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Under-corrected knees do not fail more than aligned knees at 8 years in fixed severe valgus total knee replacement

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Abstract

Purposes A fixed severe valgus knee is a surgical challenge. A safe post-operative Hip-Knee-Ankle angle (HKA) range of 180° ± 4 was recommended, but recent studies mentioned equal results from outliers of this range. Nevertheless, no distinction was made between varus and valgus knees, as well as over-corrected or under-corrected knees. Did post-operative nonaligned total knee replacements (TKR) from fixed severe valgus knees behave differently from the properly aligned population? Did over-corrected knees behave differently from under-corrected knees?

Methods Through a multi-center retrospective cohort study, we provided 557 knees of at least 10° of minimal pre-operative valgus; in this population 75 presented a post-operative Hip-Knee-Ankle angle (HKA) outside of the 180° ± 4 range; 23 of them had at least 5° of varus; 52 of them had at least 5° of valgus. Median pre-operative HKA of the entire cohort was 194° (range 190–198). Median follow-up was 8 years (range 5–11); Knee Society Score (KSS) results, HKA, Femoral and Tibial Mechanical Angles (FMA, TMA) and complication rates were obtained. The outlier group (HKA ≤ 175 or ≥ 185) was compared to the control group (HKA 180 ± 4); over-corrected (HKA ≤ 175) and under-corrected (HKA ≥ 185) sub-groups were individually tested against the control group.

Results The outlier group had a lower Final Knee Score than the aligned group ($p = 0.023$). In the over-corrected sub-group, median post-operative FMA was 88° (SD 4°) and median TMA was 87° (SD 4°). The complication rate was higher ($p = 0.019$). Knee ($p = 0.018$), Function ($p = 0.034$) and Final Knee Scores ($p = 0.03$) were statistically lower than in the control group. In the under-corrected sub-group, mean post-operative FMA was 93° (SD 2°) and mean TMA was 91° (SD 2°). The complication rate was lower ($p = 0.019$) and there was no difference with the control group concerning KSS.

Conclusions In case of pre-operative fixed severe valgus knee, one should avoid over-correcting HKA angle and especially the TMA. Over-correction of a severe preoperative valgus in a post-operative varus was prejudicial for TKA survival. Keeping a severe valgus knee in low valgus to avoid using a more constrained implant and/or ligament releases will not decrease the 5–10 year implant survival and functional scores.

Level of evidence Level IV—Case series.

Keywords Valgus deformity · Knee arthritis · Total knee arthroplasty · Residual deformity

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Introduction

While total knee arthroplasty (TKR) can be considered as an effective and reliable procedure [10, 28], extreme cases remain challenging [17].

Fixed severe valgus knee is considered as a particular entity [20, 26], still needing definite answers regarding surgical approaches, ligament releases and implant choices [3, 9, 12, 14, 18, 23]. Few studies have focused on valgus knees, most of them with a moderate number of knees as compared to varus deformity.

To achieve long-term results, a neutral post-operative Hip-Knee-Ankle (HKA) angle was advocated for years [5, 9, 25], as it was proven that a misaligned knee could increase contact stresses [5, 29, 31]. Recent studies have impeached these certainties and increased the accepted range to ±4° [15], or even further for Parratte et al. [21] who found no survival differences between all outliers and neutrally aligned TKRs. However, the outlier population in this study was not separated in under-corrected and over-corrected knees and did not discriminate varus and valgus knees pre-operatively.

A multi-center retrospective study was conducted only on preoperative fixed severe valgus TKRs of more than 10°. Data on 557 knees were collected; 75 strict outliers from the ±4° range, separated in over-corrected and under-corrected knees, were specifically selected to seek differences from the aligned knees.

The possibility that post-operative nonaligned TKRs of fixed severe valgus knees would behave differently from the properly aligned population was defined as our primary hypothesis. Our secondary hypothesis was over-corrected knees behaved differently from under-corrected knees in severe valgus knees.

Materials and methods

The study was designed as a multi-centric retrospective cohort study on Total Knee Replacement. Seventeen centers participated in the study. The minimal follow-up was 5 years; mean follow-up was 8 years (minimum 5 years; maximum 22 years). The oldest case was operated in May 1984 and the most recent in September 2011. Each center was given the same data requirements, based on clinical and radiological findings. No Institutional Review Board approval or patient signed consent was required by our national institution, as the procedures and patient follow-up followed usual practice and the study conducted under the leadership of the national orthopaedic society.

