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Functional scores and prosthetic implant placement are different for navigated medial UKA left in varus alignment

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Abstract

Purpose The purpose of this study was to analyze the clinical outcomes and radiologic position of the knee in two groups of patients after medial unicompartmental knee arthroplasty (UKA): one group with residual varus axis (RVA) alignment and other one with neutral mechanical axis (NMA) of the lower limb.

Methods All patients who underwent UKA between January 2015 and January 2018 were evaluated retrospectively. Inclusion criteria were: medial UKA for isolated medial femoro-tibial osteoarthritis, a varus deformity of $< 15°$, and a minimal follow-up of 2 years. All patients had a preoperative and postoperative clinical examination with functional scores (New International Knee Score (NewIKS) and Knee injury and Osteoarthritis Outcome Score (KOOS) and radiographs. Preoperative and postoperative values for continuous outcomes were compared using the Student's *t* test for paired data and differences between the groups were compared with the Mann–Whitney *U* test. $p < 0.05$ was considered statistically significant.

Results The RVA group consisted of 48 cases of medial UKA in 48 patients (22 females). Mean postoperative hip–knee–ankle (HKA) angle was $174.3° \pm 2.8$ and the corresponding mean AKI angle (tibial mechanical angle) was $82.9° \pm 2.9$. The NMA group consisted of 35 cases of medial UKA in 35 patients (14 females). Mean postoperative HKA angle was $178.9° \pm 3$ and the corresponding mean AKI angle was $85.5° \pm 3.1$. A significant difference was found between the two groups for the KOOS score and for global NewIKS, with a better score in the RVA group.

Conclusions RVA alignment after medial UKA results in a significant improvement in functional knee scores at 2-year post-surgery. Return to sport and recreational activities was better than in patients with postoperative NMA.

Level of evidence Level 3; retrospective cohort study.

Keywords Arthroplasty · Residual varus axis alignment · Knee · Replacement · Unicompartmental · Knee replacement · Unicondylar knee arthroplasty · Kinematic alignment · Computer assisted · Surgery

Introduction

Unicompartmental knee arthroplasty (UKA) offers faster recovery and better restoration of knee kinematics while maintaining limb alignment than total knee arthroplasty in selected patients [24, 26]. UKA was introduced in the 1970s to treat single-compartment arthritis, with satisfactory initial results [14, 29, 35]. The indications for UKA are different from those of total knee arthroplasty (TKA) with different advantages, such as less trauma to the soft tissues.

Early failures after UKA have been correlated with surgical technique error [10] and inaccurate positioning of the components leading to overcorrection or undercorrection of the final limb alignment [2, 15, 23]. Malalignment of the leg is associated with increased polyethylene wear [10], disease progression to the opposite compartment [10, 17], and aseptic implant loosening [6, 20]. For medial UKA, progression to lateral compartment osteoarthritis (OA) due to an altered stress pattern on the cartilage has been described in the literature [34]. Several authors [11, 19, 33] have recommended relative undercorrection of alignment of the knee in medial

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unicompartmental arthroplasty to avoid progressive OA of the opposite femoro-tibial compartment.

While postoperative alignment in medial UKA for the varus osteoarthritic knee has been widely studied, only a few studies have investigated the risk factors for postoperative malalignment [8, 12, 18]. Navigation by computer-assisted surgery (CAS) has been introduced to improve the accuracy of implant positioning and postoperative alignment [1]. Because of limited exposure when performing minimal invasive surgery, the navigation system can be helpful in achieving precise positioning [25]. However, the optimal alignment for a knee undergoing medial UKA remains controversial.

The purpose of this study was to analyze the clinical outcomes and radiologic positions of the knee in two groups of patients who had a medial UKA: one group with residual varus axis (RVA) and second with in a neutral mechanical axis (NMA) of the lower limb. The hypothesis of the study was that patients would have better clinical results in the case of RVA than NMA in medial UKA CAS, and RVA influences the positioning of prosthetic implants.

