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Medial unicompartmental knee arthroplasty: Does tibial component position influence clinical outcomes and arthroplasty survival?

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Summary

Introduction: In several recent studies, unicompartmental knee arthroplasty (UKA) produced better functional outcomes than did total knee arthroplasty with 10-year prosthesis survival rates greater than 95%. Nevertheless, UKA is still widely viewed as producing inconsistent results. Tibial component loosening is the leading cause of failure. We consequently sought to identify tibial component position criteria associated with outcomes of medial UKA.

Material and methods: We conducted a retrospective multicentre study of 559 medial UKAs performed between 1988 and 2010 in 421 patients (262 females and 159 males) with a mean age of 69.51 ± 8.72 years at surgery. We recorded the following radiographic parameters: joint space height, obliquity and slope of the tibial implant, whether the tibial component was perpendicular to the femoral component, and lower limb malalignment. The International Knee Society (IKS) score was used to assess clinical outcomes. Mean follow-up at re-evaluation was 5.17 ± 4.33 years.

Results: The mean 10-year prosthesis survival rate was 83.7 ± 3.5%. Factors associated with decreased prosthesis survival were a greater than 2-mm change in joint space height, a greater than 3° change in tibial component obliquity, a slope value greater than 5° or a change in slope...
Introduction

Unicompartmental knee arthroplasty (UKA) was first developed by L. Marmor in the 1970s [1–3] then introduced in France by P. Cartier et al. [4]. Although several recent studies show better functional outcomes after UKA than after total knee arthroplasty (TKA) [5–11], as well as 10-year prosthesis survival rates above 95%[12–15], the role for UKA in the management of unicompartmental femoro-tibial osteoarthritis remains controversial. UKA is still viewed as less reliable than TKA [16,17]. As no knee arthroplasty registry is available in France, we therefore referred to the data from the symposium on UKA failure held in 2011 by the French Society for the Hip and Knee (Société Française de la Hanche et du Genou [SFHG]) [18]. These data from multiple French centres were likely to reflect our clinical practice. Mean time to failure was 6.21 years (range, 0–24.7 years). Among failures, 19.1% occurred within 1 year and 48.5% within 5 years. The leading cause of failure was aseptic tibial component loosening (24.7%), in keeping with other studies [19,20].

For the Round Table on UKA held at the 2012 meeting of the orthopaedics society Société d’Orthopédie de l’Ouest (SOO), we sought to identify the tibial component position criteria associated with functional outcomes and prosthesis survival after medial UKA.

Material and methods

The UKA Round Table focused on a multicentre retrospective study of 944 medial and lateral UKA procedures performed between 1988 and 2010 in 11 centres of western France (Tours University Hospital, Caen University Hospital, Angers University Hospital, Limoges University Hospital, Brest University Hospital, Niort Regional Hospital, Alliance Hospital in Tours, St-Léonard Hospital in Angers, Jules-Verne Hospital in Nantes and Littoral Hospital in Saint-Brieuc) and in two additional centres (Purpan University Hospital in Toulouse and Regional Hospital in Fort de France). All cases of medial or lateral UKA performed for any reason were included. The inclusion period was at the discretion of each centre, but no procedures performed after 31 December 2010 were to be included.

The 944 UKA procedures were performed in 690 patients (435 females and 255 males). Mean age was 69 ± 39 years (range, 26–93 years) and mean body mass index (BMI) was 27.5 kg/m² (range, 16.65–47.6). There were 864 medial UKAs and 80 lateral UKAs. Mean follow-up was 63.8 ± 52.11 months (range, 1–266 months).

The International Knee Society (IKS) knee and function scores [21] were determined to evaluate clinical outcomes. In addition, the patients completed a quality of life questionnaire, the Knee injury and Osteoarthritis Outcome Score (KOOS) [22], at last follow-up. Weight-bearing anteroposterior and lateral radiographs and a long-leg radiograph were to be obtained preoperatively then after 3 to 6 months and at last follow-up.