Only fixed pre-operative valgus knees of at least 190° of HKA and with a total knee replacement older than 5 years were included.

A unique Excel sheet (Microsoft, Redmond, USA) with all data requirements was dispatched to all centers. Incomplete files were excluded. Pre and post-operative HKA measurements, obtained through radiograph telemetry were mandatory. Radiograph telemetry is a bilateral whole-leg standing radiograph, obtained pre-operatively and at least once post-operatively.

Seven hundred and thirty-three files were anonymously recorded (see Table 1) in the initial database; 176 of them had to be excluded.

In the 557 knee final database, 75 knees (13.5%) had a post-operative HKA out of the 180° ± 4° strict range. Twenty-three of them had at least 5° of varus; fifty-two of them had 5° of valgus.

Total knee arthroplasty was performed with or without patellar resurfacing. There was no specific requirement regarding surgical technique. Every surgical approach,

Table 1 Operative report characteristics of each group

	HKA < 176 Hyper-corrected 23 knees	Control group Properly corrected 482 knees	HKA > 184 Hypo-corrected 52 knees
Surgical approach	60% Lateral/40% medial	50% Lateral	52% Lateral
Releases (%)	70%	76%	77%
Implants	CR 4%	CR 13%	CR 17%
	PS 56%	PS 50%	PS 46%
	UC 35%	UC 31%	UC 31%
	CCK 4%	CCK 3%	CCK 4%
	RHK 0%	RHK 3%	RHK 2%
Insert type	Fixed 52%	Fixed 48%	Fixed 56%
Cementation	70%	78%	81%
Patella resurfacing	70%	73%	54%

NS non-significant, *CR* cruciate retaining, *PS* posterior stabilized, *UC* ultra congruent, *CCK* constrained condylar knee, *RHK* rotating hinged knee

implant type, ligament release technique or surgical technique was authorized but had to be notified.

Each center selected a team of at least two surgeons to collect clinical and radiological data. Clinical pre-operative data, i.e. aetiology, surgical history and diseases in other joints, as well as Charnley [2], Devane [4] and International Knee Society (KSS, first version [11]) functional scores were obtained. Devane score is a simple, reproducible, activity score, ranged from 1 (sedentary) to 5 (strenuous manual labor).

Ahlback and Iwano arthritis scores were obtained with pre-operative radiographs. On radiograph telemetry, the HKA, the Femoral and Tibial Mechanical angles (FMA, TMA, Fig. 1) and the presence of concavity laxity were recorded. All patients were assessed with the mentioned scores.

Surgical approach and ligament releases were recorded, as well as implant characteristics. Ligament releases were listed as sections of Tensor Fascia Latae (TFL), posterolateral corner, lateral collateral ligament, popliteus or Burdin's osteotomy [1].

One hundred and four knee surgeries were Computer-Assisted Surgeries (CAS, 19%).

Early and late complications were reported. Revision data and last follow-up clinical and radiological findings, following the same procedure than the pre-operative data were added in the final report.

Statistical analysis

Using the final report, data from all outliers, knees in residual valgus with post-operative HKA equal or greater than 185° and knees in residual varus with HKA equal or less than 175°, were extracted and compared to the control population for statistical relevance. Then each sub-group (over-corrected and under-corrected) was compared with the properly aligned group. These two distinct sets of comparisons were to investigate the effect of conflicting results of over- and under-corrected knees on the comparison of all outliers versus properly aligned knees, as previously performed in knee arthroplasty outlier studies. Mont et al. [19], in a comment to the study of Parratte et al. on outliers [21], advised separating varus and valgus knees, as well as varus and valgus outliers. According to Mont et al. the absence of difference between outliers and properly aligned knees in the study of Parratte et al. could have been biased by competing opposite effects of varus and valgus outliers.