Materials and methods

This was a retrospective, single-center study of data collected prospectively. The inclusion criteria were: patients who had undergone medial UKA for isolated moderate to severe medial femoro-tibial non-inflammatory OA during a 3-year period (from 2015 to 2018), a fixed flexion deformity of $< 10°$, a varus deformity of $< 15°$, an intact anterior cruciate ligament, a body mass index (BMI) of < 40 kg/m^2, and a minimal follow-up of 2 years. All patients had preoperative radiographs. Exclusion criteria were: etiology of OA a tumor or inflammatory disease, incomplete medical files, or refusal to participate in the study.

Surgical technique

All operations were performed under prophylactic antibiotic cover with the use of a tourniquet by two experienced senior surgeons (NG, PC). The approach to the medial compartment was a limited medial parapatellar incision without patellar dislocation. The same prosthesis was used for all patients: cemented Genus Uni (Adler®) UKA with a cemented tibial implant and a non-cemented femoral implant. The OrthoKid® Navigation System was used for all patients. This is a passive imageless navigation system that uses optoelectronic captors to determine the position of the femur and the tibia using pins fixed in the bones. Preoperative limb alignment, motion and ligament stability can be evaluated. Cutting blocks are tracked to allow proper placement relative to the bone.

The two surgeons had different alignment goals. The first one was trying to leave a residual varus equal to half of the native varus deformity (arbitrarily chosen number). In addition, the second desired to have a neutral alignment ($180° \pm 3$).

Clinical evaluation

Preoperative data collection included the history of symptoms, sex, age, limb alignment, knee range of motion, history of other preoperative treatments, and radiographic measurements. Pain was evaluated using a linear pain visual analog scale (VAS) ranging from 0 to 10. Patient satisfaction at the last follow-up was rated according to three qualitative categories ("very satisfied", "satisfied," or "unsatisfied"). Clinical function of the knee was evaluated at inclusion and at the last follow-up using the New International Knee Score (NewIKS) [1]. In addition, patients completed a quality of life questionnaire and the Knee injury and Osteoarthritis Outcome Score (KOOS) [28].

Radiologic evaluation

Radiologic evaluation included 45° postero-anterior flexion weight-bearing views [23], lateral views, and the 45° axial view, and was performed preoperatively and at the last follow-up. The following radiographic parameters were analyzed [26] (Fig. 1): (i) HKA and AKI angles to assess overall lower limb malalignment [9]; (ii) the angle O between the tangent to the base of the tibial component and the line through the lateral femoro-tibial joint space, to assess obliquity of the tibial component; (iii) tibial posterior slope angle [4] between the tangent to the posterior tibial cortex and the medial femoro-tibial compartment. 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; (iv) the angle between the longitudinal anatomic axis of the femur and the line perpendicular to the tangent to the tibial implant, to assess femoro-tibial component divergence from 90° in the coronal plane. Measurements of the different angles mentioned above were performed twice to assess intra- and inter-individual variability by two orthopedic surgeons (AD, PL).

Statistical analysis

Quantitative variables are expressed as mean ± standard deviation (SD) and range (min–max), and qualitative variables as absolute (n) and relative frequencies (%).

Preoperative and postoperative values for continuous outcomes were compared using the Student's *t* test for paired data and differences between the groups were compared with the Mann–Whitney *U* test. Fisher's exact test was used to analyze categorical data. The power calculation reveals a probability $\mathscr{B} = 0.3$ and a power = 0.8 on post-hoc power analysis. The intra- and inter-observer agreement analysis shows a reproducibility of the radiological measurements performed with Cohen's *k* (kappa) ($k = 0.7$). All statistical analyses were performed using EasyMedStat (www.easy-med-stat.com; Neuilly-sur-Seine, France). $p < 0.05$ was considered statistically significant.

