Total knee arthroplasty in valgus knees: Predictive preoperative parameters influencing a constrained design selection

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Summary

Introduction: In valgus knees, ligament balance might remain a challenge at total knee prostheses implantation; this leads some authors to systematically propose the use of constrained devices (constrained condylar knee or hinge types). It is possible to adapt the selected level of constraints, by reserving higher constraints to cases where it is not possible to obtain final satisfactory balance: less than 5\degree of residual frontal laxity in extension in each compartment, and a tibiofemoral gap difference not in excess to 3 mm between flexion and extension.

Hypothesis: It is possible to establish preoperative criteria that can predict a constrained design prosthetic implantation at surgery.

Materials and methods: A consecutive series of 93 total knee prostheses, implanted to treat a valgus deformity of more than 5\degree was retrospectively analysed. Preoperatively, full weight bearing long axis AP views A-P were performed: hip knee angle (HKA) averaged 195\degree (186\degree to 226\degree), 36 knees had more than 15\degree of valgus, and 19 others more than 20\degree of valgus. Laxity was measured by stress radiographies with a Telos\textsuperscript{TM} system at 100 N. Fifty-two knees had preoperative laxity in the coronal plane of more than 10\degree. Fourteen knees had more than 5\degree laxity on the convex (medial) side, 21 knees had more than 10\degree laxity on the concave (lateral) side. Statistical assessment, using univariate analysis, identified the factors that led, at surgery, to an elevated constraint selection level; these factors of independence were tested by multivariate analysis. Logistical regression permitted the classification of the said factors by their odds ratios (OR).

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**Introduction**

The correction of deformities and establishing ligament balance are priority mechanical objectives in the implantation of total knee prostheses (TKPs) to ensure a good, durable and functional result [1—4]. In cases of frontal deformity in valgus, achieving these two objectives may be difficult [5,6], notably in patients with convex laxity and/or deformity surpassing 20° [7]. Specific management techniques for the soft tissue release have been developed to treat this type of deformity:

- the lateral approach with elevation of Maissiat’s band of Gerdy’s tubercle [8—10];
- the medial articular approach and the release of lateral structures by the trans-articular approach with partial section of the iliotibial band by “pie-crusting” [11,12];
- lateral condyle osteotomy allowing the displacement of femoral insertions of the lateral collateral ligament and of the popliteal muscle for adjustment of laxity and space in flexion as in extension [13].

Other methods were proposed when the previous techniques reached their limits:

- osteotomy combined with prosthesis implantation when the deformity is extra-articular [14];
- constrained prosthesis (with constrained condylar knee [CCK] type), notably for elderly patients to simplify and shorten the operative procedure [15—17];
- hinge prosthesis to simplify the intervention to the maximum when significant laxity exists [18,19].

Several authors have raised concerns that these high-constraint prosthesis (CCK type) and hinge prostheses represent a higher risk of loosening and exposure to technical difficulties in case of revision [20—22]. Systematic recourse to prostheses implanted with high-level constraint is questionable, and several authors have proposed adjustment of this indication to the ligament balancing problems [19,23—25]. This attitude appears to be reasonable, but it presumes the availability, in operating room, of different implant types and corresponding ancillary components (or evolutive ancillary items), to adapt to operative difficulties during intervention. Among these operative problems encountered, the adjustment of ligament tension is the most unpredictable, notably, to obtain evenness of spaces in flexion and in extension [26].

To facilitate the management of operating rooms (intervention duration, ancillaries, implants), it seems justified to identify cases where recourse to high-constraint prostheses is the most probable. Our hypothesis is that preoperative data are predictive of the use of constrained prostheses in cases of valgus deformity greater than 5°.