The statistical analysis was performed with Minitab® 16 software (Minitab Inc., State College, Pennsylvania, USA). All tests were two-tailed. The Anderson–Darling test was used to determine if the data set was normally distributed. If not, kurtosis and skewness of the data distribution curve were mandatory. All tests were always one-on-one comparisons. Comparisons between the different groups of quantitative variables were performed using Student's *t* test if they were normally distributed. If not, the

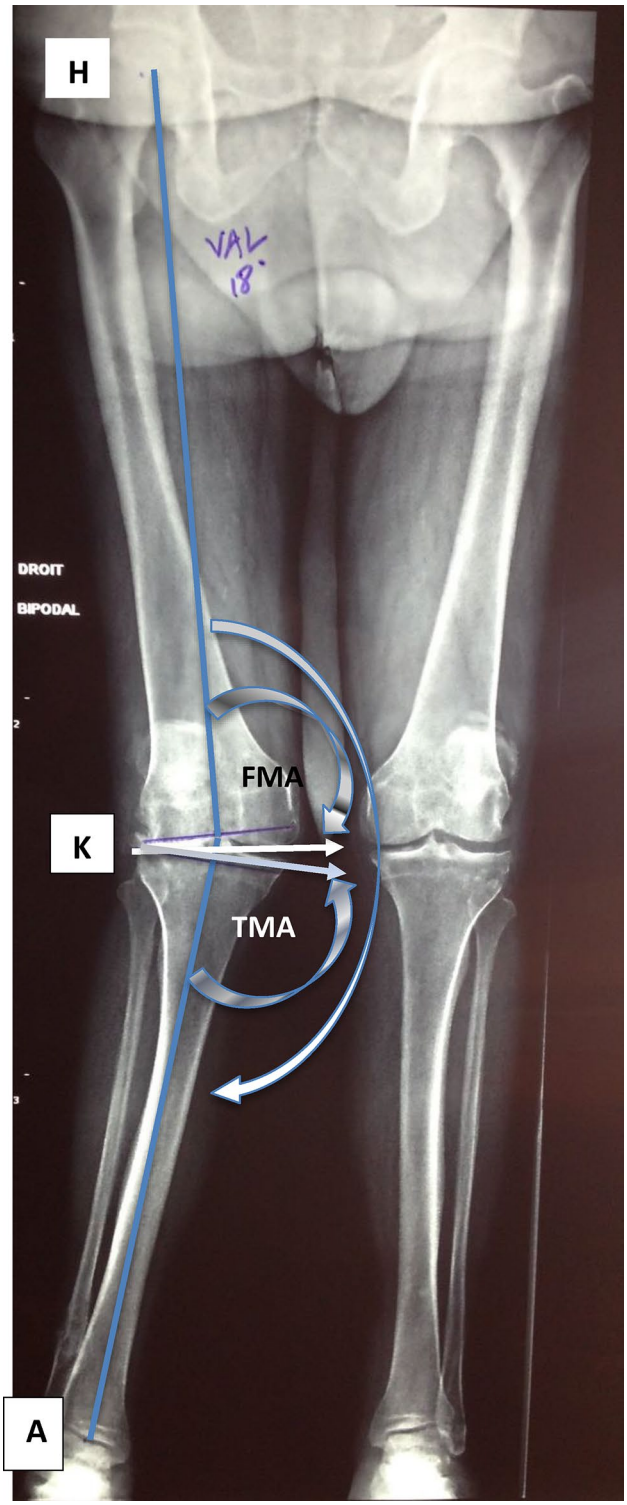

Fig. 1 Radiological measurement of Femoral Mechanical Angle (FMA, α) and Tibial Mechanical Angle (TMA, β)

non-parametric Mann–Whitney *U* test in case of independent data, Kruskal–Wallis test in case of dependent data, and Kolmogorov–Smirnov test to also compare distributions were used.

For ordinal and categorical variables, Mann–Whitney *U*, Kruskal–Wallis and Chi-square tests were chosen.

Survival curves were obtained following Kaplan–Meier method. Log-rank tests allowed comparing survival curves. A Cox regression model was designed to look for relevant influencing factors, with their respective hazard ratios whenever possible.

The significance threshold was set at $p < 0.05$.

Whenever we suspected a power issue, power was calculated with Power Analysis and Sample Size Software® 15 (PASS, NCSS, LLC. Kaysville, Utah, USA). Power is the probability of rejecting a false null hypothesis and should be close to 1.

Results

The control group (aligned knees) was composed of 482 properly aligned knees (with a post-operative HKA between 176° and 184°). Mean pre-operative HKA was 194° ± 4.

