Original article

Long-term outcomes of primary constrained condylar knee arthroplasty

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Background: Although constrained condylar knee (CCK) inserts are widely used for total knee arthroplasty (TKA), their long-term outcomes remain unclear. We sought to evaluate patients with at least 10 years’ follow-up after CCK TKA to identify potential adverse events (osteolysis, loosening, constraint-mechanism failure), assess functional outcomes with special emphasis on range of motion, and determine prosthesis survival.

Hypothesis: Increasing constraint by implantation of a CCK insert does not increase the long-term frequencies of osteolysis or mechanical loosening.

Material and methods: We studied 43 knees after Legacy® CCK TKA. The indication was severe deformity (n = 20), pre-operative laxity (n = 6), or failure to achieve intra-operative balancing (n = 17). There were 41 patients with a mean age of 66 years (21–88). A history of one or more surgical procedures was noted for 27 (63%) knees. Outcome measures were the Hospital for Special Surgery (HSS) knee score, Knee Society Score (KSS), and change in the hip-knee-ankle (HKA) angle. Prosthesis survival was assessed using revision surgery for any reason or for reasons other than infection as the censoring criterion.

Results: Complications other than venous thrombosis occurred in 16% of patients, including 3 who required revision surgery (septic loosening, n = 2; and major instability in a patient with ipsilateral hip arthrodesis). No cases of osteolysis or aseptic loosening were recorded. Mean follow-up was 12.7 years (range, 10–14). At last follow-up, the HSS score had improved from 53 (26–83) pre-operatively to 80 (55–93), the KSS knee component from 42 (16–77) to 90 (77–99), and the KSS function component from 31 (0–80) to 61 (10–90) (P < 0.001). Mean range of flexion increased from 109° (50°–140°) to 112° (90°–130°) (P = 0.12). The HKA angle changed from 182° ± 15.5° (150°–210°) to 179° ± 2.5° (174°–184°) (P = 0.5). The 11-year prosthesis survival rate was 88.5% (95% confidence interval, 0.69–0.94) overall and 97.7% (0.76–0.99) after excluding the cases of infection.

Discussion: Long-term functional gains after CCK TKA were similar to those reported after standard posterior-stabilised TKA, with no cases of constraint-mechanism failure or osteolysis. The complication rate was higher, with decreased survival compared to standard TKA, but the knee deformities and/or instability were particularly severe and two-thirds of knees had a history of one or more surgical procedures.

Level of evidence: Level IV, retrospective case-series study.

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1. Introduction

Stability is essential to successful total knee arthroplasty (TKA) [1–3]. The amount of constraint needed to achieve sufficient stability may be difficult to determine preoperatively. Increased constraint may be required in patients with valgus laxity or major deformities (e.g., related to trauma, rheumatoid arthritis, neuropathic arthropathy, or sequelae of anterior poliomyelitis) [4,5]. The use of constrained prostheses does not seem to diminish the range-of-motion (ROM) or functional gains compared to those achieved with standard posterior-stabilised TKA [6].

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Constrained condylar knee (CCK) prostheses have a number of theoretical disadvantages such as an increased risk of mechanical loosening due to the increased constraint or to the presence of polyethylene particle shedding, particularly by the tibial post [7,8]. Other theoretical risks are knee malalignment and/or increased varus/valgus instability in the long-term due to polyethylene creep at the tibial post. The risk of these complications in clinical practice is unclear, as few studies have specifically addressed CCK TKA and most of them had less than 10 years of follow-up [9–11].

We conducted a retrospective evaluation of primary CCK TKA with a theoretical follow-up of at least 10 years. Our objective was three-fold: to assess the frequency of theoretically predicted complications (osteolysis, loosening, and constraint-mechanism failure), to determine whether range-of-motion (ROM) and other functional outcomes were satisfactory, and to determine whether prosthesis survival was within the acceptable range. Our working hypothesis was that increased constraint via implantation of a CCK insert did not increase the frequency of osteolysis or loosening in the long-term.