**Materials and methods**

**Patients**

This continuous, monocentric, retrospective series comprised 93 TKPs implanted between 1996 and 2004 for the treatment of valgus knees with deformity of more than 5°. During the study period, only two hinge prostheses (excluded from the study) were implanted in first intention for genu valgum. There were 89 patients (four bilateral cases, 80 women and nine men) with an average age of 70.1 years ± 11.5 (32 to 90 years). Indications for arthroplasty were gonarthrosis in 63 knees (62.4%), rhumatoid arthritis in 14 knees (15.1%), post-traumatic arthritis in 12 knees (13%), lateral condyle necrosis in two cases (2.1%), one haemophilic arthropathy and one sequella of septic arthritis. Body mass index (BMI) was, on average, 28 ± 5 (17 to 41), and 27 patients were significantly overweight with BMI greater than 30.

In the 93 knees, 22 already had at least one intervention (12 knees with one intervention, nine knees with two interventions, and another one which underwent three interventions). The preliminary interventions consisted of eight internal fixations, seven osteotomies (four tibial valgus and three femoral varus osteotomies), 10 hardware removal, two debridement arthroscopies for arthropathy, two sections of the lateral patellar retinaculum, one transfer of the anterior
tibial tubercle and a reconstruction of the anterior cruciate ligament. The average index of arthroplasty was 1.35 (1 to 4).

According to the International Knee Society (IKS) scoring system [27], 48 knees were class A, 34 class B, and 11 class C, indicating multiarticular involvement. The IKS “knee score” averaged 30 ± 15.5/100 points (0 to 70) and the IKS “function score” was 36.8 ± 21.6/100 points (0 to 80), giving a global score of 66.8 ± 28.8/200 points (4 to 127). Preoperative mobility in flexion was, on average, 113 ± 11 (127 to 120), giving a global score of 86 times, was not inflated until the time of sealing, that is to say, after all cuts were made and ligament balance adjusted. The chosen approach was left to the discretion of the surgeon (four seniors undertook or supervised the operations): 54 lateral approaches and 39 medial approaches were taken; elevation of the anterior tibial tubercle was performed [31] 25 times, always during the lateral approach. No preoperative factor had any significant influence on the choice of approach: deformity severity, frontal laxity, patellar height, etiology, mobility and flessum, obesity (non-significant). The same surgical sequence was followed by all surgeons, with the tibial cut first (under centromedullary guidance coupled with extramedullary vision) and then the femoral cut, both undertaken orthogonally to the mechanical axis to correct the frontal axis defect.

### Operative technique

All surgeries were performed under vertical laminar flow, 53 times under general anaesthesia and 40 times under epidural anaesthesia. The pneumatic tourniquet, which was used 86 times, was not inflated until the time of sealing, that is to say, after all cuts were made and ligament balance adjusted. The chosen approach was left to the discretion of the surgeon (four seniors undertook or supervised the operations): 54 lateral approaches and 39 medial approaches were taken; elevation of the anterior tibial tubercle was performed [31] 25 times, always during the lateral approach. No preoperative factor had any significant influence on the choice of approach: deformity severity, frontal laxity, patellar height, etiology, mobility and flessum, obesity (non-significant). The same surgical sequence was followed by all surgeons, with the tibial cut first (under centromedullary guidance coupled with extramedullary vision) and then the femoral cut, both undertaken orthogonally to the mechanical axis to correct the frontal axis defect.

### Table 1

| Laxity values measured manually and radiographically by a Telos™ system with an applied force of 100 N. With manual measurements, 21 laxities of 10° or more would not have been known. | Manual measurements [number (%)] | Radiographic measurements [number (%)] |
|---|---|
| **Frontal laxity** |  
< 5° | 27 (29) | 1 (1.3) |
| 5° to 9° | 35 (37.6) | 25 (32.1) |
| 10° to 14° | 17 (18.4) | 42 (53.8) |
| ≥ 15° | 14 (15.1) | 10 (12.8) |
| **Sagittal laxity** |  
< 5 mm | 77 (82.9) |  
5 to 9 mm | 12 (12.9) |  
≥ 10 mm | 4 (4.3) |