Eighty-eight percent of the patients were females, with a mean age of 72 years (44; 98) and an average body mass index of 29 ± 5. No statistically relevant difference was found compared to the outlier group (under- and over-corrected) regarding gender or BMI.

Fifty-seven percent of the knees were Charnley A; 86% were Devane 2 or 3.

KSS was 88 (Pain score 13, Function score 47, Knee Score 35).

Mean follow-up was 97 months (range 60–134).

Table 1 shows the operative report characteristics of each of the three groups (aligned, over-corrected and under-corrected). There was no statistical relevant difference in terms of implant in the outlier group but patellar resurfacing was significantly less used in the outlier group ($p = 0.001$).

Thirty-three patients died during follow-up, two of them having been revised in the control group; while three patients from the outlier group died, none had been revised.

Mean post-operative HKA was 181° ± 3°, with a femoral mechanical axis angle of 91° ± 2° and a tibial mechanical axis angle of 90° ± 2°.

Twenty-one complications occurred during the surgery (4%), 70 during follow-up (11%): 6 sepsis, 11 loosening, 4 patellar instability, 5 extensor apparatus rupture, 13 fracture and 20 other reasons. Thirty-eight knees (7.9%) had to be revised (mean delay of 37 months).

We found 18 cases of osteolysis, 4 on the femoral side, 9 on the tibial side and 5 on both sides. Polyethylene wear was found in 26 cases (5%). Eight complications were recorded in the outlier group (11%, n.s), six of them needing to be revised (n.s.): two patellar instabilities, one tibial tray loosening, one late sepsis, one patient was revised for knee stiffness and one case for important polyethylene wear.

Mean last follow-up KSS score in the control group was 156 (SD 37), divided in 44 (SD 10) for Pain score, 85 (SD 19) for Knee score, 69 (SD 26) for Function score. Median last follow-up KSS score in the outlier group was 144 (SD 40), divided in 45 (SD 9.5) for Pain score, 81 (SD 22) for Knee score, 65 (SD 26) for Function score. The difference found between the two groups was only significant for the Final Knee Score ($p = 0.023$).

Over-corrected knees with residual varus (Table 2; Fig. 2)

Post-operative HKA distribution was not normal, with a kurtosis of 2 and a skewness of 0.5. Median HKA was 175 [174; 175]. Mean FMA was 88.5 (SD 3) and mean TMA was 87 (SD 3). The differences between this group and the control group with regard to both FMA and TMA were statistically significant ($p < 0.001$). The over-correction was twice as high on the tibial side (3° versus 1.5°), while the pre-operative correction angle necessary was three times lower on the tibial side (2° versus 7°).

Six complications were recorded in this group (26%), four of them needing to be revised: two patellar instabilities, one tibial tray loosening, and one late sepsis. The complication rate difference with the aligned knee population was statistically relevant ($p = 0.019$).

No case of osteolysis and three cases of polyethylene wear (13%, $p = 0.096$) were found during the radiological follow-up.

Mean last follow-up KSS score was 137 (SD 40), divided in 42.5 (SD 13) for Pain score, 75 (SD 27) for Knee score, 58 (SD 20) for Function score. Differences were statistically significant for Knee Score ($p = 0.018$), Function Score (0.034) and Final Knee Score ($p = 0.03$).

Under-corrected knees with residual valgus (Fig. 3)

The pre-operative FMA angle was lower in this group than in the properly aligned group (95 versus 97, $p = 0.01$). This sub-group with a higher HKA had a femur found less in valgus than in the properly aligned group; this population could have a valgus HKA more related to soft tissues than to bone deformation, as their higher HKA could not entirely be explained by bone deformation.

HKA Distribution was not normal, with a kurtosis of 2 and a skewness of 1.6. Median HKA was 187 [185; 189]. Mean FMA was 95 (SD 2) and median TMA was 91 (SD 2), meaning the under-correction was primarily located on the femoral side, the mean FMA angle being the same,

Table 2 Pre-operative, post-operative and last follow-up findings in the three groups