The following radiographic parameters were analysed [23]:

- the HKA and AKI angles, to assess overall lower limb malalignment (Fig. 1) [24];
- the height difference between the tangent to the tibial component joint surface and the lateral femoro-tibial joint space, to assess the level of the prosthetic joint space (Fig. 2);
- the angle subtended by the tangent to the tibial component and the line prolonging the lateral femoro-tibial joint space, to assess obliquity of the tibial component (Fig. 1), with varus angles being given positive values and valgus angles negative values;
- the angle subtended by the tangent to the posterior tibial cortex and the medial femoro-tibial compartment, to assess tibial slope [25]; preoperatively, the line connecting the anterior and posterior rims of the medial tibial plateau was taken as the sagittal axis of the medial femoro-tibial compartment; postoperatively, the tangent to the tibial component was used instead;
- the angle subtended by the longitudinal axis of the femoral condyle and the line perpendicular to the tangent to the tibial implant, to assess femoro-tibial component divergence from 90° in the coronal plane (Fig. 1).

We confined our study to medial UKA procedures performed in patients who had knee osteoarthritis and who were re-evaluated at least 2 years after the procedure. Exclusion criteria were UKA to treat knee tumours or injuries and incomplete medical records. Prosthesis survival was evaluated using the Kaplan-Meier method. Failure was defined as removal of all or part of the implant. Parametric tests (Chi² and Student) were performed to compare groups. Values of P lower than 0.05 were considered significant.
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Figure 1 Radiographic angles measured for the study. The HKA angle measures malalignment of the lower limb mechanical axis (H is the centre of the hip, K the centre of the knee, and A the centre of the ankle). The AKI angle measures femoro-tibial joint space obliquity (I is the middle of the medial femoro-tibial joint space). O measures tibial component obliquity relative to the femoro-tibial joint space, which is assumed to be in the same position in the medial compartment as in the lateral compartment. D measures intraprosthetic divergence and is the angle subtended by the longitudinal axis of the femoral condyle and the line perpendicular to the tangent to the tibial component.

Figure 2 Height of the prosthetic joint space. M measures the height difference between the tangent to the articular surface of the tibial implant and the lateral femoro-tibial joint space.

Results

Of 864 identified cases of medial UKA, 559 in 421 patients (138 bilateral procedures) were included in the study. Quality of life assessed using the KOOS was available for only 85 patients, and we consequently confined our clinical assessment to the IKS score. UKA was performed between 6 June 1988 and 15 November 2010. The 421 patients were 262 females and 159 males with a mean age of 69.51 ± 8.72 years (range, 34—88 years) at surgery. The underlying knee condition was primary osteoarthritis in 83.9% of cases, secondary osteoarthritis in 7.87%, and avascular necrosis in 8.23%. A history of surgery on the same knee (meniscectomy, ligament reconstruction, and valgus tibial osteotomy) was present in 97 (17.35%) patients. Mean body weight was 73 ± 12 kg (range, 40—125 kg) and mean BMI was 27.7 ± 4.08 kg/m² (range, 16.65—47.63 kg/m²); obesity defined as BMI greater than 30 kg/m² was present in 116 (21%) patients.

The following implants were used: Alegroetto® (Zimmer, Warsaw, IN, USA), n = 62; Preservation® (Depuy, Raynham, MA, USA), n = 26; Genesis® (Smith and Nephew, Memphis, TN, USA), n = 15; Hermes® (Ceraver, Gonesse, France), n = 21; HLS® (Tornier, Montbonnot, France), n = 170; Lotus® (Ceraver, Gonesse, France), n = 26; Miller Gallante and ZUK® (Zimmer, Warsaw, IN, USA), n = 44; and Oxford® (Biomet, Warsaw, IN, USA), n = 39. Cemented all-polyethylene tibial implants were used in 241 (43.11%) of the 559 procedures. Of the 559 metal tibial trays, 520 (93%) were fixed and 39 (7%) mobile.

In the initial sample of 864 procedures, 10-year prosthesis survival was 83.7 ± 3.5%. Of the 108 failures, 33% occurred within 2 years. Mean follow-up at last evaluation for the 559 procedures included in the study was 5.17 ± 4.33 years. Of these 559 procedures, 14 failed, with loosening in five cases, premature tibial component wear in five cases, extension of the osteoarthritis to the lateral component in two cases, and infection in two cases. All 14 failures were managed by revision surgery with conversion to TKA. Mean time from UKA to revision surgery in these 14 cases was 59.1 ± 33.5 months. Mean HKA angle was 173.9 ± 4.5° preoperatively and 176.4 ± 3.4° postoperatively; corresponding mean AKI angle values were 88.1 ± 2.7° and 86.2 ± 3.4°, respectively. Mean IKS knee score was 59.3 ± 15.7 preoperatively and 90.3 ± 11.4 at last follow-up, whereas mean IKS function score was 61.2 ± 19.9 preoperatively and 82.6 ± 16.4 at last follow-up.

