

F/M: female/male; L/R: left/right.

tuberosity. Implanting the femoral insert in the PS series required a supplementary bone-cut to create a space for the central spine of the tibial insert. Postoperative care and rehabilitation protocols were identical in all cases. Continuous progressive passive mobilization from 0° to 90°, using a Kinetc Arthromoteur®, was initiated as of day 1, and unassisted walking was encouraged as of day 2.

Comparability between the 3 series was assessed on preoperative variables: age, gender, side, BMI and Charnley-Devane score; no significant differences were found (Table 1).

The principal assessment criterion was sagittal laxity in 90° flexion. Strict lateral digitized radiographs were taken at a minimum 1 year’s follow-up, implementing an anterior then posterior tibial drawer. Drawers were standardized using a Telos Stress Device® (Metax GmbH, Hungen, Germany) with a force of 150 N (Fig. 3). An independent observer using DxMM® medical imaging software (Medasys®) measured the shortest distance between the tangents to the superior edge of the posterior condyles and to the posterior edge of the tibial platform plot ensuring insert rotation (Fig. 4); the differential between the distances measured on anterior versus posterior drawer-represented the sagittal laxity of the knee. Measurements were calibrated against the real diameter of the tibial plot as provided by the manufacturer: 10.15 mm in the UC and PS series and 9.00 mm in the UC+ series. All radiographs proved interpretable.

The secondary assessment criterion was the International Knee Society (IKS) function score, determined by an independent observer at last follow-up.

Statistical analysis of inter-group comparability used the Chi² test for gender, side and Charnley-Devane score, or the Fisher exact test for age and BMI. The principal and secondary assessment criteria were compared on analysis of variance (Anova); in case of significant inter-group difference, post-hoc Bonferroni tests were applied. Analysis used StatView 5.2® software (SAS Institute Inc., Cary, NC). The significance threshold was set at 0.05.

3. Results

There was no significant difference in laxity between the UC and UC+ series: mean, 8.2 mm (range: 0–19.5 mm) and 8.4 mm (range: 4.5–15.8 mm), respectively. In contrast, both were significantly greater than the PS series values: mean, 1.4 mm (range: 0.2–3.9 mm); P < 0.0001.

Mean IKS function score was significantly lower in the UC+ series (74.6; range: 20–100) than in the UC (86.1; range: 40–100) or PS series (89.5; range: 30–100) (P = 0.0007).

4. Discussion

Sagittal laxity is one of the objective indices of TKR stability [10,11] but is difficult to interpret. In the present study, UC TKRs showed significantly greater sagittal laxity than PS models. Sur et al. [12] studied sagittal laxity in 90° flexion in the same models as in the present UC and PS series, with results similar to those of the present study: mean global sagittal laxity of 9.78 mm (range: 1.50–19.38 mm) in UC implants versus 3.01 mm (range: 0–7.61 mm) in PS. The present results, however, differ from those of Bignozzi et al. [13], who reported equivalent anterior laxity between UC and PS designs, using intraoperative measurement via the navigation system, with joint capsule open and a non-standardized manual anterior drawer. Nabeyama et al. [14], with a study design similar to the present, reported that sagittal laxity in

Fig. 3. Photograph of knee installation during application of posterior drawer.
75° flexion in PS knees progressively diminished over the first 3 years, becoming significantly less than that of a healthy knee. Hal et al. [11] suggested that the degree of UC insert concavity should also influence sagittal laxity, which would be limited by the height of the anterior lip, restraining posterior displacement of the tibia; the present results fail to support this hypothesis. The literature on anteroposterior translation of the tibiofemoral contact in flexion in UC TKRs [15,16] reports reduced movement, implying better sagittal stability. However, Massin et al. [16] found that the UC TKR with the greatest paradoxaonal anterior displacement required surgical revision for instability. The present results did not determine the predominant direction of laxity; according to Sur et al. [12], it is predominantly posterior. It should be borne in mind that paradoxaonal anterior displacement of the tibiofemoral contact is reported as a drawback of UC inserts [17–19], impairing extensor system function [20] due to increased patellar pressure. Moreover, Heyse et al. [21] showed in vitro that UC inserts required greater quadriceps force than central spine models to extend the limb. The present results point to poorer function with deep-dish ultracongruent TKR (UC+) compared to posterior stabilized TKR (PS). Finally, the greater sagittal laxity found with UC TKRs may be due to polyethylene delamination [5,22], promoting wear particle production and osteolysis caused by loosening forces induced by greater congruence [19,24], despite the advantages this should provide [3,23].

The present study involved certain limitations. Victor et al. [25], in a comparative fluoroscopy study of 3 identical TKA series, with the same surgical technique performed by 3 different surgeons, found sagittal laxity to be operator-dependent. In the present study, 4 different surgeons operated.

The sagittal laxity assessment procedure was standardized, and had been previously validated in non-implanted knees [26] and employed in 2 similar studies [12,14]. It was, however, 2-dimensional, in 90° flexion, which fails to take account of the real kinetics and stress patterns involved in walking and climbing stairs: tibial internal rotation in flexion, and differential anteroposterior displacement between lateral and medial condyles [10]. The 90° flexion position does not correspond to the Lachman test and the contributions of anterior and posterior drawer could not be differentiated. Fluoroscopic analysis associated to 3D digital imaging would provide more precise measurements [27].

Finally, the UC+ series implant had a different condylar design from the UC and PS series. Nevertheless, Stodard et al. [28] reported equivalent anteroposterior laxity values in single-radius and multi-radius TKR in an in vitro study.

5. Conclusion

UCTKR showed significantly greater sagittal laxity in 90° flexion than the PS model. Complications may be multiple (function and wear-related), and require better understanding of the conditions under which they occur; long-term follow-up of these implants is justified. The ideal sagittal laxity for an ultracongruent implant remains to be defined.
Disclosure of interest

The authors B.AF, E.K and E.H declare that they have no competing interest.
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P.M: royalties from X-Nov; consultant for DePuy and Stryker.

References