Results

The two groups were comparable in terms of sex, BMI, preoperative score, American Society of Anesthesiologists (ASA) group, and preoperative radiologic data (Tables 1 and 2).

RVA group

This group consisted of 48 cases of medial UKA in 48 patients, including 22 females (45.8%). The demographic data are summarized in Table 1. No patients were lost to follow up.

The mean follow-up was 33 months ± 9 (range: 24−60).

The preoperative and final functional scores with range of motion, rate of forgotten knees and reoperation/revision for this group are shown in Table 2.

Mean preoperative HKA angle was 173.8° ± 3.2° (range: 166.7−178.2). The postoperative radiographic results are summarized in Table 3. Of the 48 tibial implants, 73% were within the range of physiologic obliquity (± 3°), 23% were in varus (> 3°), and 4% were in valgus (< 0°).

NMA group

This group consisted of 35 cases of medial UKA in 35 patients, including 14 females (40%). No patients were lost to follow up. The mean follow-up was 3 months ± 9 (range: 24−60).

The preoperative and final functional scores with range of motion, rate of forgotten knees and reoperation/revision for this group are shown in Table 2.

Mean preoperative HKA angle was 173.6 ± 2.2° (range: 169.4−179.1). The postoperative radiographic results are summarized in Table 3. Of the 35 tibial implants, 52% were within the range of physiologic obliquity (± 3°), 37% were in varus (> 3°), and 11% were in valgus (< 0°).

Comparison of RVA and NMA groups

Figure 2 shows the average HKA angles between the two groups. A difference was found between the two groups for the global KOOS score ($p < 0.01$) and for the global NewIKS ($p < 0.01$) with a better score for the RVA group.

There was no significant difference in secondary outcomes between the two groups (Table 2).

A comparison of the postoperative HKA angle showed a significant difference between the RVA and NMA groups (174.3 ± 2.8° vs. 178.9 ± 2.9°, respectively; [95% CI − 2.86; − 0.30]; ($p < 0.0001$), and the corresponding mean AKI angles were 82.9 ± 2.9° vs. 85.5 ± 3.1° [95% CI − 4.4; − 1.5] ($p = 0.001$), respectively.

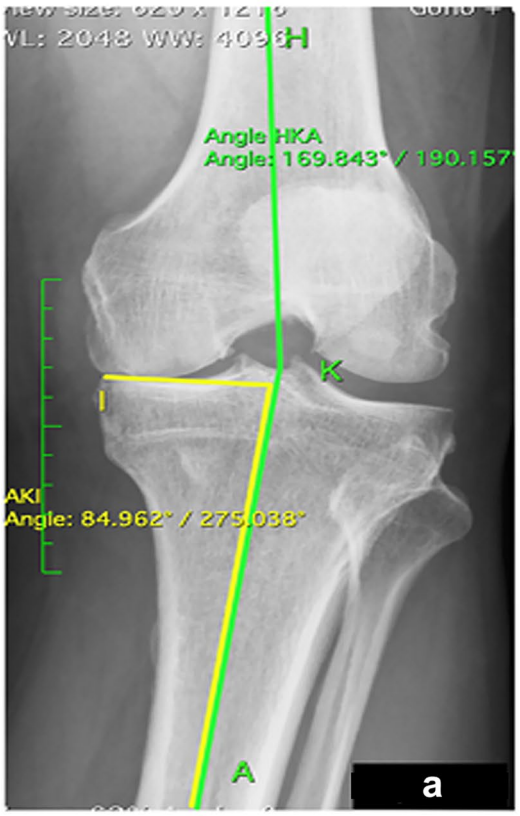
Concerning the component position, mean tibial component obliquity in the coronal plane was 3.5 ± 2.3° valgus and 2.9 ± 1.4° valgus [95%CI − 0.34, 1.58] ($p < 0.05$) for the RVA and NMA group, respectively. The other measured parameters are reported in Table 3.