A difference in joint space height between the prosthetic and healthy compartments was noted in 61.8% of cases: the prosthetic joint space was lower in 48.1% of cases and higher in 13.7% of cases. The measured height difference was 1 mm in 19.2% of cases, 2 mm in 24.7%, 3 mm in 17.5%, and more than 3 mm in 12.7%. A joint space height difference was significantly associated with shorter prosthesis survival (P = 0.014). Differences in joint space height greater than 2 mm significantly affected prosthesis survival (P = 0.0099) (Fig. 3). Failures related to a lower position of the prosthetic joint space were due to loosening, whereas failures related to a higher position of the prosthetic joint space were due to premature tibial component wear and extension of the osteoarthritis to the lateral femoro-tibial compartment. The mean IKS function score was 81.0 ± 16 overall compared to only 75.5 ± 15.3 in the group with prosthetic joint space elevation, whereas a depressed position of the prosthetic joint space had no significant impact on the IKS function score. The IKS knee score was not significantly influenced by prosthetic joint space height as assessed on the radiographs.
Mean tibial component obliquity in the coronal plane was $0.8 \pm 3.4^\circ$ of varus. Of the 559 tibial implants, 48.7% were within the physiological obliquity range ($\pm 3^\circ$), 40.4% were in varus ($>3^\circ$), and 10.9% were in valgus ($<0^\circ$). Tibial component obliquity correlated with the HKA angles measured preoperatively ($z = 3.097$, $P = 0.002$) and postoperatively ($z = 5.812$, $P < 0.0001$). Two factors were significantly associated with mechanical failure, namely, postoperative valgus of the limb (HKA $\leq 175^\circ$, $P = 0.001$) and varus position of the tibial component (varus obliquity $>3^\circ$, $P = 0.029$) (Figs. 4 and 5). Tibial component obliquity was not significantly associated with IKS knee or function score values.

Mean tibial component slope was $3.2 \pm 3.6^\circ$ in our caseseries. Mean slope change relative to the preoperative value was $0.19 \pm 3.86^\circ$ but varied widely across knees as shown by the standard deviation (SD) of $14.9^\circ$ and the range of $-14^\circ$ to $20^\circ$. Prosthesis survival was significantly shorter when slope exceeded $5^\circ$ ($P < 0.0001$) or changed by more than $2^\circ$ ($P = 0.0003$, Fig. 6). Tibial component slope was not significantly associated with IKS knee or function score values.

Mean femoral and tibial component divergence from a $90^\circ$ angle in the coronal plane was $4.8 \pm 5.9^\circ$, with marked variations across knees (SD, $34.7^\circ$; range, $-12^\circ$ to $29^\circ$). Although divergence was not significantly associated with prosthesis survival ($P = 0.278$), mean absolute divergence was significantly greater ($P = 0.0023$) in the group with UKA failure ($7.6 \pm 7.9^\circ$) than in the group with UKA survival at last follow-up ($1.9 \pm 4.8^\circ$). Thus, intraprosthetic divergence greater than $6^\circ$ seems to constitute a risk factor for mechanical failure (Fig. 6).

**Discussion**

The analysis of our data indicates that tibia component position influences medial UKA survival and can also affect functional outcomes in some cases. We were able to identify a number of criteria for optimal tibial component positioning: the joint space height difference with the lateral compartment must be less than $3\text{ mm}$, overall varus obliquity
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Figure 7  Mechanical failure according to intraprosthetic divergence. Absolute intraprosthetic divergence (in either direction) is shown on the Y-axis and mechanical failures on the X-axis. Mean absolute divergence differed significantly ($P=0.0023$) between the group with failed prostheses (7.6 ± 7.9°) and the group with surviving prostheses at last follow-up (1.9 ± 4.8°). These data indicate that intraprosthetic divergence greater than 6° is a risk factor for mechanical failure.

The height of the prosthetic joint space affects load transfers between the two femoro-tibial compartments. F. Mazas [26] pointed out that joint space lowering associated with 5° of under-correction generated 54% of the loads through medial UKAs and, in contrast, joint space elevation associated with 5° of over-correction transferred 88% of the loads to the lateral femoro-tibial compartment. Our results confirm these biomechanical data and indicate that the prosthetic joint space height should be within 3 mm in either direction of the lateral compartment joint space height to restore the balance between the two femoro-tibial compartments. In addition, if the transverse tibial cut is placed too distally, the tibial implant rests on cancellous bone, which offers less resistance to compression forces, as demonstrated in an experimental study by Lesaka et al. [27].