2. Material and methods

2.1. Patients

Between January 1997 and December 2002, 1769 primary TKA procedures were performed in our unit, including 43 (2.4%), in 41 patients, using the NexGen® Legacy® CCK (NexGen LCCK, Zimmer, Warsaw, IN, USA). The decision to use a CCK insert was taken pre-operatively in 26 cases based on the laxity measurements and on the deformities assessed clinically and radiographically (standard and varus/valgus stress radiographs) (Figs. 1 and 2). In the remaining 17 cases, the decision was taken intra-operatively when it proved impossible to achieve satisfactory ligament balancing, i.e., less than 5° of laxity in the coronal plane and a smaller than 3-mm difference between gaps in flexion and extension [5]. Follow-up was at least 10 years in all patients. Two patients underwent CCK TKA on both knees, at an interval of 11 and 12 months, respectively. Table 1 reports the main baseline patient characteristics.

![Fig. 1. CCK prosthesis implanted in a 65-year-old woman because of a 28° varus deformity of the left knee. A. Pre-operative radiographs of the left knee: total leg radiograph and schuss view. B. Radiograph of the left knee after 13 years: total-leg radiograph. No abnormalities are visible at the bone-prosthesis interfaces.](image1)

![Fig. 2. CCK prosthesis in a 54-year-old patient with a valgus deformity of 25°. A. Pre-operative radiographs: total-leg and schuss views. B. Radiographs after 12 years: non-progressive lucent line under the medial tibial plateau.](image2)
Table 1

Main pre-operative patient characteristics.

<table>
<thead>
<tr>
<th>Clinical and demographic features</th>
<th>n (%), or mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males/females, n</td>
<td>14/27</td>
<td></td>
</tr>
<tr>
<td>Age in years, mean ± SD</td>
<td>66 ± 12.3</td>
<td>21–88</td>
</tr>
<tr>
<td>BMI in kg/m², mean ± SD</td>
<td>29.5 ± 6.1</td>
<td>19.1–44.3</td>
</tr>
<tr>
<td>BMI &gt; 30 kg/m², n (%)</td>
<td>15 (35)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities, n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Glucocorticoid therapy</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Diagnosis, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idiopathic osteoarthritis</td>
<td>34 (79.1)</td>
<td></td>
</tr>
<tr>
<td>Post-traumatic osteoarthritis</td>
<td>4 (9.3)</td>
<td></td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>4 (9.3)</td>
<td></td>
</tr>
<tr>
<td>Avascular necrosis of the medial condyle</td>
<td>1 (23)</td>
<td></td>
</tr>
<tr>
<td>HKA in°, mean ± SD</td>
<td>182 ± 15.5</td>
<td>150–210</td>
</tr>
<tr>
<td>Normal alignment (180° ± 3°), n (%)</td>
<td>11 (25.6)</td>
<td></td>
</tr>
<tr>
<td>Varus deformity, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤10°</td>
<td>5 (11.6)</td>
<td></td>
</tr>
<tr>
<td>&gt;10°</td>
<td>10 (23.3)</td>
<td></td>
</tr>
<tr>
<td>Valgus deformity, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤10°</td>
<td>7 (16.2)</td>
<td></td>
</tr>
<tr>
<td>&gt;10°</td>
<td>10 (23.3)</td>
<td></td>
</tr>
</tbody>
</table>

BMI: body mass index; HKA: hip-knee-ankle angle [12].

Of the 43 knees, 27 (63%) had had one to three previous surgical procedures: tibial valgus osteotomy, n = 9; fixation hardware removal, n = 7; meniscectomy, n = 4; ligament surgery, n = 4; articular fractures, n = 2; arthrolysis, n = 1; synovectomy, n = 1; posterior knee dislocation, n = 1; recurrent patellar dislocation, n = 1; and medial condyle epiphysiodesis, n = 1.

2.2. Operative technique

Mean operative time was 176 min (125–285). A pneumatic tourniquet was used at prosthesis fixation. The following additional intra-operative procedures were performed: anterior tibial tubercle osteotomy, n = 7, to achieve sufficient exposure; hardware removal, n = 3; and autologous bone grafting, n = 1.

We used the MIS Multi-Reference® 4-in-1 instrument (Zimmer). The approaches were as follows: medial para-patellar (n = 22), lateral as described by Keblish [13] (n = 9), mid-vastus [14] (n = 7), or medial tricenter [15] (n = 5). The tibia was cut perpendicularly to the tibial axis, with 7° posterior tibial slope. The distal femur was cut using an intramedullary guide angled 6° from the mechanical axis.