	HKA < 176 Hyper-corrected 23 knees	176 ≤ HKA ≤ 184 Control group 482 knees	HKA > 184 Hypo-corrected 52 knees
Pre-operative			
Age	71 (SD 8)	72 (SD 9)	70 (SD 9)
BMI	31 (SD 7)	28 (SD 6)	27 (SD 7)
HKA	193 (SD 3)	194 (SD 4)	194 (SD 4)
FMA	98 (SD 2)	97 (SD 3)	95 (SD 3) ($p = 0.01$)
TMA	92 (SD 3)	92 (SD 4)	92 (SD 4)
Post-operative			
HKA	175 [174;175]	181 (SD 3)	193 [191;195]
FMA	88.5 (SD 3) ($p < 0.001$)	91 (SD 2)	95 (SD 4) ($p < 0.001$)
TMA	87 (SD 3) ($p < 0.001$)	90 (SD 2)	91 (SD 4) ($p < 0.001$)
Complications	26% ($p = 0.019$)	11%	4% ($p = 0.02$)
8 years follow-up			
IKS Pain	43 (SD 13)	44 (SD 10)	46 (SD 8)
IKS Knee	75 (SD 27) ($p = 0.018$)	85 (SD 19)	84 (SD 20)
IKS Function	58 (SD 20) ($p = 0.034$)	69 (SD 26)	67 (SD 28)
IKS Final	137 (SD 40) ($p = 0.03$)	156 (SD 37)	147 (SD 40)

The "hyper-corrected group" showed a significant higher rate of complications. This group presented also significant lower IKS results with the two other groups

both pre- and post-operatively. Also in this group was the difference with the aligned group statistically significant ($p < 0.001$) for both mechanical angles.

Two complications were recorded in this group (4%, $p = 0.019$), both needing to be revised: one sepsis and one case of important poly wear.

No case of osteolysis and two cases of polyethylene wear (4%, n.s.) were found during the radiological follow-up.

Median last follow-up KSS score was 160 (128; 174), divided in 50 (45; 50) for Pain score, 90 (81; 97) for Knee score, 70 (50; 95) for Function score. No statistically significant difference was found between this outlier sub-group and the aligned knee group with regard to any of the constituents of the KSS score.

Global cumulative incidence curves (Fig. 4) were extracted from the survival analysis, comparing cumulative incidences of the three groups with regards to revision or complication. Due to a high proportion of competing elements (mainly patient death), survival curves could not be drawn. Find and Gray test, with complication or revision set as endpoints, was not statistically significant.

Discussion

The most important finding of our study was that under-corrected knees did not behave differently from aligned knees, while over-corrected knees showed a statistically higher rate of complications and lower KSS scores. This study was to our knowledge the largest series focusing on severe valgus knees, thus allowing selecting two outlier sub-groups, over-corrected and under-corrected.

A potential limitation could be the relatively short follow-up (8 years), probably reducing the frequency of complications, especially in the under-corrected group, as contact stresses might have a more insidious effect on implant fixation than other loosening mechanisms [7].

The meta-analysis from Hadi et al. [8] reported that 64% of studies showed no association between nonalignment and complications; only in 50% of the studies an association between misalignment and low risk radiological findings could be statistically proven. No clear distinction between outliers was mentioned in all of the studies.

It is worth mentioning that a few of the series focusing on severe valgus knees did not have a mean HKA of 0 ± 4 and did not report increased failure rates; Krackow et al. reported a HKA of 87.6 ± 11 [14], mean HKA for Whiteside et al. was 97 [32].

Over-corrected valgus knees with varus deformity showed a statistically higher rate of complications and lower KSS scores. The post-operative varus was primarily set at 3° on the tibial side, versus 1.5° on the femoral side. An over-correction on the tibial side could cause a higher rate of complications, whereas over-correction of the FMA, thus modifying the movement of the knee [6], could explain a rise of the complication rate, as Ritter et al. [25] demonstrated. Under-corrected valgus knees, on the contrary, showed statistically fewer complications than the aligned population and similar KSS scores. FMA and TMA were not corrected in this sub-group and it did not impact the complication rate.