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average ± S.D.</th>
<th>Range</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackburne &amp; Peel Tibial slope</td>
<td>0.86 ± 0.16</td>
<td>0.5 to 1.52</td>
<td>3 patella baja and 8 alta</td>
</tr>
<tr>
<td>Patellar position</td>
<td>5° ± 3.1°</td>
<td>0° to 17°</td>
<td>17 knees with more than 7°</td>
</tr>
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<td>0° to 17°</td>
</tr>
<tr>
<td>HKA</td>
<td>195° ± 6.8°</td>
<td>186° to 226°</td>
<td>36 knees &gt; 15° of valgus and 19 knees &gt; 20° of valgus</td>
</tr>
<tr>
<td>HKS angle</td>
<td>6.8° ± 1.4°</td>
<td>4° to 11°</td>
<td>27 knees with divergence &gt; 7°</td>
</tr>
<tr>
<td>Alpha angle (anatomical femoral varus)</td>
<td>101.5° ± 4°</td>
<td>89° to 115°</td>
<td>56 knees with &gt; 100° and 18 knees with &gt; 105°</td>
</tr>
<tr>
<td>Beta-angle</td>
<td>93.7° ± 4.8°</td>
<td>85° to 118°</td>
<td>Only 9 tibia in varus (&lt; 90°) but 35 tibia in valgus &gt; 5° (beta &gt; 95°)</td>
</tr>
<tr>
<td>Laxity in varus (concavity)</td>
<td>7.9° ± 3.1°</td>
<td>1° to 17°</td>
<td>21 knees with 10° or more</td>
</tr>
<tr>
<td>Laxity in valgus (convexity)</td>
<td>3° ± 2°</td>
<td>1° to 10°</td>
<td>14 knees with 5° or more</td>
</tr>
</tbody>
</table>

HKA: hip-knee angle; HKS: angle between the mechanical axis and femoral shaft axis.
Ligament balancing was guided and evaluated by tension (V-Stat™ or HLS™ tensioning device) and/or wedges of increasing thickness reproducing gaps in flexion and extension. Ligament tension was regulated with instruments by progressive release and, as needed, by lateral (54 cases) and/or medial structures (six cases) according to the method proposed by Insall et al. [4,6]. In principle, for all the surgeons, a posterostabilised (PS) prosthesis was implanted (Nexgen-Legacy™, HLS™) if the tensioning device and/or the wedges indicated that there was less than 5° of residual frontal laxity in extension in each compartment and a difference of less than 3 mm between the spaces in flexion and extension. In opposite cases, the cuts were revised for the implantation of a constrained prosthesis (Nexgen-Legacy CCK™). The lateral patellar retinaculum was sectioned in 54 surgeries by the lateral approach and in 19 of 39 surgeries by the medial approach (with no statistical correlation to preoperative subluxation). One lateral condyle osteotomy, according to Burdin & Brilhaut [13] was done to refine ligament balance to allow the use of a PS prosthesis.

**Evaluation and statistical methods**

The judging point was the recourse to a constrained prostheses implanted because of defective balance according to the modalities mentioned above. Statistical analysis was performed with SAS software (SAS, Cary, CA, USA) to identify the factors that could predict variations of the judging point. Univariate analysis was conducted by the Chi² test for categorical variables, analysis of variance for the comparison of averages, and logistic regression for quantitative variables. Univariate analyses identified the factors that had an influence on the choice of constrained prostheses. The independence of these factors was evaluated by multivariate analysis, and logistical regression analysis then permitted the classification of factors by odds ratios (OR) (with 95% confidence intervals). The alpha risk was 5%.

**Results**

PS prostheses (36 HLS™ and 31 Nexgen-Legacy™ prostheses) were implanted in 67 of the 93 knees (72%). In 26 cases (28%), the surgeon estimated that the balancing criteria were not met, and a constrained prosthesis (Nexgen-Legacy LCCK™) was inserted.