2.3. Assessment methods

The study data were collected from the patient records and the electronic hospital database. We reviewed the medical notes, correspondence, and pre-operative scores including the Hospital for Special Surgery (HSS) score [16] and Knee Society Score (KSS) [12]. We recontacted all patients between August 2012 and June 2013. Among them, 16 (17 TKAs) had died, a mean of eight years after TKA (range, 2–13). For each of these patients, we reviewed the medical records and contacted the usual physician and family to assess the occurrence of complications and need for further surgery. Of the 25 other patients (26 TKAs), 22 (22 TKAs) underwent a clinical and radiological re-evaluation; two patients (3 TKAs) were unwilling to travel to our institution but completed a telephone questionnaire and one patient was lost to follow-up.

We were thus able to assess the survival of 42 prostheses after a mean follow-up of 11 years (2–14). Long-term outcome data were obtained for 25 knees, after a mean follow-up of 12.7 years (range, 10–14).

The clinical and radiographic assessment was performed by an observer who had not been involved in the surgical procedures. The physical examination included an evaluation for complications (infections, clinically measured laxity values, and loosening) and determination of the HSS, KSS, and Oxford knee scores [17]. The radiographs included a strict antero-posterior view, a schuss view, a lateral view in 30° of flexion, a tangential patellar view in 30° of flexion, and a weight-bearing total-leg view. The HKA angle was measured and radiolucent lines were sought using Knee Society criteria [12].

2.4. Statistical analysis

The Shapiro-Wilk test was applied to determine whether numerical variables were normally distributed. To compare changes between the pre-operative and last-follow-up assessments, we chose repeated-measures ANOVA for numerical variables, a test of symmetry (extension of McNemar’s test) for qualitative variables, and repeated-measures Wilcoxon’s test for ordinal variables. Prosthesis survival was assessed according to the Kaplan-Meier method [with computation of 95% confidence intervals [95%CIs]], with two different censoring criteria, namely, revision for any reason and revision for a reason other than infection. Statistical analyses were performed using SAS software version 9.3 (SAS, Cary, NC, USA). Values of P ≤ 0.05 were considered significant.

3. Results

Of the 16 patients (17 TKAs) who died during follow-up, one had required prosthesis removal because of delayed infection. In the 22 patients (22 TKAs) who were re-evaluated, mean follow-up was 152 months (12.7 years; range, 10–14 years) and mean age at re-evaluation was 76 years (range, 31–95 years).

3.1. Osteolysis, luencies, constraint–mechanism failure

According to Knee Society criteria, radiolucent lines were present at the tibia in 9/22 (41%) knees, femur in 1/22 (5%) knees, and patella in 1/22 (5%) knees. These luencies had already been identified on the post-operative radiographs. In addition, none of the 22 knees had evidence of loosening requiring revision surgery; one patient had loosening of the tibial tray and extension stem. None of the three surgical revisions described below were required because of mechanical loosening. The HKA angle was 182° ± 15.5° (150°–210°) pre-operatively and 179.5° ± 2.3° (174°–184°) at re-evaluation (P = 0.55) (Fig. 3).

Pre-operatively, 36/43 (84%) knees had greater than 5° coronal laxity, including 5/43 (12%) with major coronal laxity greater than 15°. At re-evaluation, 19/22 (86%) patients had no coronal laxity and no patients had major coronal laxity (P < 0.006) (Table 2).

Fig. 3. Distribution of hip-knee-ankle angle values before TKA and at last follow-up.
Fig. 4. Disassembly of the screws securing the polyethylene insert to the tibial tray in a 52-year-old patient. A. Pre-operative radiographs. The choice of a constrained prosthesis was made intra-operatively because of failure to achieve adequate balancing. B. Radiographs after 7 years. C. Radiographs after 11.5 years. Despite screw migration, the patient is symptom-free (IKS score, 165; Oxford score, 18/60).

Table 2
Knee laxity in the coronal plane before surgery and at last follow-up. This parameter improved significantly \( P < 0.0062 \).

<table>
<thead>
<tr>
<th>Coronal laxity</th>
<th>Pre-operative ((n = 43))</th>
<th>Last follow-up ((n = 22))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt;5^\circ)</td>
<td>7 (18)</td>
<td>19 (86)</td>
</tr>
<tr>
<td>(5^\circ) to (9^\circ)</td>
<td>19 (47)</td>
<td>3 (14)</td>
</tr>
<tr>
<td>(10^\circ) to (15^\circ)</td>
<td>9 (22)</td>
<td>0</td>
</tr>
<tr>
<td>(&gt;15^\circ)</td>
<td>5 (13)</td>
<td>0</td>
</tr>
</tbody>
</table>

3.2. Functional outcomes and complications

Substantial clinical improvements were achieved (Table 3): mean gains on the HSS, KSS knee, and KSS function scores were 27, 48, and 30 points, respectively \( P < 0.001 \). Mean flexion ROM increased from \(109^\circ (50^\circ - 140^\circ)\) to \(112^\circ (90^\circ - 130^\circ)\) \( P = 0.12 \). At last follow-up, the patients were satisfied with the procedure: the mean Oxford score was 22.7/60 (range, 12–41). None of the patients reported disappointment with knee ROM or function.