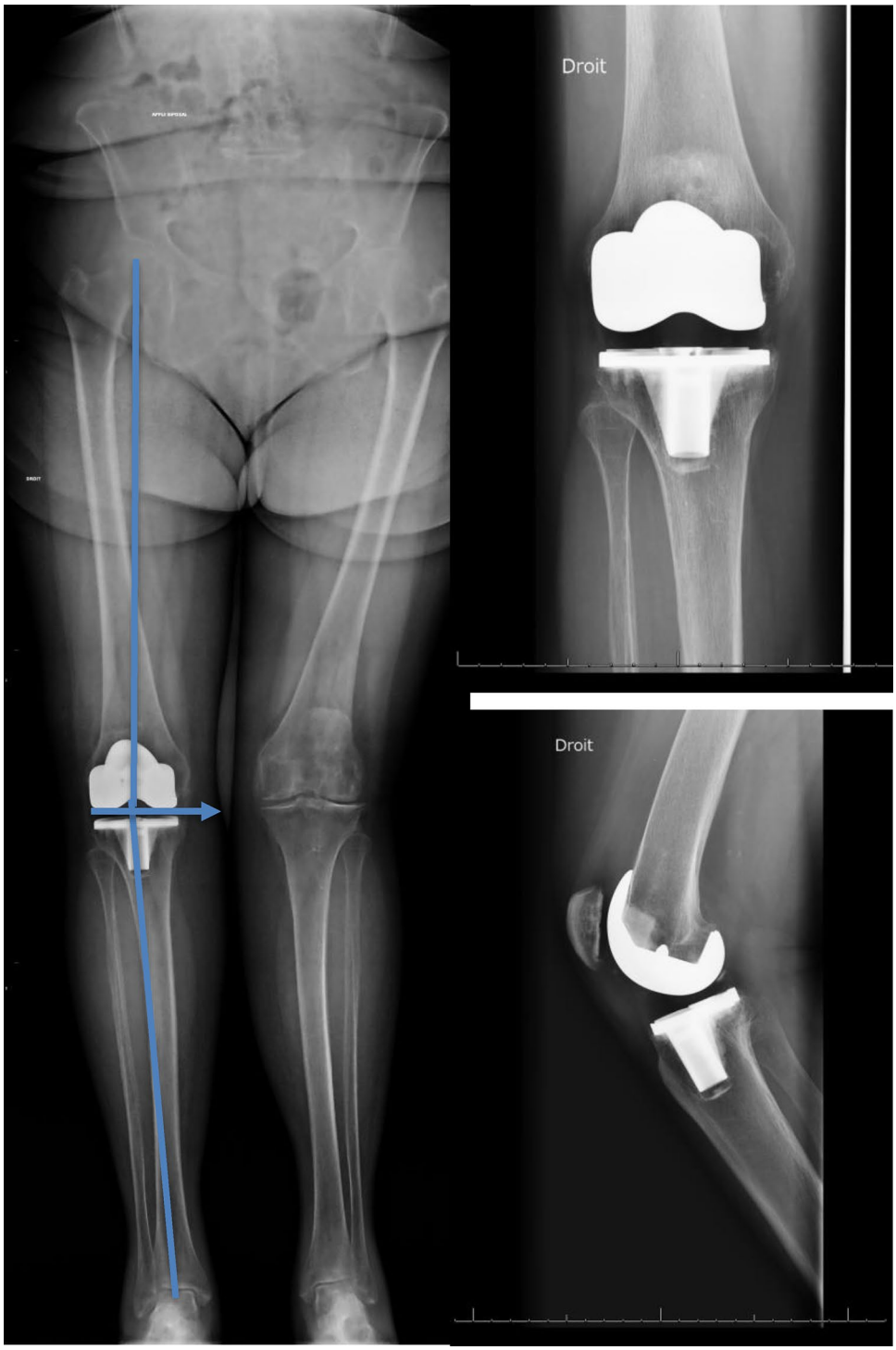

Fig. 2 Radiograph telemetry, antero-posterior and profile radiographs of an over-corrected knee

Another study by Ritter et al. [24] concluded on lower results of under-corrected valgus knees compared to aligned knees. The groups in their study were differently designed, as over-corrected knees were below 182.5° of post-operative HKA, under-corrected knees were over 187.4° of HKA and the "neutral" population between 182.5 and 187.4 of HKA (versus 180° ± 4 in our series). It is therefore difficult to compare both series, but there could be a threshold around 187.5° of HKA where the benefits of under-correcting HKA (minimizing the need for ligament releases or using less constrained implants) could be outweighed by its drawbacks (higher contact stresses). Kim et al. [13] also studied the effect of post-operative alignment on TKR survival and although it was about a particular population (93% of