Discussion

The most important findings of the present study were RVA in medial UKA CAS improves knee function and pain according to the KOOS, NewIKS, and VAS, confirming the hypothesis. Furthermore, there was a low rate of complications after this procedure (3.6%) at a mean follow-up of 34 months.

This result suggests that varus alignment may be a valid option to treat isolated symptomatic unicompartmental medial OA. These results are in agreement with the literature, as some authors have recommended a moderate undercorrection of both mechanical and anatomic axes, with a residual varus deformity of 3–5° for the lower lib axis to avoid OA progression in the contralateral compartment and early loosening of the implant [5, 7]. Vasso et al. [32] found that minor varus alignment (≤ 7°) was associated with better outcomes and medium-to-long-term survival of medial UKA. Furthermore, overall IKS was significantly higher with increasing postoperative varus. In the current series, this result was confirmed ($p < 0.01$).

As in TKA, it has been widely demonstrated that the precision of implantation is a major factor affecting the long-term outcome of UKA [13, 29]. Previously reported modes of failure after UKA have included polyethylene wear, progression of arthritis of the other compartment, aseptic loosening, or patellofemoral symptoms [3]. In this series, there have been no revisions with TKA at final follow-up, but this can be explained by the mid-term follow-up in the current study. Marmor et al. [22], in a 10−13-year follow-up study, identified a failure rate of 30%, with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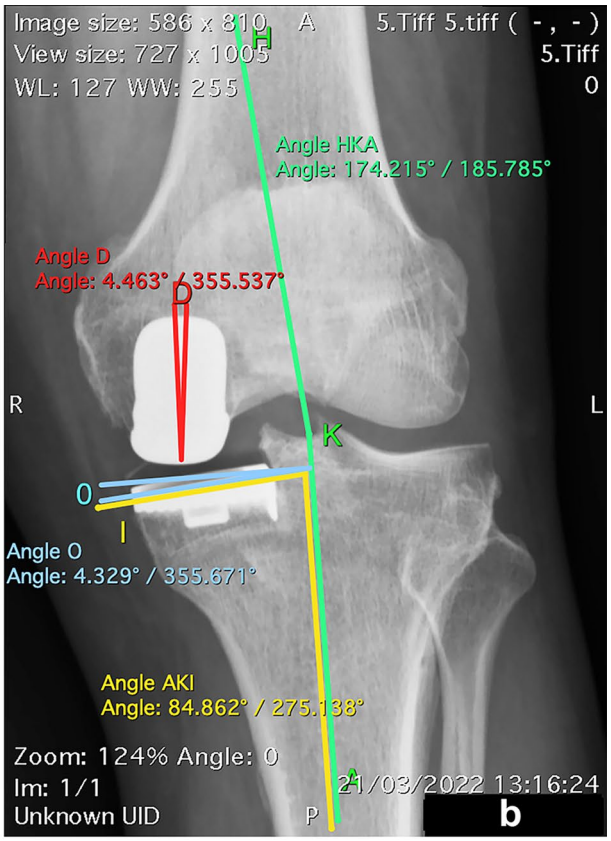
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◂**Fig. 1** Radiographic angles measured in the study **a** preoperatively and **b** postoperatively. The HKA (hip–knee–ankle) angle measures malalignment of the lower limb mechanical axis (H is the center of the hip, K the center of the knee, and A the center of the ankle). O measures tibial component obliquity relative to the femoro-tibial joint space. The AKI angle measures femoro-tibial joint space obliquity (I is the middle of the medial femoro-tibial joint space). D measures intraprosthetic divergence and the angle subtended by the longitudinal axis of the femoral condyle and the line perpendicular to the tangent to the tibial component. **c** Preoperative lower limb axis and **d** postoperative lower limb axis

loosening as the major etiology and with the majority of tibial failures resulting in depression of the cancellous bone of the medial plateau. Squire et al. [30], with their minimum 15-year follow-up, found that 10.4% of knees had tibial subsidence.