Table 3
Changes in the Hospital for Special Surgery (HSS) Score [16] and the Knee Society Score (KSS) [12].

<table>
<thead>
<tr>
<th></th>
<th>Mean scores (n)</th>
<th>Pre-operatively</th>
<th>At last follow-up</th>
<th>Gain</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSS [16]</td>
<td>53 ± 13 (26–83)</td>
<td>80 ± 9 (55–93)</td>
<td>27</td>
<td>(&lt;0.0001)</td>
<td></td>
</tr>
<tr>
<td>KSS knee [12]</td>
<td>42 ± 16 (16–77)</td>
<td>90 ± 7 (77–99)</td>
<td>48</td>
<td>(&lt;0.0001)</td>
<td></td>
</tr>
<tr>
<td>KSS function [12]</td>
<td>31 ± 21 (0–80)</td>
<td>61 ± 25 (10–90)</td>
<td>30</td>
<td>(&lt;0.0001)</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 reports the complications. Venous thrombosis occurred in four patients, who had favourable outcomes after curative-dose heparin therapy. Wound dehiscence with superficial necrosis in one patient also had a good outcome. A non-displaced fracture around the tibial stem was managed non-operatively, to good effect. A patient with ipsilateral hip arthrodesis showed major...
Table 4

<table>
<thead>
<tr>
<th>Complications</th>
<th>Knees, n (%)</th>
<th>Revision procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>4 (9.3)</td>
<td>Lavage, n = 2</td>
</tr>
<tr>
<td>Venous thrombosis</td>
<td>4 (9.3)</td>
<td>Replacement, n = 2</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>1 (2.3)</td>
<td></td>
</tr>
<tr>
<td>Major instability</td>
<td>1 (2.3)</td>
<td>Replacement, n = 1</td>
</tr>
<tr>
<td>Peri-prosthetic fracture</td>
<td>1 (2.3)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11 (25.5)</td>
<td>5 (11)</td>
</tr>
</tbody>
</table>

residual instability with 45° of genu recurvatum deformity; the
management in this patient involved hip de-arthrodesis followed
by replacement then knee revision surgery with implantation of
a hinged prosthesis after 10 years. In another patient (Fig. 4),
re-evaluation after 11.5 years showed disassembly of the screw
securing the insert to the tibial tray, with a cortical reaction around
the tibial stem, which was loose and displaced in varus; she had
no neurovascular complications, was satisfied with the procedure
(KKS, 165 [knee, 85 and function, 80]; HSS, 83; and Oxford score,
18), and refused revision surgery.

Prosthesis infection occurred in four knees, after four months
(in a patient with a previous history of infection), three years,
six, and eight years, respectively. Treatment involved lavage
and synovectomy (n = 2) with replacement of the insert, two-stage
prosthesis replacement (n = 1), and two-stage arthrodesis (n = 1),
respectively.

3.3. Prosthesis survival curves

When we used revision for any reason as the censoring crite-
ron, survival after a mean of 11 years was 88.5% (95%CI, 0.69–0.94)
(n = 27 knees still under study after 11 years). With revision for
non-infectious events as the censoring criterion, 11-year survival
was 97.7% (95%CI, 0.76–0.99) (n = 29 knees) (Fig. 5).

4. Discussion

Our findings confirm our working hypothesis: CCK TKA is not
associated with increased 10-year rates of osteolysis or loosening.
Progressive peri-prosthetic lucencies and osteolysis did not occur,
extcept in a patient with disassembly of a screw securing the insert
to the tibial tray. The frequencies of tibial and femoral lucencies
were consistent with those in previous studies of similar prostheses
and indications (Table 5). None of the three patients who required
replacement of the prosthesis had mechanical loosening.