Five preoperative factors were identified by univariate analysis to be associated more frequently with the implantation of sliding, constrained prostheses:

- preoperative valgus severity measured by Hip–Knee–Ankle angle (HKA), 193° in the group with PS prostheses versus 198° in the group with constrained prostheses ($p = 0.009$). On the other hand, other angles evaluating femoral deformity (alpha, HK5) were not correlated with the use of a high-constraint device;
- elevated tibial slope (4.8° in the group with a PS prosthesis versus 6.5° in the TKP-constrained group ($p = 0.02$));
- tibial valgus identified by beta angle of 93° in the PS group versus 96° in the TKP-constrained group ($p = 0.01$);
- a low patella identified by the index of Blackburne and Peel of 0.89 in the group with PS prostheses versus 0.77 in the TKP-constrained group ($p = 0.001$);
- radiological laxity in valgus was higher than 4.3° in the TKP-constrained prostheses group versus 2.3° in the PS prostheses group ($p = 0.0001$).

On the other hand, other factors were not correlated with the use of constrained prostheses: (1) significant laxity in varus, (2) osteotomy history, (3) correction of the deformity on stress radiographs, and (4) ligament loosening.

No other preoperative clinical factor (age, aetiology, obesity, mobility, flexsum, function and IKS score), operative (approach, type of anaesthesia, tubercle elevation) or radiographic procedure (patella position on the defile) was correlated with the greater frequency of constrained prostheses.

Multivariate analysis showed that the sole independent factor associated with the more frequent implantation of constrained prostheses was laxity in valgus with an OR of 1.9 (1.2–2.7) ($p = 0.0008$). Each increase of 1° in laxity in valgus augmented the risk of inserting a constrained prosthesis by 1.9-fold ($p = 0.0003$). The existence of a low patella was at the limit of significance as an independent risk factor ($p = 0.08$).

The frequency of per- or postoperative complications was comparable for PS and constrained prostheses with, however, three conversions of PS to constrained prostheses: one lateral tibial plateau fracture, initially unseen, revised at day 10, and two revisions for frontal instability at 15 and 18 months by CCK type constraint prostheses (one being a Burdin and Brilhaut type osteotomy (Fig. 1)). Fibular nerve palsy occurred once, with partial recovery after a PS prosthesis. On the other hand, surgical duration was much greater in the case of constrained prosthesis (171 minutes versus 141 minutes [$p = 0.0006$]), and while intraoperative bleeding was comparable between the two groups, postoperative bleeding was more significant in the constrained prostheses group (1233 ml versus 1081 ml [$p = 0.02$]).

**Discussion**

This study confirmed the seriousness of convex laxity during TKP implantation in valgus. The idea has already been proposed by Stern et al. [6] and Miyasaka et al. [7], but it has not been confirmed statistically by multivariate analysis of a large series. In fact, Stern et al. [6], Miyasaka et al. [7], and Anderson et al. [17] also emphasized the role of deformity severity in valgus that our study refuted, demonstrating that the only independent factor predictive of constrained prostheses is laxity in valgus (that is to say, of convexity).

Our study has limits due to its high number of operators, but all respected the same criteria of indications for a constrained prosthesis. A principle position on the indication of CCK prostheses was followed by all operators, guided by instruments (tensioning devices and/or wedges). No authors have cited this type of reference, but it seems reasonable to report these numbers which correspond to a laxity threshold classified as “abnormal” on the IKS score [27,28]. Our principal objectives were to obtain comprehensive, preoperative radiographic measurements, notably radio-
Figure 1 A 64-year-old patient suffering from lateral arthrosis of the left knee (sequellae of hip dysplasia with varus tibial osteotomy history and hip prosthesis). A and B. Valgus knee of 19°, normal patellar height and tibial slope at 9°. C: Valgus stress radiograph on Telos™: convex laxity of 6°. D and E. Lateral approach with elevation of the tibial tubercle and condylar osteotomy: correction of the deformity and proper ligament balance with a PS prosthesis (radiographs at 4 months). F, G and H. Reappearance of convex laxity 14 months later necessitating revision with a CCK type prosthesis.

graphic quantification of frontal laxity by means of a Telos™ type dynamometer [32,33] which improved the reproducibility of measurements in relation to manual assessments [34,35]. Our study stresses the point that 21 frontal laxities surpassing 10° would have remained unknown by manual measurements, hampering the prediction of recourse to constrained prostheses. The Société orthopédique de l’Ouest symposium on TKP for valgus deformities of more than 10° reported four situations of reducibility and of convex laxity: reducible deformity without convex laxity, irreducible deformity without convex laxity, reducible deformity with convex laxity, and irreducible deformity with convex laxity [36]. Our investigation did not confirm the statistical influence of deformity correction as a factor predictive of recourse to constrained prostheses. On the contrary, convex laxity, a criterion proposed by Hulet et al. [36], is seen as an essential and independent predictive factor in our study.