The current study has demonstrated a mean residual varus alignment of > 5° in the RVA group. RVA alignment of medial UKA implants tends towards valgus orientation for the femoral ($p = 0.017$) and varus orientation for the tibial components ($p = 0.039$), similar to kinematic positioning of TKA components [14]. Rivière et al. reported that kinematic simulation for UKA improved the interaction of the components by optimizing their surface contact area, as the femoral and tibial components were often in more contiguous and convergent positions on extended knee simulation. Innocenti et al. [16] reported that a slight varus alignment in the coronal plane can effectively extend the life-expectancy of a UKA, as it is compatible with the soft tissues. Furthermore, Hernigou et al. [13] showed that a slight varus postoperative deformity in medial UKA seemed to decrease wear of the polyethylene. Thus, the literature seems to demonstrate that residual varus alignment in medial UKAs optimizes the survival rates of the implants. Recently, Rivière et al. [27] reported good mid-to-long-term clinical safety and efficacy of UKA in a systematic review.

In this series, one patient had 11.5° (HKA = 169.5) of postoperative residual varus (RVA group) for an initial varus of 13.3° (HKA = 166.7). His functional scores and satisfaction were within the range of the RVA group. It is, therefore, possible to obtain good results despite a pronounced residual varus. Nevertheless, it is difficult to conclude on the survival of the implant in view of the length of the follow-up of the study. It seems that a residual varus of 5–7° is reasonable.

We have combined UKA implantation with CAS navigation and have confirmed the utility and reproducibility of this tool as there was a significant difference between the two groups with a more varus position of the tibial implant for the RVA group corresponding to the initial axis goal. Some authors have reported that CAS allowed more accurate and reproducible alignment than conventional UKA [21, 24]. Our study has shown that limb alignment is well-estimated by CAS and surgeons can be more accurate in their placement. Nevertheless, there was two cases in NMA group (181.9° and 183.9°), where the HKA angle was in valgus. This is probably due to variability in HKA angle measurement on the axis [31]. It was decided to use CAS to improve the positioning of the implants and to provide the surgeon with intra-operative feedback. This technique could be recommended to less experienced surgeons and could improve their learning curve when performing arthroplasty and particularly UKA.