Restoring joint space height is therefore crucial in terms of both joint mechanics and joint kinematics. The normal joint space height can be determined intraoperatively when the osteoarthritic lesions are confined to the cartilage. If the epiphysis is affected, we believe UKA is unwise. Therefore, the indications of UKA may be confined to stages I, II, and III in the Ahlbäck and Rydberg classification system [28], to the exclusion of stage IV.

Tibial component obliquity is another issue that affects joint kinematics restoration and bone resistance to loading [29]. Our results indicate that the physiological obliquity of the femoro-tibial joint space, which is about 3° of varus [30], should be restored to within 3° in either direction, in keeping with previously published recommendations [20,27,29,31].

As pointed out by Hernigou and Deschamps [29], this seems to apply only when there is less than 5° of overall lower limb varus (HKA < 5°). As with joint space height, these data have implications not only for the operative technique, but also for patient selection. Thus, deformities of the tibial epiphysis, whether constitutional (congenital tibia vara) or acquired (stage IV in the Ahlbäck and Rydberg classification system [28]) constitute major obstacles to following these recommendations, unless corrective tibial osteotomy is performed in addition to UKA.

Finally, as with joint space height and tibial component obliquity, our data indicate that the normal tibial slope should be restored. We identified two criteria: absolute slope should not exceed 5° and the change in slope should not be greater than 2° relative to the physiological value. Slope influences both bone quality [32] and knee kinematics. A greater change in slope value affects the flexion range of the prosthetic knee [33,34]. Excessive slope results in active anterior tibial translation [29,34], placing excess loads on the anterior cruciate ligament. Subsequent distension of this ligament may result in knee instability, whereas absence of ligament distension on load transfer to the prosthetic plateau may result in tibial component loosening. These data further support the conclusions drawn in 2004 by P. Hernigou and G. Deschamps [35].

In addition to the above-described criteria for tibial component positioning, the tibial and femoral components should form a 90° angle with each other. Our data indicate a margin of tolerance of 6° in either direction. Divergence is influenced by both implant position and implant geometry, as shown by studies of Scandinavian registries [36,37]. In recent prosthetic designs, the large radius of the circular prosthetic condyle curvature in the coronal plane is able to ‘‘tolerate’’ greater degrees of intraprosthetic divergence compared to the older designs, in which stress peaks occurred at the edges of the flat prosthetic condyle if the angle with the polyethylene tibial component differed even slightly from 90°. We believe that the distribution of these two prosthesis types in our sample influenced the value of the margin of tolerance (6°) found in our study. Although we do not advocate the use of a less stringent criterion for this parameter, we believe that intraprosthetic implant alignment depends chiefly on prosthesis design. Therefore, alignment issues should be discussed in the recommendations developed by manufacturers.

Although our retrospective study provided numerical criteria for tibial component positioning during medial UKA, it has a number of limitations in terms of both the study design and the population. Missing data upon re-evaluation required patient selection that modified the initial protocol to some degree. The study was retrospective, and considerable variability occurred in implant types, surgical techniques, and surgeons. The technique used to analyse the radiographs is open to criticism: thus, we assumed that the normal medial joint space height was identical to the height of the lateral femoro-tibial joint space, and we did not assess intraobserver or interobserver reproducibility. Finally, in our statistical analysis of prosthesis survival we included the failures recorded during the first 2 years, which were excluded from the other analyses. Strengths of our study include the large sample size, the investigation of a
sample whose heterogeneity was representative of clinical practice in France, and the consistency between our findings and those reported previously. These strengths support the relevance of our conclusions and recommendations to clinical practice.

Our results demonstrating that a high degree of accuracy is required for proper tibial implant positioning during mediolateral UKA is further evidence not only that considerable technical expertise with the procedure is crucial, but also that UKA is chiefly a conservative procedure. Implant positioning must be optimal to restore normal knee kinematics and to prevent wear of adjacent knee compartments and of the prosthetic components. Thus, UKA may be even more likely than TKA to benefit from computer-assisted navigation and individually tailored cutting guides designed to increase implant position reproducibility even outside highly specialised centres [38].

Disclosure of interest

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