The limitations of our study include those inherent in the
retrospective design. The 10-year clinical and radiographic eval-
uation could not be performed in the 16 patients who died during
follow-up, but we obtained accurate data on prosthesis survival.
In addition, a single patient (2%) was lost to follow-up, which is
acceptable in a study aiming for a follow-up of at least 10 years.
Information bias may have occurred as some data were missing
(the medical records were incomplete for one case). Finally, lucency
measurement is less accurate on radiographs than on computed
tomography scans. However, the cobalt-chrome used to make the
prosthesis, together with the size of the implant, can induce sub-
stantial artefacts that limit the accuracy of computed tomography.

Our clinical outcomes are comparable to those recorded in
other studies of primary CCK TKA [9–11,18]. Significant functional
improvements were achieved, most notably in terms of flexion
ROM (Table 5).

We had a high complication rate (16% after exclusion of venous
thrombosis). The only revision procedure performed in the absence
of infection was related to faulty patient selection: CCK TKA
was performed despite ipsilateral hip arthrodesis responsible for
mechanical failure (with major laxity) of the knee prosthesis after
10 years. Infection (n = 4) was the leading complication (4/11) and
the most common reason for re-operation (4/5) and prosthetic
revision (2/3) (Table 5). In three of the four cases, the infection
was delayed. In a study of primary TKA, Jansen et al. [19] found
higher infection rates with constrained or hinged prostheses [19].

Table 5

<table>
<thead>
<tr>
<th>Prosthesis</th>
<th>TKA, n</th>
<th>FU, mo</th>
<th>HSS gain</th>
<th>KSS knee gain</th>
<th>KSS function gain</th>
<th>Flexion, gain</th>
<th>Tibial lucent lines (%)</th>
<th>Femoral lucent lines (%)</th>
<th>Mechanical loosening (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lachiewicz and Soileau [9]</td>
<td>LCCK</td>
<td>30</td>
<td>65</td>
<td>25.2</td>
<td>56.4</td>
<td>13.5</td>
<td>106</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Lachiewicz and Soileau [18]</td>
<td>TCJ and IB2</td>
<td>54</td>
<td>108</td>
<td>29.7</td>
<td>56.3</td>
<td>6.3</td>
<td>93.2</td>
<td>21.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Anderson et al. [10]</td>
<td>Optetrak NMCC</td>
<td>70</td>
<td>45</td>
<td>59</td>
<td>34</td>
<td>103</td>
<td>12.2</td>
<td>4.1</td>
<td>0</td>
</tr>
<tr>
<td>Maynard et al. [11]</td>
<td>LCCK</td>
<td>127</td>
<td>110.7</td>
<td></td>
<td></td>
<td></td>
<td>117</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Our study</td>
<td>LCCK</td>
<td>43</td>
<td>152</td>
<td>27</td>
<td>48</td>
<td>30</td>
<td>112</td>
<td>47</td>
<td>5</td>
</tr>
</tbody>
</table>

FU: follow-up; mo: months.
We found a higher infection rate (9.3%) than in previous studies of CCK TKA (1.6 and 3.3%) [9–11,18]. Factors possibly involved in this higher rate include the long operative time, large prosthesis sizes and, above all, patient-related factors, with obesity in one-third of patients and a previous history of surgery in 27 (63%) knees.

The high infection rate adversely affected prosthesis survival, which was 88.5% after 11 years (95%CI, 0.69–0.94). When only revisions for reasons other than infection were counted, 11-year survival was 97.7% (95%CI, 0.76–0.99), which is close to the values reported with unconstrained prostheses [20].

5. Conclusion

We documented good long-term clinical and radiographic outcomes after primary CCK TKA in patients with major ligament laxity and/or deformities precluding the implantation of standard prostheses. The long-term mechanical complications predicted on theoretical grounds did not occur, probably because the level of constraint decreased over time due to polyethylene creep at the tibial post. CCK TKA is therefore a safe and durable alternative to hinge prostheses, which imposed greater constraints associated with a high rate of long-term osteolysis. CCK TKA requires longer-term studies to check the absence of the metaphyseal stress shielding inherent in the use of hinge TKA.

Disclosure of interest

Gilles Pasquier is an educational and research consultant for Zimmer. Henri Migaud is an educational and research consultant for Zimmer and Tornier. Pierre Cholewinski, Laurent Vasseur, Sophie Putman, Alain Duhamel, and Hélène Behal declare no potential conflicts of interest related or unrelated to this work.

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