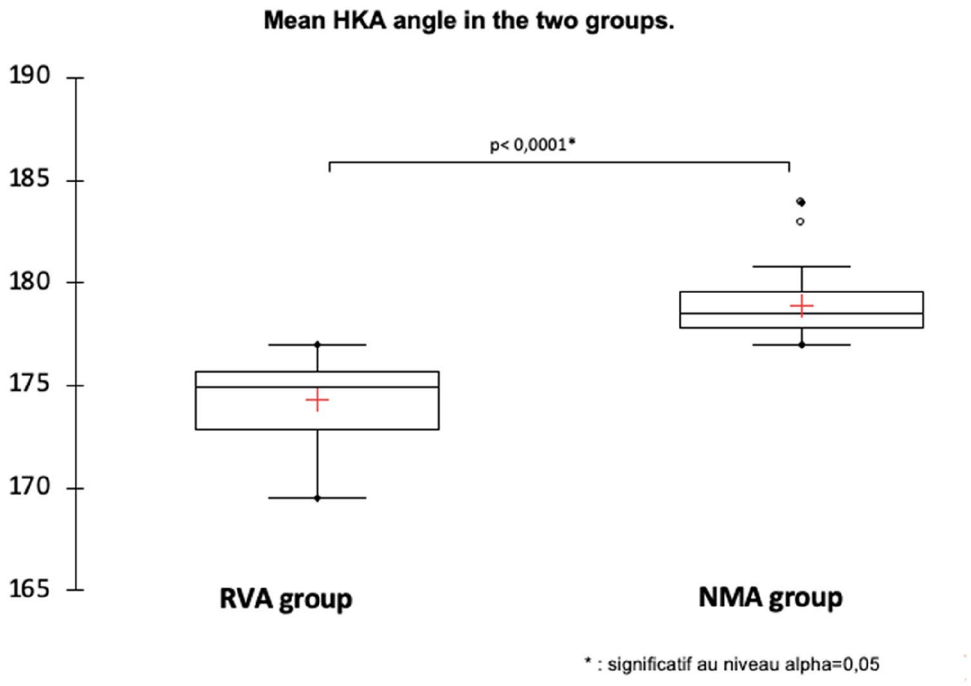

Fig. 2 Mean HKA angle in the two groups of patients. Absolute mean HKA angles (in either direction) are shown on the y axis and type of alignment on the x axis. Mean (SD) HKA angles differed significantly ($p = 0.017$) between the RVA group (175.7 ± 2.8°) and the NMA group (177.3 ± 2.9°) at the last follow-up. *HKA* hip–knee–ankle, *RVA* residual varus axis, *NMA* neutral mechanical axis

Table 1 Demographic data for the two groups of patients

Characteristic	RVA group	NMA group	*p* value (RVA vs. NMA)
No. of patients	48	35	
Sex (female)	22	14	n.s
Age at inclusion (years)	66 ± 9.5	67.2 ± 9	n.s
Age at last follow-up (years)	68.8 ± 9.6	70 ± 7.7	n.s
BMI (kg/m^2)	27.3 ± 3.4	29.3 ± 3.7	n.s
Mean tourniquet time (min)	48.2 ± 10.9	57.6 ± 21	n.s
American society of anesthesiologists (ASA)			
ASA 1	6	6	n.s
ASA 2	30	17	n.s
ASA 3	11	10	n.s
ASA 4	1	2	n.s
Indications of medial UKA	Primary OA: 95% Secondary OA: Avascular necrosis 3% Fracture 2%	Primary 0A: 97% Secondary OA: Avascular necrosis 3%	n.s
History of surgery of the same knee	10 (20%)	8 (22%)	

Data shown are number, or mean ± standard deviation

RVA residual varus axis, *NMA* neutral mechanical axis, *BMI* body mass index, *OA* Osteoarthritis

This study has some major strengths. To our knowledge, this was the first study to analyze the results of UKA combined with CAS navigation. Furthermore, the patient population studied was homogenous with isolated medial femoro-tibial unicompartmental OA. Radiographic follow-up was also obtained for all patients. Thus, the NMA group

Table 2 Pre- and postoperative functional scores (KOOS, NewIKS), pain evaluation (VAS), proportion of forgotten knees, reoperation and range of motion in the two groups of patients