Fig. 3 Radiograph telemetry of an under-corrected knee

females); they also found that the population of 183–187.5 of post-operative HKA had the best results. As our distribution of HKA in the under-corrected sub-group did not follow a normal law and most of our under-corrected knees being in the 185–189 range of HKA, our favorable results could be explained by an HKA staying in a somewhat "reasonable" range. The under-corrected valgus knee followed the same function scores than the under-corrected varus knees, which even exceeded aligned knee scores according to Magnussen et al. [16]. So a fixed severe valgus knee should not be over-corrected, whereas keeping this knee in a mild valgus, possibly between 184 and 187.5 of HKA, might not impact the TKR survival, at least during the first 5–10 years.

The potential excessive contact stresses due to the non-alignment might only be one factor amongst many, at least until a certain threshold. Gallo et al. [7] offered a review of the potential failure mechanisms of TKR and concluded peri-prosthetic osteolysis is multi-factorial, with a synergistic effect of mechanical forces and biological responses. There is also a combination of load and use in the overall solicitation of the implants. Schmalzried et al. [27] demonstrated that the annual number of knee cycles varies from 72,000 (sedentary) to 32 million (active). Additionally, there seems to be no incidence of misalignment on muscle strength [30].

Keeping a severe valgus knee in a residual valgus, as under-corrected valgus knees showed statistically less complications and similar KSS scores than the aligned population, could allow preventing a ligament release or the use of a more constrained implant, both known to give lower functional results [17, 22].

Conclusion

In case of a fixed severe valgus knee, one should be concerned not to over-correct the HKA angle, especially the tibial mechanical angle.

Keeping a severe valgus knee in a mild residual valgus, to use a less constrained implant or to prevent extensive ligament releasing, should not negatively influence the 5–10 year implant survival and the functional scores.

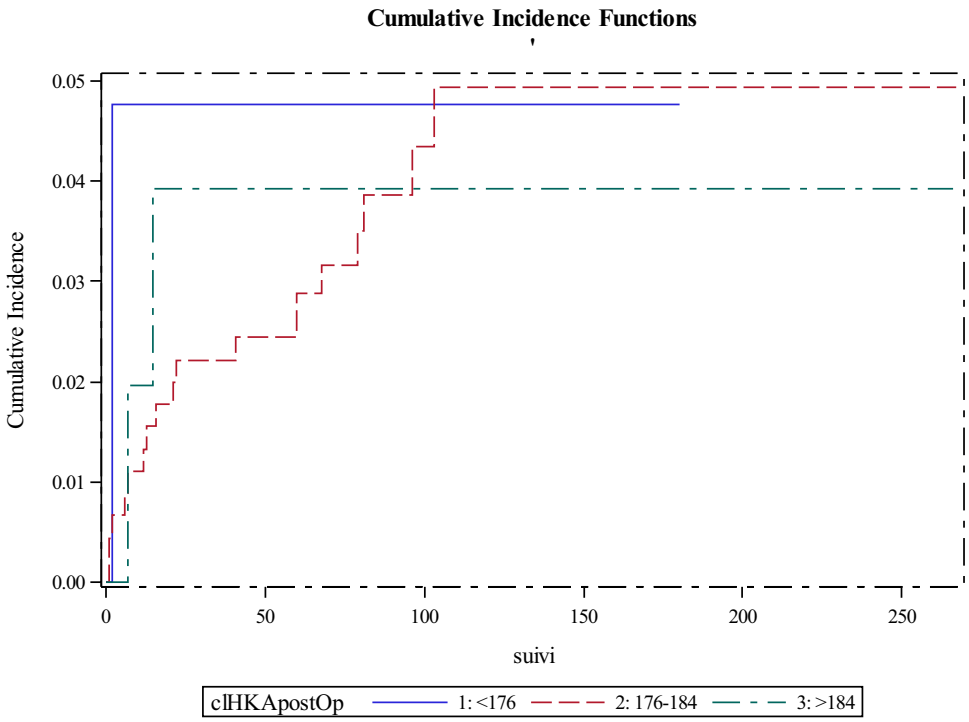

Fig. 4 Global cumulative incidence curves of the three sub-groups (n.s.; Find and Gray test). Revision was set as endpoint

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval French Orthopedic Society SOFCOT does not require an ethical approval statement for inhouse studies.

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