Some authors have suggested that it is possible to treat all knee arthropathies with deformity in valgus by sliding, non-constrained prostheses: Ranawat et al. [5] did not implant any constrained prostheses in 85 TKPs in valgus of more than 10°, and Whiteside [37] inserted no constrained prostheses among 231 TKPs in valgus of 12 to 45°. However, the tolerance level of residual instability was not specified, and these series both came from a single operator.
[5,37]. On the contrary, as we have observed three times in our study, the use of "limit" conditions of a PS prosthesis exposed patients to secondary instability, seen in 24% of cases by Miyasaka et al. [7], while CCK type prostheses avoided secondary instability in this indication [17]. The solution proposed by Brilhaut et al. [13] is the most effective in limiting the implantation of constrained prostheses. This technique is the only one that allows imbalance to be controlled between the medial and lateral compartments in flexion and extension. The only case where we applied it was initially successful, but secondary loosening of the medial collateral ligament at 12-month follow-up (Fig. 1) was probably associated with varus tibial osteotomy history and led to failure. This observation suggests difficulties in establishing durable balance of multisurgery knees on the medial side as they are exposed to secondary loosening of the medial collateral ligament. To treat ligament imbalance with convex laxity, the Brilhaut et al. [13] procedure appears to be more reliable than ligament retensioning abandoned by their promoter [38], and it is the only one able of avoiding increased constraint for frontal instability combined with imbalance of the space in flexion and extension [39].

We chose the valgus threshold of minimum 5° to include patients in this study, whereas other authors retained deformities in valgus of more than 10° [5–7], sometimes even more than 15° [17]. It appears to us that valgus of more than 5° indicates a deformity which could not be explained by simple wear of the lateral compartment, suggesting bone deformity. The deformities that we observed were proportionately comparable to those reported by Desmège et al. [40], who indicated that the majority of arthrosic valgus deformities comes from the femur, emphasizing tibial involvement in 21% (6/28 cases), a little lower than in our study (33%).

In the literature, the results with CCK type constrained prostheses [17,20,23] are generally favourable up to follow-up of 10 years. However, we emphasize that these models have preferentially been used in elderly and less active patients [16], and some series have reported loosening and pains at the extremities of diaphyseal extensions [41,42]. Similarly, hinge prostheses for such indications are discussed [19], as their survival at five years is less than 70%, despite the introduction of newly-conceived, modern implants [22]. Also, the attitude of choosing the constraint level according to balancing difficulties appears to be more prudent [23,24]. However, this attitude supposes the use of a TKP model with constraint level and ancillaries which can evolve during the intervention, for fear of having to change the implant type during surgery, exposing patients to excessively prolonged operating time. Our study allows us to achieve appropriate reliability at the level of constraint required and thus to adapt intervention duration, implant and ancillary stock.

Theoretically, navigation, which allows us to refine the adjustment of cuts and better ligament balancing before the cuts, should reduce the frequency of constrained prostheses [43,44]. If the orientation of cuts seems to be more precise with navigation, the precision of ligament management in some comparative studies seems as reliable with classical ancillary components as with computer assistance [43,45,46].

Conclusions

This study shows that, in choosing the level of constraint to be applied in arthroplasty of a valgus knee deformity of more than 5°, it is important to undertake preoperative radiographic quantifications of convex laxity, the only independent parameter. The four other classical factors, identified by univariate analysis (excessive slope, low patella, valgus severity, valgus of tibial origin), were not independent but their association should warn even more surgeons about problems of ligament balancing. Respecting these conditions should allow us to foresee, preoperatively with serenity, the use of high-constraint prostheses for the treatment of knee arthropathy with valgus deformity.

References