Group	RVA group			NMA group			RVA vs. NMA
	Preoperative score [95% CI]	Score at last follow-up [95%CI]	*p* value	Preoperative score [95%CI]	Score at last follow-up [95%CI]	*p* value	*p* value
Global KOOS	41.7 [40.6; 47.4]	94.4 [91.7; 96.3]	0.0001	41.1 [34; 38]	90.7 [89.7; 91.7]	0.0001	**< 0.01**
Symptoms and stiffness	55.9 [45.4; 64.6]	96.4 [94.3; 97.5]	0.0001	51.1 [37.2; 44.2]	95 [93.7; 96.2]	0.0001	n.s
Pain	43.5 [40.5; 48.9]	96.3 [94.3; 98]	0.0001	44.9 [42; 45.1]	93.9 [92.6; 95.1]	0.0001	n.s
Function, daily living	46.2 [39.9; 52.7]	96.1 [93.3; 97.9]	0.0001	44.9 [34.1; 39.7]	93 [92.2; 94.2]	0.0001	n.s
Function, sports and recreational activities	20.9 [17.4; 24.2]	81.4 [75.5; 86.9]	0.0001	22.9 [22.7; 25.3]	69.8 [61.3; 68.7]	0.0001	**< 0.001**
Quality of life	19.7 [16.2; 22.2]	96.1 [89.3; 96.7]	0.0001	21.7 [20.2; 23.5]	93.2 [97.1; 98.3]	0.0001	n.s
Global NewIKS	129.7 [134.5; 144.8]	237.5 [230; 237.4]	0.0001	129.1 [103.3; 113.1]	234.6 [233.7; 240.7]	0.0001	**< 0.01**
Function	42.1 [40; 46.6]	93.5 [90.2; 95.4]	0.0001	41.7 [36.7; 41.3]	88.2 [86.4; 90.1]	0.0001	**< 0.01**
Visual analog scale (VAS)	7.9 [7.7; 8.1]	0.76 [0.45;1.1]	0.0001	7.8 [7.6; 7.9]	1.0 [0.8; 1.4]	0.0001	n.s
Knee flexion	127.4° [126.6; 128.3]	132° [129.8;131.6]	0.0001	125.3° [122.4; 124.9]	130.1° [126; 127]	0.0001	n.s
Knee extension	0 [− 0.2; 0.2]	0 [− 0.4; 0.5]	n.s	1.7 [0.6; 2.7]	0 [− 0.3; 0.5]	n.s	n.s
Forgotten knee (%)		87			86		n.s
Reoperation/revision for TKA	2 stiffness (4.2%)/0			1 acute sepsis (2.9%)/0			

In bold, the significant data ($p<0.05$)

RVA residual varus axis, *NMA* neutral mechanical axis, *TKA* Total knee arthroplasty

Table 3 Postoperative radiographic results for the two groups of patients

	RVA group ($N=48$)	NMA group ($N=35$)	p value
Postoperative radiographic results			
HKA angle	174.3° (169.5−177)	178.9° (177−183.9)	**< 0.0001**
AKI angle	82.9° (75.3−89.7)	85.5° (80.1−90.8)	**0.001**
Obliquity of the tibial component	3.5° (-1.8−11)	2.9° (0.5−9)	**0.039**
Femoro-tibial component divergence	4.1° (0.8−10.7)	3.4° (0.7−14)	**0.017**
Implant posterior slope	3.2° (0−7.9)	3.2° (0−13)	n.s

In bold, the significant data ($p<0.05$)

Data shown are mean and range (min–max)

RVA residual varus axis, *NMA* neutral mechanical axis, *HKA* hip–knee–ankle, *AKI* tibial mechanical angle

could be considered as a control group with a comparable population.

The limitations of the study are the weaknesses of retrospective analyses. The study populations were small but were sufficient to detect statistically significant differences even if the follow-up was too short to be able to assess implant survival. Future studies may address these limitations and should consider outcomes, with particular attention to revision rates, after a longer duration of follow-up.

This study shows that the UKA positioned in residual varus gives better overall functional results than the standard-axis UKA. In medial UKA surgery, the goal should not be to correct the axis, but to respect the soft tissue and tolerate the deformity. The navigation assistance facilitates the gesture and contributes to the learning curve.

Conclusions

RVA alignment for medial UKA in cases of OA provides significant improvement in functional knee scores at 2 years of follow-up. Return to sport and recreational activities was better in the RVA group than in patients with postoperative NMA. CAS is a helpful tool to reliably and accurately perform UKA. Prospective studies with long-term follow-up could help to determine the most appropriate postoperative alignment of medial UKA to increase survival rates.

Author contribution (1) The conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted, (4) Statistics: AD: 1–2–3–4; NB: 2–3; AB: 2–3; PC: 2–3; PL: 2–3–4; NG: 1–2–3. All authors read and approved the final manuscript.

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Data availability Raw data for dataset are not publicly available to preserve individuals' privacy under the European General Data Protection Regulation.

Declarations

Conflict of interest All authors declare that they have no competing interests.

Ethical approval This study was accepted by our institutional ethical committee.

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